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From: Howes, Sarah (DEQ)
Sent: Tuesday, March 17, 2015 12:38 PM
To: Shekter Smith, Liane (DEQ); Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Tommasulo, Karen (DEQ)
Subject: Flint Drinking Water Letter?

Hi all---

I just got a call from Rep. Neeley's office and it's their understanding that DEQ will be issuing a letter on Flint Drinking Water tomorrow. Is this true? If so, could you please PDF me a copy and I'll distribute to the legislative offices that have asked for updates when appropriate.

Thanks;
Sarah

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Sent: Monday, March 16, 2015 4:28 PM
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Subject: TTHM Draft Letter
Attachments: ycn-infection-safedrinkingwaterguidelines-sept2004 (1).pdf; vulnerable to drinking water.pdf; TTHM fact sheet (1).pdf; KrasnerWright-DBPBoil-WatRes2005 (1).pdf; Guidance for People with Severely Weakened Immune Systems.pdf; Egorov-ExpDBPsRussia-Proofs (1).pdf; CA study on THMs and pregnancy (1).pdf; Bottled Water NRDC.pdf; Draft - Flint Letter to Healthcare Providers.docx

Team,

We have received our notice from the DEQ and our next step is to have this group preview the letter that we intend to send to the public along with it. I have forwarded everyone a draft of the letter for any comments and I am also sending again all of the literature that was forwarded from Mr. Wright of the EPA and DR. Rose of MSU.

We expect to have an additional FAQ ready and out to this group on Tuesday and we anticipate the violation notice going out in the near future.

The citizens advisory group will meet again on this Thursday, we are currently looking to have another **Technical Advisory Committee** with this group in early April.

Thank you,

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Yorkshire Cancer Network

INFECTION GROUP

PROVISION OF SAFE DRINKING WATER FOR CANCER PATIENTS WITH IMMUNOCOMPROMISE

September 2004

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1. Background

Immunocompromised patients, such as those rendered neutropenic following cytoreductive therapy for malignancy are at risk of acquiring a wide range of potentially pathogenic microorganisms from drinking water. These include environmental Gram-negative bacteria, such as pseudomonads, and atypical mycobacteria. Despite the risk for these patients, there are few guidelines on the provision of safe drinking water for immunocompromised individuals including those with solid organ or haematological malignancy.

In the UK, guidelines¹ have been focused almost exclusively on ensuring that water is free of *Cryptosporidium hominis* and *C. parvum*. These belong to a genus of coccidian protozoa, which, whilst causing self-limiting gastrointestinal infection in immunocompetent individuals, may result in life-threatening diarrhoeal illness in immunosuppressed patients. Other guidelines e.g.² make little reference to the safety of potable water for immunocompromised patients other than that which relates to the potential acquisition of *Cryptosporidium* spp. In contrast, scant attention is paid to opportunistic Gram-negative bacteria which can be found in both bottled and tap water³ and there are almost no references in published guidelines to the possibility that fungal pathogens, such as *Aspergillus* species, might be acquired through potable water.⁴

Given the lack of information provided by national guidelines, it is unsurprising that there is considerable inter-unit variation in the methods of provision of potable water to cancer and other immunocompromised patients. This was highlighted in a regional survey⁵

In the survey, questionnaires were sent to 15 Trusts across Yorkshire and Humberside. Ten Trusts replied, reporting on provision of potable water in 14 separate units. Of these, nine provided only tap water to all patients, irrespective of underlying condition. In two units, iced water, with ice from commercially available makers, was used. Five units distinguished between neutropenic and non-neutropenic patients, with the former group receiving cooled, boiled water (three units), sterile water and sterile water or carbonated water (one unit each). No unit provided filtered water. Water in jugs was changed daily, twice daily or only when empty in 7, 3 and 4 units, respectively. Water jugs were dishwasher-dried in 7 units, dried naturally in 4 and by paper or cloth towels (two and one units, respectively). On 10 units patients were allowed to provide their own potable water, but no unit provided written advice to patients on PW.

The marked disparity in practice as identified in the regional survey contrasts sharply with the guidance given in the report, *Cryptosporidium in Water Supplies* (DETR, 3rd report, 1998), which states that, *all water, from whatever source, that might be consumed by immunocompromised persons should be brought to the boil and allowed to cool before use.*¹ Drinking water for immunocompromised patients on some units which follow these guidelines may be boiled (either using a geyser or kettle), left to cool in jugs on kitchen work surfaces and then cooled further in refrigerators before distribution to patients in accordance with these guidelines.

Boiling of large volumes of water on a daily basis has, however, significant health and safety implications. Because of the perceived risk to health care workers, the options for providing safe drinking water for immunocompromised cancer patients were reviewed. The aim was to

identify methods which, while aiming for optimal protection of patients from *Cryptosporidium* spp., environmental bacteria and fungi, would not compromise safety. This is discussed elsewhere.⁵

2. Optimal provision of potable water for immunocompromised patients

The criteria to be met in providing drinking water for immunocompromised patients are:

- Microbiological safety
- Respect for patient confidentiality (of particular importance for patients with AIDS-related malignancy nursed on general wards, as provision of cooled, boiled water, may result in the identification of these patients as HIV-positive by staff and, indeed, other patients)
- Organoleptic acceptability
- Preparation of water using methods which minimise risk staff
- Uniformity of approach to provision
- Cost-effectiveness

Options available

A number of options are available:

- 2.1 Untreated tap water
- 2.2 Boiled tap water
- 2.3 Sterile bottled water
- 2.4 Commercially available bottled water
- 2.5 Filtered tap water

2.1 Untreated tap water

Although untreated tap water is provided to immunocompromised cancer patients on many units ⁵ without any apparent problems, this practice is not consistent with UK national guidelines for the prevention of cryptosporidiosis in these individuals.¹ Moreover, tap water may contain other potentially harmful microorganisms such as environmental Gram-negatives and *Mycobacterium* spp and it would seem prudent not to expose vulnerable patients to these bacteria.

2.2 Boiled tap water

The major disadvantage of this option is that there are considerable health and safety implications for health care workers. In addition, preparation of cooled, boiled water places significant demands on staff time. Moreover, heating of the water and cooling it refrigerators have associated energy costs.

2.3 Sterile bottled water supplied by pharmacy

Two significant drawbacks are associated with this approach. Firstly, the organoleptic quality of this product is poor and this might lead to problems with patient acceptability. If some patients were to reject sterile bottled water as being unpalatable, then an alternative source of treated water would have to be made available. This would not meet the criterion of uniformity of practice. Secondly, there would be considerable logistical problems for delivery of water, storage of bottles on wards and collection of empty bottles. Many chemotherapy patients are advised to drink at least 4 litres of water daily to maintain adequate hydration. Assuming a “worst case scenario” of 20 patients on a given ward all undergoing chemotherapy, then pharmacy would supply the ward with at least 80 one-litre bottles each day. Space would have to be found to store these before distribution to patients. It is reasonable to assume that at some times, such as weekends, Bank and other holidays, that daily deliveries might not be possible, thus delivery of three day’s supply to a ward (at least 240 bottles) might be necessary compounding storage problems.

2.4.1 Commercially available non-carbonated bottled water

This option has an important drawback in that water of this nature represents a significant hazard to many immunosuppressed patients. In particular, it may contain large numbers (in excess of 10^6 ml⁻¹) of Gram-negative bacteria such as *Stenotrophomonas maltophilia*³ and environmental pseudomonads which may represent a particular risk for neutropenic individuals.

2.4.2 Commercially available carbonated bottled water

Carbonated bottled water is considerably safer than the non-carbonated variety because of the low pH of these products.³ However, the low pH can result in poor patient acceptability in patients with chemotherapy-associated mucositis. As with sterile bottled, logistical problems in delivery and storage of water before distribution to patients may arise.

2.5 Filtered water

Filter devices in a self-contained cartridge are readily available from commercial sources and, if of the appropriate specification, produce water that is essentially sterile and, for this reason alone, filters are an attractive option. However, several aspects of this approach require further consideration

- Robust protocols for their use. Filter units should be changed according to the manufacturer's recommendations. There is thus a requirement to identify members of staff responsible for changing the filters who will change the devices as per the manufacturer's recommendations. There should be a system in place for recording when filter changes have been carried out. Regular audit of the system is also necessary.
- Microbiological safety. Although water produced by the filter is sterile, could "splash back" occur leading to bacterial/fungal colonisation of the cartridge distal to the filter?
- Patient acceptability of water quality
- End-user acceptability of providing water in this way
- Cost. Not only of the devices have themselves, but also this cost incurred in modifying, where necessary, taps to accommodate them.

To address these issues a one-month trial was conducted of end-line filter units on two wards at LTHT. Sinks in each ward kitchen which were to receive the filters were identified and taps were modified to accommodate the filter units (cost per tap £37.62 [2002 prices]). Designated persons who were to change the filters twice a week were identified on each ward. Education of nursing staff and ward housekeepers were conducted by a representative of the filter manufacturer and an ICN. Filters were swabbed inside and outside of exit nozzle after four days' use.

At the end of the trial, staff on wards which had previously provided cooled, boiled water for immunocompromised patients were very impressed with this method. The ward staff thought it saved time, was safer and that there was more space in a cooler working environment.

Staff on other wards where patients were previously given only tap water were, however, less impressed. There appeared to be an attitude of "why bother?" especially as it took the ward housekeeper longer to fill the jugs than before. There were concerns over the cost of the filters. Nevertheless, the acceptability of the filtered water for patients was very good.

The protocol for changing filters when time-expired was followed without difficulty.

Microbiological investigations revealed growth from only 2 of 22 specimens obtained from time-expired cartridges. In both instances, scanty coagulase-negative staphylococci were isolated. No specimen yielded Gram-negative bacteria. The former might have represented contamination from personnel handling the filters and might, in any case, be deemed of doubtful clinical significance for patients.

A comparison of selected options is given below. These assume that a given ward has twenty patients who are advised to drink 4 litres/day (2002 prices).

- Sterile bottled water supplied by pharmacy
Cost - £3.56 for 6 X 1litre bottles
Approx overall cost per ward - per day is £ 47.50
- per week is £336

- Carbonated bottled water supplied by supplies
Cost - £1:98 for 6 X 1litre bottles
Approx overall cost per ward per day is £ 26:40
- per week is £184:80
- Still bottled water supplied by supplies
Cost - £1:98 for 6 X 1litre bottles
Approx overall cost per ward per day is £ 26:40
per week is £184:80
- Filtration at the point of use – PALL Aquasafe Water Filters
Cost - £19:65 per filter (2 required per week*)
Approx overall cost per ward - per week is £39:30*

(Not included in the above is the once-only cost, where appropriate, of converting taps to accommodate cartridges)

*Pall have now introduced a filter which requires to be changed every 7 days.

3. Overall conclusions

- i) Provision of untreated tap water for immunocompromised cancer patients would be failing to comply with current UK guidelines.¹ Some form of treated water should, therefore, be made available to patients.
- ii) Cooled, boiled water has several disadvantages, most notably relating to the health and safety of health care personnel.
- iii) Bottled water has a number of drawbacks, including significant cost implications.
- iv) Filtered water also has cost implications (although these are less than bottled water). It is sterile at point of production (unlike some types of bottled water) and has no obvious health and safety implications. Filters require to be changed every seven days and protocols should ensure that this occurs. N.B. water quality may influence significantly the operation of the filters – for example water which contains high levels of particulates may impair filter performance. Under these circumstances, remedial action should be taken before the filters are introduced. In wards where HIV/AIDS patients are cared for, provision of filtered water does not permit identification of these patients as does, for example, cooled, boiled water.

4. Recommendations

Taking into account the criteria outlined in section 2, filtered water is the most appropriate option for the provision of potable water for immunocompromised cancer patients.

5. Ice provided by commercial ice-making machines

Ice from ice-making machines is frequently contaminated with potentially pathogenic bacteria⁶ and hospital-acquired infection from this source has long been recognised.⁷ Accordingly, ice provided for immunocompromised cancer patients should be made only from microbiologically safe water.

6. Water from water coolers

Standalone water coolers are likely to yield water contaminated with environmental bacteria⁸ and are not recommended for use on wards and other areas where immunocompromised cancer patients are cared for. Plumbed-in water coolers are less likely to yield water contaminated with Gram-negative bacteria, but still pose a risk of transmission of cryptosporidiosis as mains water is used. Water coolers for the use of staff should be sited away from patient care areas.

7. References

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ARE YOU MORE VULNERABLE TO DRINKING WATER CONTAMINANTS?¹

Even when tap water is safe for most healthy people to drink because a water utility is doing a good job of meeting or surpassing all standards set by the EPA, there are some groups of people — such as those undergoing chemotherapy treatment for cancer, people with HIV/AIDS or other immune disorders, those who have undergone organ transplants, and some elderly and infants — who are more vulnerable to microbial and some other contaminants in their drinking water.

That is why the Environmental Protection Agency (EPA) requires that every annual water quality report, (sometimes called “Consumer Confidence Report”), include the following cautionary explanation:

“ Some people may be more vulnerable to contaminants in drinking water than the general population. Immunocompromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. EPA/CDC [Centers for Disease Control and Prevention] guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the **Safe Drinking Water Hotline (800-426-4791)**”

This fact sheet will answer some frequently asked questions about health risks for such people and the precautions they may choose to take. For more information about drinking water including health risks associated with any contaminant found in your drinking water, contact the EPA hotline number highlighted above or their drinking water web site: www.epa.gov/safewater/mcl.html (*scroll down to Table*). Additional materials are also available from the Coordinator of the Campaign for Safe and Affordable Drinking Water, Lynn Thorp, who may be contacted at 202-895-0420, x 109 or by e-mail: csadw@cleanwater.org.

1 What is *Cryptosporidium* (Crypto)?

- *Crypto is a protozoan that takes the form of tiny cysts that can survive chlorination and slip through standard municipal water filters. Crypto is known to enter the water supply through sewage leakage or agricultural run off that is contaminated with feces. People with healthy*

¹This fact sheet has been prepared by Consumer Federation of America for **The Campaign for Safe and Affordable Drinking Water**. The Campaign is a coalition of more than 300 organizations including: Clean Water Action, Consumer Federation of America, League of Women Voters, National Association People with AIDS, Natural Resources Defense Council; Physicians for Social Responsibility and US PIRG. The Campaign urges consumers to protect the sources of drinking water from contamination and to work with local water utilities to assure that everyone can safely drink their tap water.

immune systems may not become ill or, if they do, will usually recover within 7-20 days from Cryptosporidiosis (Crypto). Symptoms include: diarrhea, nausea, abdominal cramps, and a low fever. There is no medical cure for Crypto and it can be fatal for people with severely compromised immune systems. In 1993, Milwaukee experienced a major outbreak of Crypto (about 400,000 people were affected) that resulted in about 100 deaths, mostly among the immune compromised. Smaller outbreaks and individual cases occur each year and can cause severe weight loss and death in the immune compromised, such as people with HIV/AIDS.

2 How do I know if there is Crypto in my tap water?

- You don't. Crypto is known to exist in 86% of lakes, rivers and streams. It also exists in some underground water supplies that are subject to surface contamination. Currently, there is neither an EPA maximum contaminant limit (MCL) for Crypto nor a required treatment to fully remove it. EPA plans to establish stricter standards and specific techniques for Crypto removal or disinfection by the year 2002. Water utilities may report that Crypto was not found in the treated water. Unfortunately, tests are not accurate enough to detect all Crypto cysts that can make you ill. If any Crypto is detected in either the source water or in water after treatment, it is prudent for the immune suppressed to take precautions such as those suggested in #5 below. (However the failure to find Crypto is no guarantee that it is not in the water.)*

3 Are all elderly and infants more vulnerable to these infections?

- Probably not. Healthy older people and older children in good health are unlikely to be especially vulnerable. However, some vulnerable people may feel well but not be aware that the kinds of medical care they receive in order to stay well put them at risk of microbial infections. For example, long term and heavy use of steroids for arthritis and other conditions, and chemotherapy for cancer treatment, suppress the immune system and therefore makes one more vulnerable to a Crypto infection. Moreover, infants have immature immune systems and young children are subject to dangerous dehydration from Crypto-caused diarrhea. It is best to consult your health care provider if you have questions about the vulnerability of a particular child or elderly person.*

4. Is it always safer to drink bottled water?

- No. Although the Food and Drug Administration(FDA) regulates all bottled water, it subjects that water to less rigorous testing and purity standards than the EPA requires for your tap water². Moreover, FDA does not regulate bottled water that is packaged and sold only within a state even*

² NRDC, Bottled Water: Pure Drink or Pure Hype, 1999: www.nrdc.org/find/hebw.html.

though such water comprises 60-70% of all bottled water sold³. About 25% of all bottled water is municipal tap water (sometimes further treated, sometimes not). If you or someone in your family must drink an alternative to tap water, carefully read bottled water labels and the answers to #5 and 7 below.

5. What water is safe to drink for someone who is more vulnerable to Crypto and other waterborne microbial diseases?

- *Tap water that has been boiled for one minute (not longer⁴); or*
- *Bottled water that has been treated as follows:⁵*
 - *Distilled water (Preferred by many health care providers); or*
 - *Other bottled water that has been filtered using reverse osmosis or an absolute one micron filtration system. Read the fine print on the label and call the company or National Sanitation Foundation (NSF)⁶ to confirm the treatment used; or*
- *Tap water that has been filtered in the home using a filter that is certified by the NSF to remove cysts (The label on the filter on the faucet or under the sink should read "NSF Standard #53 for cyst reduction." ⁷) It is important to change filters as frequently as directed because over time contaminants trapped by the filter build up and may enter and seriously contaminate your drinking water.*

³ Call your state Health Department to learn if and how your state regulates bottled water.

⁴ At an altitude of 6,000 feet or higher, it is necessary to boil water longer than 1 minute.

⁵ Centers for Disease Control and Prevention (CDC) approved methods for Crypto removal. See also CDC's web page: cdc.gov/ncidod/dpd/crypto.htm.

⁶ Or go to the California's excellent listing of certified water treatment devices on the web at <http://www.dhs.ca.gov/ps/ddwem/technical/certification/device/table.htm>

⁷ Call NSF at 1-800-NSF-MARK or go to www.nsf.org to learn which brands of bottled water or models of water filters have the NSF certification for the type of treatment you require. NSF is an independent, not-for-profit organization that tests and verifies that each certified product meets all the requirements of the specified standard(s) and that the manufacturers' claims are true. Be aware however, as a non-governmental group, its testing records are not open to the public and its certifications do not have the force of law. The Natural Resource Defense Council (an independent non-profit organization) conducted a large study of bottled water in 1998. Find the results on its web page: www.nrdc.org.

6. Are vulnerable people also at risk from any other contaminants in water?

- *Yes. For example, lead, nitrates/nitrites and Total Trihalomethanes (TTHMs), are not only known to increase the risk of certain chronic diseases after long term exposure, they also can cause acute (immediate) adverse health effects in some groups of vulnerable people. There is also concern that organic chemicals in pesticides sometimes found in drinking water pose an increased health threat to children.⁸ This fact sheet only addresses the acute health effects of lead, TTHMs and nitrates. You can learn about both the chronic and acute health effects of any contaminant in your drinking water by accessing the Safe Drinking Water Hot Line 800-426-4791 or EPA's web site, www.epa.gov/safewater.*

7. If I want to protect someone not just from microbes but also from any other contaminants in the tap water, can I just use any of the same alternatives as listed in the answer to #5?

- *Boiling water will not necessarily remove contaminants other than microbes. In fact, prolonged boiling (longer than one minute) will only increase the concentration in the water of contaminants such as lead and other metals, many chemicals, and nitrate. Contact the NSF or the California Department of Health Services (footnotes 5 and 6) for those brands of bottled water or home filters that are not only certified to remove Crypto cysts but also remove other specifically named contaminants that are reported to be in your tap water and that you wish removed.*

8. What are nitrates and why are they a concern?

- *Nitrates/nitrites are nutrients in nitrogen-based fertilizer and manure that are washed off the land into surface source water or enter some ground water from dissolved natural deposits. Nitrate levels in your water may rise quickly for short periods of time due to rainfall or agricultural activity. Nitrate is a health risk for fetuses and can cause the potentially fatal blue baby syndrome in infants of less than six months of age. **DO NOT BOIL THE WATER** to remove nitrates. Instead, use a carefully selected bottled water or a filter certified by NSF for nitrate removal.*

9. Is lead in drinking water dangerous for children?

- *Exposure to lead is not good for anyone. However, the fetus, infants and young children whose brains and nervous systems are still developing are particularly vulnerable to this toxic metal which may be found in lead paint, dust and some drinking water. According to the CDC, even low levels of lead are harmful and associated with decreased intelligence, impaired development and*

⁸ The National Academy of Science's Committee on Pesticides in the Diets of Infants and Children [National Academy Press, 1993]

decreased growth. Nearly 1 million children in the US have lead levels in their blood that are high enough to cause irreversible damage to their health.⁹ Lead in drinking water is primarily a problem of home plumbing or service connections; most drinking water leaves the treatment plant containing little or no lead. Corrosion of lead plumbing fixtures in older buildings or service lines, or leaching of lead solder used in the copper pipes of newer buildings, are the most frequent cause of lead in drinking water. (Since August 1998, all components of pipes and plumbing fixtures that dispense drinking water must be "lead free.")

10. How do I know if lead is in my tap water? What can I do about it?

- Test the water from your own tap particularly if you are in an apartment or any high rise building where flushing the pipes (see below) may not be effective. Call the Safe Drinking Water Hotline (800-426-4791) for further information and a list of certified testing labs in your state. In addition to testing, and, if needed, purchasing a carefully selected filter or bottled water, there are immediate, inexpensive actions you can take to reduce potential exposure to lead in drinking water. It is especially important to take these precautions if you are pregnant or have young children:

! First thing in the morning or whenever the tap water has been sitting in the pipes for hours, "flush" the cold water pipe by running the water until it is cold (30 seconds to two minutes). The more time water has been sitting in your pipes, the more lead it may contain. Do not waste the flushed water. Catch it in a container and use it to water plants or for any other non-cooking or non-drinking purpose.

! Use only cold water for drinking and cooking. (Hot water leaches more lead out of the pipes)

11. Should I use tap water in my baby's bottle?

- An infant is more vulnerable to microbial pathogens, and to nitrite/nitrates, lead, and many chemicals that may be in your tap water. Studies have found that as much as 85% of the blood lead in infants who are bottle fed may come from drinking baby formula with lead-contaminated water. A spike in nitrates in the drinking water may cause the "blue baby syndrome" as noted in #8 above. The safest and simplest options for feeding a baby are breast feeding or ready-mixed formula. However, if you know that your tap water is free of lead and nitrate/nitrite, you can reduce possible microbial contamination if you boil tap water for one minute (not longer; see answer to #7 above) before mixing it with dry formula. Remember to cool the water before feeding the baby! If lead or nitrates are in the tap water, a carefully selected filter or bottled water (see # 5 above) can be used for water in a baby's bottle. Refrigerate any remaining bottled water after opening.

⁹ See web page www.cdc.gov/nceh/pubcatns/97fsheet/leadfcts/leadfcts.htm

12. I am pregnant or thinking about getting pregnant. Are there any drinking water contaminants in addition to nitrates and lead that can harm the fetus?

- *Yes, Several studies have found that Trihalomethanes (TTHMs) in drinking water are associated with miscarriages and certain birth defects when consumed during the first three months of pregnancy. TTHMs are a group of contaminants that form in drinking water during treatment when disinfectant reacts with decomposing organic matter. The amount of TTHMs in tap water can vary from day to day and may be higher in some parts of the distribution system than in others. This may explain why even when the tap water does not surpass EPA's maximum permitted level of 100 ug/L TTHMs as averaged over the course of a year, reproductive ill effects still may occur. A recent large scale California study assessed the risk of miscarriage for women drinking tap water containing TTHMs during the first trimester of pregnancy and found that some women who drank a lot of tap water that contained high levels of TTHMs (at least 75 ug or "micrograms" per liter of TTHMs) had a miscarriage rate significantly higher than those who drank less of that tap water or than those who drank tap water with lower concentrations of TTHMs.*

13. How can I protect myself from TTHMs?

- *Remember to drink lots of liquids during pregnancy and follow the advice of your health care provider. If you are concerned about TTHMs in your tap water, call your water utility, or look at your annual water quality report, to see if your tap water sometimes contains high levels of TTHMs. If it does, you have several options. Some experts suggest that you refrigerate tap water in an open container for several hours before drinking to allow TTHMs to leave the water and enter the air. Especially, if in addition to TTHMs, lead, nitrates or pesticides are a concern, it may be prudent to drink a carefully selected bottled water (check www.nrdc.org for bottled water test results and **footnote 7**) or water that has been filtered by a home system that has been certified to remove lead, nitrate and organic chemical contaminants. (See answer to #5)*

TTHM (total trihalomethanes) FACT SHEET

WHY ARE THERE TTHMS IN DRINKING WATER?

TTHM are what is known as Disinfection- By- Products (DBPs) and are formed in water treatment.

The TTHMS are an indicator of how disinfection of the drinking water is managed. This includes the time the water is in the pipes.

Disinfection of water is important to prevent waterborne disease and thus is essential for the water industry as part of the *Safe Drinking Water Act*. Health agencies including the World Health Organization support disinfection to control microorganisms. Thus the goal for water treatment is to obtain microbial safe water while minimizing these DBPs.

WHAT ARE THE HEALTH ISSUES?

Of the many studies looking at long-term exposure a few have shown a small number of people were affected and thus the standard for TTHM levels was reduced in 1990s. A few People who drink water containing THMs in excess of the standard (MCL) over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer. However no links have been established when drinking water in excess of the standard for a few days.

A few studies have suggested that THMs in drinking water are associated with miscarriages and certain birth defects when consumed during the first three months of pregnancy. However, EPA has concluded that no link has been established between adverse reproductive outcomes and the TTHMs levels found in drinking water.

NOTE: Some individuals who are severely compromised immune compromised the elderly, and young infants may be at greater risk when using tap water. Even when tap water is safe for most healthy people to drink because a water utility is doing a good job of meeting or surpassing all standards set by the EPA, there are some groups of people such as those undergoing chemotherapy treatment for cancer, people with HIV/AIDS or other immune disorders, those who have undergone organ transplants, and some elderly and infants — who are more vulnerable to microbial and some other contaminants in their drinking water.

A particular concern is if other contaminants lead, nitrates or pesticides are in the tap water. These have been tested and are at safe levels in the drinking water.

WHAT TO DO

If you are concerned about TTHMs in your tap water, call (us the water utility, health dept?).

Some experts suggest that you can refrigerate tap water in an open container for several hours before drinking to allow TTHMs to leave the water and enter the air.

A carefully selected bottled water (check www.nrdc.org for bottled water test results) or water that has been filtered by a home system could be used.

SOURCES:

<http://water.epa.gov/lawsregs/rulesregs/sdwa/stage2/regulations.cfm>

National Primary Drinking Water : Stage 2 Disinfectants and Disinfectant By Products Rule Issues January 1, 2006 which modified the original regulation from 1979.

C2 DBP Health Effects

"EPA concludes that no dose response relationship or causal link has been established between exposure to chlorinated drinking water or disinfection byproducts and adverse developmental or reproductive effects. "

They go on as a way to justify adding the DBP2 requirements by saying: " EPA's evaluation of the best available studies, particularly epidemiological studies is that they do not support a conclusion at this time as to whether exposure to chlorinated drinking water or disinfection byproducts cause adverse developmental and reproductive health effects, but do provide an indication of a potential health concern that warrants incremental regulatory action beyond Stage 1 DBPR."



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The effect of boiling water on disinfection by-product exposure

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Abstract

Chloraminated and chlorinated waters containing bromide were used to determine the impact of boiling on disinfection by-product (DBP) concentrations. No significant changes were detected in the concentrations of the dihalogenated haloacetic acids (DXAAs) (i.e., dichloro-, bromochloro-, dibromoacetic acid) upon boiling of chloraminated water, whereas the levels of the trihalogenated haloacetic acids (TXAAs) (i.e., trichloro- (TCAA), bromodichloro- (BDCAA), dibromochloroacetic acid (DBCAA)) decreased over time (e.g., 9–37% for TCAA). Increased DXAA concentrations (58–68%) were detected in the boiled chlorinated sample, which likely resulted from residual chlorine reacting with DXAA precursors. TCAA concentration was unchanged after boiling chlorinated water for 1 min, but a 30% reduction was observed after 5 min of boiling. BDCAA concentrations decreased 57% upon boiling for 1 min and were completely removed after 2 min of boiling, whereas DBCAA was removed after boiling chlorinated water for 1 min. Trihalomethane concentrations were reduced in both chloraminated (74–98%) and chlorinated (64–98%) water upon boiling. Boiling chloraminated water for 1 min reduced chloroform concentration by 75%. Chloroform was reduced by only 34% in chlorinated water after a 1 min boil, which indicates that simultaneous formation and volatilization of chloroform was occurring. Most of the remaining DBPs (e.g. halo ketones, chloral hydrate, haloacetonitriles) were removed by at least 90% after 1 min of boiling in both samples. These data suggest that other mechanisms (e.g., hydrolysis) may have been responsible for removal of the non-volatile DBPs and further highlight the importance of examining individual species when estimating thermal effects on DBP concentrations.

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Keywords: Disinfection by-products; Trihalomethanes; Haloacetic acids; Haloketones; Haloacetonitriles; Boiling water

1. Introduction

Disinfection by-products (DBPs) are ubiquitous in chemically disinfected water containing natural organic matter and/or bromide. Carcinogenic and reproductive effects of DBPs have been reported in toxicological and epidemiological studies (Nieuwenhuijsen et al., 2000;

Villanueva et al., 2003). Epidemiologic studies of DBPs have often relied on ecologic measures, including type of treatment, type of source water, and trihalomethane (THM) compliance monitoring data (e.g., utility average concentrations) to estimate individual-level exposures. These indirect measures of exposure lead to measurement error, which can result in bias and reduced statistical power to detect associations. Key DBP research needs have been identified to address these exposure assessment limitations, including collection of detailed individual water use data, examination of

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non-volatile DBPs, use of sensitivity and uncertainty analysis, and development of exposure prediction models (Arbuckle et al., 2002; Nieuwenhuijsen et al., 2000). Recent DBP research has begun to address some of these DBP exposure assessment issues (Whitaker et al., 2003; Waller et al., 2001; Wright and Bateson, 2004; Wright et al., 2004; Dodds et al., 2004; Fenster et al., 2003; Windham et al., 2003), but it remains unclear which of these needs are most critical.

Information on exposure modifying factors, such as point-of-use filtration and boiling water prior to consumption (e.g., hot water-based beverages) needs to be considered in epidemiologic studies, because these activities can influence estimates of DBP ingestion exposure (Egorov et al., 2003; Eslinger and Weinberg, 2003). Experimental data have shown that boiling water prior to consumption can greatly impact DBP concentrations (Table 1). Batterman and colleagues (2000) examined thermal effects on THM concentrations by heating chlorine-free distilled water in an electric kettle. Average volatilization rates of 81% for chloroform (trichloromethane (TCM)) and 73% for bromodichloromethane (BDCM) were reported at 100 °C, with a 69% reduction in the four regulated THMs (THM4). Wu and colleagues (2001) conducted boiling experiments of Seattle tap water typically containing 0.9 mg/L chlorine residual and 0.9–1.5 mg/L of dissolved organic carbon (DOC). As boil time increased from 1 to 5 min, reductions of 68% and 83% for chloroform and 75% and 94% for BDCM were observed. Lahl and colleagues (1982) reported THM4 volatilization losses of 73% for a 1-min boil and 88% following a 5-min boil. Chloroform had the highest loss, and the amount removed during boiling decreased with increasing bromine substitution. Kuo and colleagues (1997) found similar removals of chloroform and BDCM upon boiling chlorinated water from Taiwan.

Different effects of boiling on haloacetic acid (HAA) concentrations have been reported in previous experimental studies (Table 1). Trichloroacetic acid (TCAA), a trihalogenated acid (TXAA), has been shown to be more readily removed (30–70%) upon boiling compared to the other subclasses of HAAs (i.e., dihaloacetic acids (DXAAs) and monohaloacetic acids (MXAAs)). Wu and colleagues (2001) reported more than a doubling of dichloroacetic acid (DCAA) levels in chlorinated water upon boiling for 1 or 5 min, whereas Kim (1997) observed no change in DCAA levels in distilled water following a 5-min boil. These results suggest that DCAA originally present was not impacted by boiling and that, in the presence of chlorine, additional DCAA could form during the boiling process. Changes in MXAA concentrations from previous studies varied from –28% to 46%. The MXAAs are typically present (if detected) at concentrations near their minimum reporting levels (MRLs) in most chlorinated waters, which limits the ability to quantify changes upon heating.

Table 1
Previous experimental studies of boiling effects on disinfection by-product concentrations^a

Study (boiling time)	TCM (%)	BDCM (%)	DBCM (%)	THM4 (%)	MCAA (%)	MBAA (%)	DCAA (%)	BCAA (%)	DBAA (%)	TCAA (%)
Kim (1997) (5 min) ^b							0			–40
Dajido et al. (1999) (10 min) ^c						–28	–18			–70
Wu et al. (2001) (1 min) ^d	–68	–75			25	40	122	–13	–11	–30
Wu et al. (2001) (5 min) ^d	–83	–94			32	46	130	–7		–46
Batterman et al. (2000) (12.5 min) ^b	–81	–73		–69						
Kuo et al. (1997) ^{d,e}	–79	–79	–93							
Lahl et al. (1982) (1 min) ^f	–80	–76	–71	–73						
Lahl et al. (1982) (5 min) ^f	–91	–90	–87	–88						

Abbreviations: TCM = chloroform (trichloromethane), BDCM = bromodichloromethane, DBCM = dibromochloromethane, THM4 = sum of the four regulated trihalomethanes, MCAA = monochloroacetic acid, MBAA = monobromoacetic acid, DCAA = dichloroacetic acid, BCAA = bromochloroacetic acid, DBAA = dibromoacetic acid, TCAA = trichloroacetic acid.

^aNegative value corresponds to decrease in concentration of DBP, whereas positive value corresponds to increase in concentration of DBP.

^bDistilled water with known DBP concentration.

^cOzonated and chlorinated water.

^dChlorinated water.

^eBoil time not reported.

^fHypochlorite treated water.

Hot and cold water use is an increasingly important consideration for DBP exposure assessment, because hot water-based beverages can contribute substantially to overall water consumption levels (Kaur et al., 2004; Egorov et al., 2003) and may have higher levels of certain DBPs compared to cold water. Balko and colleagues (2001) reported TCAA and DCAA concentrations up to three times as high in tea, coffee, and juice samples compared to chloraminated tap water, suggesting that the residual chlorine reacted with HAA precursors in the beverages. In the present study, boiling experiments were conducted on chloraminated and chlorinated water containing bromide. The effects of boiling on a wide range of regulated and emerging DBPs of health concern (Woo et al., 2002) were examined in relation to degree of DBP volatility and bromine substitution.

2. Methods

The boiling experiments were conducted on water samples from the Weymouth water treatment plant (La Verne, CA) in winter 2000. Although not measured, the DOC and bromide levels of this water were typically ~ 3.0 and ~ 0.1 – 0.2 mg/L, respectively. Conventional water treatment does not remove bromide, so bromide would have been present in the finished water. The typical pH of this water was ~ 8.2 . Separate aliquots of chlorinated filter effluent and chloraminated plant effluent were collected in 1-L glass bottles. Although not measured, the chlorine and chloramine residuals at these locations were each typically ~ 2.5 mg/L as Cl_2 . Residual chlorine and chloramines were not measured in each sample, but were at comparable levels, based on treatment plant specifications. The disinfectant residuals of these samples were not quenched. Shortly after sampling, the water samples were boiled using a 2.5-quart tea kettle on a stovetop in the Metropolitan Water District of Southern California (MWDSC) laboratory kitchen. The experiments consisted of 1-, 2-, and 5-min boil times. The samples were allowed to cool down prior to extraction. Control samples consisted of water that was not boiled (i.e., boil time = 0). Note, the comparisons between the two water treatments are the results from a single set of samples. The samples underwent liquid/liquid extraction (LLE) and were analyzed for DBPs by gas chromatography/electron capture detection (GC/ECD) (Krasner et al., 2001). Additional samples underwent LLE, were derivatized with an acidic methanol solution, and were analyzed by GC/ECD for HAAs (Munch et al., 1995). Sample analysis included standard measures of quality assurance for precision, accuracy, and bias.

Values for Henry's Law constant—a measure of the volatility of a compound—were obtained from the literature or were estimated using a quantitative structure activity relationship model (HENRYWIN version 3.10, part of the Estimation Program Interface for Windows from the US Environmental Protection Agency) (Westerhoff, 2003). HENRYWIN provided experimental values where available and predicted the Henry's Law Constants at 25 °C by the bond contribution method for those DBPs without experimental values. Henry's Law Constants were not determined for boiling water at 100 °C. The Henry's Law Constants served as a tool to ascertain if a DBP was considered volatile (10^{-1} – 10^{-3} atm-m³/mol), moderately volatile (10^{-3} – 10^{-5} atm-m³/mol), slightly volatile (10^{-5} – 10^{-7} atm-m³/mol) or non-volatile ($<10^{-7}$ atm-m³/mol). DBPs that are not volatile would still be considered relatively non-volatile in boiling water.

3. Results

3.1. Overview

The HAAs were the most prevalent DBP in the chlorinated and chloraminated samples, followed by the THMs (Tables 2 and 3). Significant amounts of haloaldehydes, haloacetonitriles (HANs), and halo ketones (HKs) were also detected. Because of the presence of bromide in the treated source waters, there was a mix of bromine- and chlorine-containing DBP species detected for those DBP classes (i.e., THMs, HANs, haloaldehydes, HAAs) in which brominated species were analyzed. An iodinated THM (dichloroiodomethane) was detected in the chlorinated water, while low levels of chloropicrin (trichloronitromethane (TCNM)) were found in both the chlorinated and chloraminated samples. As shown in Tables 2 and 3, with the exception of the HAAs as a class sum, the sum of the THMs and that of the other DBPs were significantly reduced following a 1-min boil. More modest reductions in these DBP concentrations occurred upon boiling for 2 and 5 min. Within some DBP classes, however, there were significant differences in the impact of boiling on the concentrations of individual DBPs (Fig. 1).

3.2. THMs

Reduction (presumably due to volatilization) in the sum of the THMs (i.e., THM4 and dichloroiodomethane) was (in general) comparable for chlorinated and chloraminated waters, especially after 2 and 5 min of boiling (Tables 2 and 3). THM4 removals ranged from 64% to 98% across the different boiling times.

Table 2

Cumulative percent change (from time 0) in DBP concentrations ($\mu\text{g/L}$) from boiled chloraminated water^a

DBP class	Analyte	Time (min)			
		0	1	2	5
Regulated trihalomethanes (THMs)	Chloroform (trichloromethane) (TCM)	18	4.6 (–75%)	3.0 (–84%)	0.6 (–97%)
	Bromodichloromethane (BDCM)	26	6.3 (–75%)	4.2 (–84%)	0.6 (–98%)
	Dibromochloromethane (DBCM)	13	4.1 (–70%)	2.1 (–84%)	ND (–100%)
	Bromoform (tribromomethane) (TBM)	0.9	0.4 (–60%)	ND (–100%)	ND (–100%)
	Sum of 4 regulated THMs (THM4)	58	15 (–74%)	9.3 (–84%)	1.2 (–98%)
Haloacetonitriles (HANs)	Dichloroacetonitrile (DCAN)	4.3	0.2 (–96%)	0.1 (–98%)	ND (–100%)
	Bromochloroacetonitrile (BCAN)	1.1	0.05 (–96%)	0.07 (–94%)	ND (–100%)
Haloaldehydes (HAs)	Dichloroacetaldehyde (DCA)	1.5	0.5 (–70%)	0.4 (–75%)	0.2 (–85%)
	Chloral hydrate (CH) (trichloroacetaldehyde)	5.1	0.1 (–98%)	0.1 (–98%)	ND (–100%)
Haloketones (HKs)	1,1-Dichloropropanone (1,1-DCP)	0.5	ND (–100%)	ND (–100%)	ND (–100%)
	1,3-Dichloropropanone (1,3-DCP)	0.1	0.07 (–42%)	ND (–100%)	ND (–100%)
	1,1,1-Trichloropropanone (1,1,1-TCP)	2.2	ND (–100%)	ND (–100%)	ND (–100%)
	1,1,3-Trichloropropanone (1,1,3-TCP)	0.1	ND (–100%)	ND (–100%)	ND (–100%)
Halonitromethane (HNM)	Chloropicrin (trichloronitromethane) (TCNM)	1.4	0.7 (–50%)	0.5 (–67%)	ND (–100%)
Sum of other DBPs (i.e., HANs, HAs, HKs, HNM)		16	1.6 (–90%)	1.1 (–93%)	0.2 (–99%)
Haloacetic acids	Dichloroacetic acid (DCAA)	38	34 (–9%)	37 (–3%)	40 (7%)
	Bromochloroacetic acid (BCAA)	14	14 (4%)	15 (9%)	15 (12%)
	Dibromoacetic acid (DBAA)	4.5	4.2 (–7%)	4.1 (–9%)	4.3 (–4%)
	Sum of dihalogenated HAAs (DXAAs)	56	53 (–6%)	56 (–1%)	60 (7%)
	Trichloroacetic acid (TCAA)	26	23 (–9%)	20 (–21%)	16 (–37%)
	Bromodichloroacetic acid (BDCAA)	15	7.1 (–53%)	3.2 (–79%)	1.1 (–93%)
	Dibromochloroacetic acid (DBCAA)	3.9	ND (–100%)	ND (–100%)	ND (–100%)
	Sum of trihalogenated HAAs (TXAAs)	45	30 (–32%)	23 (–48%)	17 (–61%)
Sum of HAAs		100	83 (–17%)	79 (–22%)	77 (–23%)

Abbreviations: DBP = disinfection by-product, ND = not detected.

^aPercent changes were calculated from the values of the concentrations before those values were rounded to the number of significant figures given in this table.

Table 3

Cumulative percent change (from time 0) in DBP concentrations ($\mu\text{g/L}$) from boiled chlorinated water^a

DBP class	Analyte	Time (min)			
		0	1	2	5
Regulated trihalomethanes (THMs)	Chloroform (trichloromethane) (TCM)	30	20 (−34%)	2.8 (−91%)	1.0 (−97%)
	Bromodichloromethane (BDCM)	33	6.4 (−81%)	2.2 (−93%)	0.7 (−98%)
	Dibromochloromethane (DBCM)	16	2.9 (−82%)	0.4 (−97%)	ND (−100%)
	Bromoform (tribromomethane) (TBM)	1.0	0.2 (−76%)	ND (−100%)	ND (−100%)
	Sum of 4 regulated THMs (THM4)	80	29 (−64%)	5.4 (−93%)	1.6 (−98%)
Iodinated THM	Dichloroiodomethane (DCIM)	0.8	ND (−100%)	ND (−100%)	ND (−100%)
Sum of THMs		81	29 (−64%)	5.4 (−93%)	1.6 (−98%)
Haloacetonitriles (HANs)	Dichloroacetonitrile (DCAN)	6.2	0.1 (−98%)	ND (−100%)	ND (−100%)
	Bromochloroacetonitrile (BCAN)	1.6	0.1 (−94%)	ND (−100%)	ND (−100%)
Haloaldehydes (HAs)	Dichloroacetaldehyde (DCA)	1.2	0.9 (−27%)	0.2 (−85%)	0.06 (−95%)
	Chloral hydrate (CH) (trichloroacetaldehyde)	12	0.4 (−97%)	ND (−100%)	ND (−100%)
	Tribromoacetaldehyde (TBA)	0.4	0.4 (0%)	ND (−100%)	ND (−100%)
Haloketones (HKs)	Chloropropanone (CP)	1.1	0.08 (−93%)	ND (−100%)	ND (−100%)
	1,1-Dichloropropanone (1,1-DCP)	0.3	ND (−100%)	ND (−100%)	ND (−100%)
	1,3-Dichloropropanone (1,3-DCP)	0.2	ND (−100%)	ND (−100%)	ND (−100%)
	1,1,1-Trichloropropanone (1,1,1-TCP)	6.2	ND (−100%)	ND (−100%)	ND (−100%)
Halonitromethane (HNM)	Chloropicrin (trichloronitromethane) (TCNM)	1.5	0.7 (−57%)	ND (−100%)	ND (−100%)
Sum of other DBPs (i.e., HANs, HAs, HKs, HNM)		31	2.6 (−92%)	0.2 (−99%)	0.06 (−100%)
Haloacetic acids (HAAs)	Monochloroacetic acid (MCAA)	3.4	3.9 (15%)	4.2 (24%)	4.6 (35%)
	Dichloroacetic acid (DCAA)	43	68 (59%)	72 (69%)	75 (76%)
	Bromochloroacetic acid (BCAA)	17	26 (51%)	25 (48%)	25 (49%)
	Dibromoacetic acid (DBAA)	4.3	7.4 (72%)	6.9 (60%)	6.8 (58%)
	Sum of dihalogenated HAAs (DXAAs)	64	101 (58%)	104 (63%)	107 (68%)
	Trichloroacetic acid (TCAA)	31	31 (0%)	28 (−10%)	21 (−30%)
	Bromodichloroacetic acid (BDCAA)	17	7.4 (−57%)	3.1 (−82%)	ND (−100%)

Table 3 (continued)

DBP class	Analyte	Time (min)			
		0	1	2	5
	Dibromochloroacetic acid (DBCAA)	4.6	ND (–100%)	ND (–100%)	ND (–100%)
	Sum of trihalogenated HAAs (TXAAs)	52	38 (–27%)	31 (–41%)	21 (–60%)
Sum of HAAs		120	142 (19%)	139 (16%)	133 (11%)

Abbreviations: DBP = disinfection by-product, ND = not detected.

^aPercent changes were calculated from the values of the concentrations before those values were rounded to the number of significant figures given in this table.

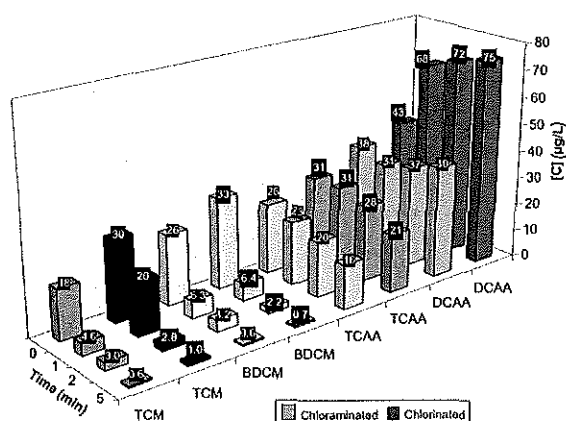


Fig. 1. The effects of boiling chlorinated and chloraminated water on the concentrations of the major THM and HAA species.

Individual THM removals in the chloraminated water ranged from 60% to 75% in chloraminated water boiled for 1 min (Table 4). The THMs are the most volatile group of the DBPs studied, based on their values of Henry's Law constant (the higher the value, the more volatile the compound). Eighty-four percent or more of each species was removed following a 2-min boil, whereas 97% or more of each THM was removed upon boiling for 5 min (Table 2). In the chlorinated water, slightly higher removal of the bromine-containing THMs was detected following a 1-min boil (76–82%), whereas there was limited removal (34%) of chloroform (Table 3). There was little difference between THM removal in chlorinated versus chloraminated water upon further boiling, with both samples having removals of 97% or greater for each THM detected after 5 min of boiling. The only iodinated THM that was detected, dichloriodomethane, was completely eliminated after boiling chlorinated water for 1 min.

Table 4

Relationship of volatility of DBPs to percent change from time 0 after 1 min of boiling in chloraminated water

DBP	Henry's Law Constant (atm-m ³ /mol)	% Change from time 0 at 1 min in chloraminated water ^a
TCM	3.67E–03 ^b	–75
BDCM	2.12E–03 ^b	–75
TCNM	2.05E–03 ^b	–50
DBCM	7.83E–04 ^b	–70
TBM	5.35E–04 ^b	–60
DCA ^c	8.42E–06	–70
DCAN	3.79E–06	–96
DCAA	3.52E–07 ^b	–9
TBA	1.04E–07	N/A
BCAA	2.22E–08	4
TCAA	1.35E–08 ^b	–9
BDCAA	7.83E–09	–53
MCAA	9.42E–09 ^b	N/A
DBAA	7.27E–09	–7
CH	5.71E–09	–98

Abbreviations: DBPs = disinfection by-products, N/A = not applicable (not detected in chloraminated water at time 0).

^aVolatility comparisons were made with the test in chloraminated water, to eliminate the confounding phenomena of simultaneous formation of some DBPs in the presence of chlorine.

^bFrom literature values provided in HENRYWIN. Other Henry's Law Constants in this table were estimated by HENRYWIN.

^cHenry's Law Constant was estimated for dichloroacetaldehyde and not for its hydrate.

3.3. HAAs

The overall impact of boiling on HAAs gave different results in the two water samples that were

analyzed. Increased HAA formation occurred in the chlorinated water after 1 min of boiling, and the concentration was still relatively high after 5 min of boiling (Table 3). A reduction in overall HAA concentration was observed in chloraminated water after 1 min of boiling, and the levels changed very little upon further boiling.

Boiling of the chloraminated sample produced no significant changes (–9% to 7%) in DCAA concentrations (Fig. 1), where the coefficient of variation of DCAA and other DBP samples is typically on the order of approximately $\pm 20\%$ (Fair et al., 2002). Similar results were observed in the chloraminated sample for the other DXAAs, with no significant change in bromochloroacetic acid (BCAA) and dibromoacetic acid (DBAA) concentrations (Table 2). DCAA concentrations in chlorinated water increased from 59 to 76% as boiling time increased from 1 to 5 min (Table 3). BCAA and DBAA concentrations increased by at least 50% in chlorinated water for a 1-min boil but remained relatively constant upon further boiling. No change in TCAA concentration was observed for a 1-min boil of chlorinated water, but 10% and 30% reductions were noted in water boiled for 2 and 5 min, respectively (Fig. 1). Among the chloraminated samples, somewhat larger reductions (9–37%) in TCAA concentrations were found as boil time increased. Similar reductions were observed over time for bromodichloroacetic acid in both the chlorinated (57–100%) and chloraminated samples (53–93%). Although found in smaller concentrations compared to the other TXAAs, dibromochloroacetic acid was not detected upon boiling for 1 min. Small increases in the monochloroacetic acid (MCAA) concentration were noted for the chlorinated sample upon boiling.

3.4. HKs

For the chloraminated water sample, substantial reductions in concentrations were noted for most of the other DBPs upon boiling (Table 2). The following HKs were not detected after 1 min: 1, 1-dichloropropanone (1,1-DCP), 1, 1, 1-trichloropropanone (1,1,1-TCP), and 1, 1, 3-trichloropropanone (1,1,3-TCP). The level of 1, 3-dichloropropanone (1,3-DCP) decreased 42% upon boiling for 1 min and was completely removed after 2 min of boiling. Similar reductions were observed in the chlorinated water with complete removal of 1,1-DCP, 1,1,1-TCP and 1,3-DCP upon boiling for 1 min (Table 3). In addition, the concentration of chloropropanone (CP) was reduced by 93% following a 1-min boil and was not detected after 2 min. CP was not detected in the chloraminated water sample, and 1,1,3-TCP was not found in the chlorinated water sample.

3.5. HANs

HAN concentrations in chloraminated water were reduced by 94–98% following a 1- and 2-min boil, and were not detected upon 5 min of boiling (Table 2). Similar removal of the HANs (94–98%) occurred upon boiling the chlorinated sample for 1 min, and no HANs were detected in the chlorinated water after 2 min (Table 3).

3.6. Haloaldehydes

The concentration of dichloroacetaldehyde (DCA) in chloraminated water was reduced from 70% to 85% for 1- to 5-min boil times (Table 2). Boiling chlorinated water for 1 min had a minimal effect on the level of DCA (–27%), but reductions from 85% to 95% were observed upon further boiling (Table 3). Chloral hydrate (CH) (i.e., trichloroacetaldehyde) concentration was reduced by at least 97% following a 1-min boil of both chlorinated and chloraminated water and was not detected after 2 min. Tribromoacetaldehyde (TBA) was not detected in the chloraminated water and a minimal amount was found in chlorinated water (0.37 $\mu\text{g/L}$). TBA was unchanged upon boiling for 1 min and was not detected after 2 min of boiling.

3.7. Halonitromethane

TCNM concentration was 50–67% lower in the chloraminated water boiled for 1–2 min and was not detected at 5 min (Table 2). A reduction similar in magnitude (57%) was observed for chlorinated water boiled for 1 min, and TCNM was not detected after 2 min of boiling (Table 3).

4. Discussion

Overall, large reductions in most DBP concentrations were observed in boiling experiments of chloraminated and chlorinated finished water samples. Removal rates among the THMs were similar to those noted in previous studies (Lahl et al., 1982; Kuo et al., 1997; Batterman et al., 2000; Wu et al., 2001), although a smaller net removal of chloroform was detected in the chlorinated water (34%) compared to the chloraminated water (75%) for 1 min of boiling (Fig. 1). Because there was a free chlorine residual in the chlorinated water at the time of boiling, it is likely that chloroform was being formed from the reaction of the chlorine with DBP precursors in the water at the same time that chloroform was being volatilized. Although the residuals were not measured after boiling in these tests, preliminary experiments at MWDSC have shown

that the chlorine residual was removed during the first minute of boiling. Thus, the critical issue is that there can be simultaneous formation and volatilization during the first minute, whereas in subsequent minutes of boiling only volatilization can occur. In the chloraminated water, volatilization appeared to be the most important phenomenon, even during the first minute of boiling. In that sample, the two more brominated THMs were removed to a lesser extent (60–70%) than the two more chlorinated THMs (75%). This is similar to the finding of Lahl and colleagues (1982) for a 1-min boil.

Different effects were observed in haloaldehyde concentrations upon boiling. The semi-volatile haloaldehydes, DCA and TBA (Table 4), were not significantly impacted by boiling chlorinated water for 1 min, suggesting that there was simultaneous formation and removal of these haloaldehydes while a free chlorine residual was present. Note, because conventional water treatment does not remove bromide, there can still be bromide in the finished water available to react with free chlorine to form TBA. Their removal at longer boiling times in the chlorinated water and the removal of DCA in the chloraminated water may be due to a combination of volatilization and degradation. Alternatively, the removal of the non-volatile CH (Table 4) was probably due to base-catalyzed hydrolysis. Although hydrolysis is more significant at pH 9 than at pH 7 for CH (Stevens et al., 1989), the combination of elevated temperature and alkaline pH may have resulted in the degradation of this DBP.

HAN concentrations were dramatically reduced upon boiling of chloraminated and chlorinated water. Dichloroacetonitrile (DCAN) is a semi-volatile DBP (Table 4), which can also undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989). DCAN's degradation product is dichloroacetamide, which can be further hydrolyzed to DCAA (Reckhow et al., 2001). Therefore, it is possible that some of the HANs degraded (e.g., due to hydrolysis), in addition to volatilizing, during the boiling process. TCNM does not undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989) and has a Henry's Law Constant similar to that of the THMs (Table 4), so reductions in TCNM concentrations were likely due to volatilization.

Henry's Law constant values were not obtained for the HKs. Some HKs (e.g., 1,1,1-TCP) are known to undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989). The pH of the samples in the present study was ~8.2; therefore, it is possible that some of the HKs degraded (e.g., due to hydrolysis) during the boiling process. Chloroform is the degradation product of 1,1,1-TCP and CH hydrolysis; therefore, these degradation processes may have contributed to the limited removal of chloroform that was observed during the initial boil of chlorinated water.

In general, the DXAAs were not significantly impacted by boiling in the chloraminated water (Table 2), whereas their concentrations increased significantly in the chlorinated water (Table 3). Most of the increased formation occurred during the first minute of boiling as shown for DCAA (Fig. 1). These data suggest that free chlorine reacted with DBP precursors to form additional DXAAs (and perhaps MCAA), which were not volatilized or degraded by the boiling process. The DXAAs and other HAAs are not volatile (Table 4). A reduction in TXAA concentrations during the boiling process was observed, with the rate of loss higher with increased bromine substitution. Bromine-containing TXAAs have been shown to be less stable with increasing bromine substitution and are subject to thermal- and photo-degradation (Pourmoghaddas and Dressman, 1993). Thus, the loss of the brominated TXAAs in the present study was most likely due to the relative instability of these DBPs. The net impact on the sum of the HAAs (increased concentrations of 11–19% for chlorinated water and decreased concentrations of 17–23% in the chloraminated samples) reflect the very different impact of boiling on the two subclasses of HAAs, DXAAs and TXAAs. These findings highlight the importance of considering the varied formation and degradation processes of individual HAAs when estimating the impact of heating and boiling on exposures.

5. Conclusion

The different effects of boiling within DBP classes in chlorinated versus chloraminated water have important implications for DBP exposure assessment efforts in epidemiologic studies. Previous DBP research has rarely included individual-level water use information, and only two epidemiological studies have examined individual data on hot and cold beverage consumption. Compared to THM water concentrations alone, Klotz and Pyrch (1999) and Waller and colleagues (1998) reported smaller relative risks for reproductive outcomes with THM exposures that considered hot and cold water consumption. Neither study attempted to adjust estimates of individual exposure to account for volatilization or other exposure modifying effects. These studies were also limited in their ability to adequately consider the impact of dermal and inhalation exposures, which may be more important than ingestion for volatile DBPs (Gordon et al., 1998; Keating et al., 1997). THM concentrations can increase upon heating water at lower temperatures than boiling (Weisel and Chen, 1994; Batterman et al., 2000), so future studies should also consider potential exposure modifying activities (e.g., water temperatures during showering or in swimming pools) that may impact overall DBP exposure.

Based on the results of this study and the previous research cited, the effects of heating and boiling on DBPs are dependent on the degree of DBP volatility and compound stability, water temperature, type of residual disinfectant present, as well as the amount of DBP precursors and chlorine residual present in the water. Because chlorine residual can vary considerably within a distribution system, boiling and heating effects may differ between individuals using the same water supply. Failure to directly measure residential DBP concentrations or adequately capture spatial variability in residual chlorine and DBP formation/degradation when estimating individual level exposures can lead to measurement error in epidemiologic studies.

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Guidance for People with Severely Weakened Immune Systems

(co-released with the Centers for Disease Control and Prevention, 1995)

INTRODUCTION

Cryptosporidium is a parasite commonly found in lakes and rivers, especially when the water is contaminated with sewage and animal wastes. *Cryptosporidium* is very resistant to disinfection, and even a well-operated water treatment system cannot ensure that drinking water will be completely free of this parasite. Current EPA drinking water standards were not explicitly designed to assure the removal or killing of *Cryptosporidium*. Many large water systems already voluntarily take actions for greater control of *Cryptosporidium* and other microbial contaminants. By 2001, the water systems serving the majority of the United States population (those relying on a surface water source, such as a river, and serving more than 10,000 people) must meet a new EPA standard that strengthens control over microbial contaminants, including *Cryptosporidium*. EPA continues to conduct research on microbial contaminants which will be used for determining priorities for the drinking water program, including setting future standards and reevaluating existing standards.

Cryptosporidium has caused several large waterborne disease outbreaks of gastrointestinal illness, with symptoms that include diarrhea, nausea, and/or stomach cramps. People with severely weakened immune systems (that is, severely immunocompromised) are likely to have more severe and more persistent symptoms than healthy individuals. Moreover, *Cryptosporidium* has been a contributing cause of death in some immunocompromised people. Individuals who are severely immunocompromised may include those who are infected with HIV/AIDS, cancer and transplant patients taking immunosuppressive drugs, and people born with a weakened immune system.

BACKGROUND

Data are not adequate to determine how most people become infected. For example, we do not know the importance of drinking water compared to other possible sources of *Cryptosporidium*, such as exposure to the feces of infected persons or animals, sex involving contact with feces, eating contaminated food, or accidentally swallowing contaminated recreational water.

Thus, in the absence of an outbreak, there are insufficient data to determine whether a severely immunocompromised individual is at a noticeably greater risk than the general public from waterborne *Cryptosporidiosis*. Even a low level of *Cryptosporidium* in water, however, may be of concern for the severely immunocompromised, because the illness can be life-threatening. The risk of a severely immunocompromised individual acquiring *Cryptosporidiosis* from drinking water in the absence of an outbreak is likely to vary from city to city, depending on the quality of the city's water source and the quality of water treatment. Current risk data are not adequate to support a recommendation that severely immunocompromised persons in all U.S. cities boil or avoid drinking tap water.

In the absence of a recognized outbreak, this guidance has been developed for severely immunocompromised people who may wish to take extra precautions to minimize their risk of infection from waterborne *Cryptosporidiosis*. To be effective, the guidance must be followed consistently for all water used for drinking or for mixing beverages. During outbreaks of waterborne *Cryptosporidiosis*, studies have found that people who used precautions only part of the time were just as likely to become ill as people who did not use them at all.

GUIDANCE

EPA and CDC have developed the following guidance for severely immunocompromised people who may wish to take extra precautions. Such individuals should consult with their health care provider about what measures would be most appropriate and effective for reducing their overall risk of *Cryptosporidium* and other types of infection.

Although data are not sufficient for EPA/CDC to recommend that all severely immunocompromised persons take extra caution with regards to their drinking water, individuals who wish to take extra measures to avoid waterborne Cryptosporidiosis can bring their drinking water to a full boil for one minute. **Boiling water is the most effective way of killing *Cryptosporidium*.** As an alternative to boiling water, people may use the following measures:

- **A point-of-use (personal use, end-of-tap, under-sink) filter.** Only point-of-use filters that remove particles one micrometer or less in diameter should be considered. Filters in this category that provide the greatest assurance of *Cryptosporidium* removal include those that use reverse osmosis, those labeled as "Absolute" one micrometer filters, or those labeled as certified by NSF International under standard 53 for "Cyst Removal." The "Nominal" one micrometer rating is not standardized and many filters in this category may not reliably remove *Cryptosporidium*. As with all filters, people should follow the manufacturer's instructions for filter use and replacement. Water treated with a point-of-use filter that meets the above criteria may not necessarily be free of organisms smaller than *Cryptosporidium* that could pose a health hazard for severely immunocompromised individuals.
- **Bottled water.** Many, but not all, brands of bottled water may provide a reasonable alternative to boiling tap water. The origin of the source water, the types of microorganisms in that water, and the treatment of that water before it is bottled vary considerably among bottled water companies and even among brands of water produced by the same company. Therefore, individuals should not presume that all bottled waters are absolutely free of *Cryptosporidium*. Bottled waters derived from protected well and protected spring water sources are less likely to be contaminated by *Cryptosporidium* than bottled waters containing municipal drinking water derived from less protected sources such as rivers and lakes. Any bottled water treated by distillation or reverse osmosis before bottling assures *Cryptosporidium* removal. Water passed through a commercial filter that meets the above criteria for a point-of-use device before bottling will provide nearly the same level of *Cryptosporidium* removal as distillation or reverse osmosis. Bottled waters meeting the above criteria may not necessarily be free of organisms other than *Cryptosporidium* that could pose a health hazard for severely immunocompromised individuals.

Neither EPA nor CDC maintains a list of point-of-use filters or bottled water brands that meet the above criteria. NSF International can provide a list of filters that meet the NSF criteria. The NSF address is 789 N. Dixboro Road, PO Box 130140, Ann Arbor, Michigan 48113-0140; phone number (877) 8-NSF-HELP (<http://www.nsf.org/>). Individuals who contact bottlers or filter manufacturers for information should request data supporting claims that a brand of bottled water or filter can meet the above criteria.

FURTHER INFORMATION

When an outbreak of waterborne Cryptosporidiosis is recognized and is determined to be on-going, officials of the public-health department and/or the water utility will normally issue a "boil water" notice to protect both the general public and the immunocompromised.

Current testing methods cannot determine with certainty whether *Cryptosporidium* detected in drinking water is alive or whether it can infect humans. In addition, the current method often requires several days to get results, by which time the tested water has already been used by the public and is no longer in the community's water pipes.

Severely immunocompromised people may face a variety of health risks. Depending on their illness and circumstances, a response by such individuals that focuses too specifically on one health risk may decrease the amount of attention that should be given to other risks. Health care providers can assist severely immunocompromised persons in weighing these risks and in applying this guidance.

Exposures to drinking water chlorination by-products in a Russian city

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Abstract

Exposures to water disinfection by-products (DBPs) via ingestion of drinking water, and dermal absorption and inhalation during showering/bathing were assessed in the city of Cherepovets, Russia, which uses heavy chlorination to disinfect organic-rich surface water. Concentrations of DBPs (mean $\pm$ standard deviation) in tap water were the following: total trihalomethanes (THMs) 205 ± 70 $\mu\text{g/l}$, five haloacetic acids (HAAs) 150 ± 30 $\mu\text{g/l}$, and 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (mutagen X or MX) 160 ± 50 ng/l . Concentrations of THMs and HAAs exceeded the corresponding US standards by a factor of 2.5, while MX concentrations were the highest ever reported. The mutagenic activity of tap water extracts in the *Salmonella* TA-100 assay was 14,900 net revertants/l. Concentrations of chloroform in breathing zone air in bathrooms during showering were 330 ± 260 $\mu\text{g/m}^3$, shower room air at an industrial plant $2,600 \pm 1,100$ $\mu\text{g/m}^3$, and bedrooms of local residents 2 ± 2 $\mu\text{g/m}^3$. The mean concentration of chloroform was 3.2 $\mu\text{g/m}^3$ in exhaled air samples collected before showering and 110 $\mu\text{g/m}^3$ after showering. Data on water ingestion and water use practices in the general population and for pregnant women were collected using questionnaires and diaries. Due to concerns over microbiological safety of water, average daily consumption of non-boiled tap water in pregnant women was only 0.01 l/day, while consumption of boiled tap water was 0.81 l/day. This resulted in low ingestion exposures to volatile THMs. Inhalation and dermal absorption determined total exposures to these compounds. HAAs and MX persist in boiled water and drinks resulting in high ingestion exposures. Several brands of inexpensive home water filters were tested for removal of these compounds. To demonstrate a method of exposure reduction in a sensitive subpopulation, the most efficient filters were given to a group of pregnant women. These women and a control group of pregnant women without filters maintained water ingestion diaries for two weeks. The use of home filters resulted in reduction of exposures to HAAs by a factor of three and a greater reduction in exposures to MX.

Key words: DBPs – trihalomethanes – haloacetic acids – MX – water – ingestion – inhalation – dermal absorption – pregnant women

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Introduction

Chlorination of water results in formation of an array of DBPs (disinfection by-products). THMs (trihalomethanes) are the most common volatile DBPs and HAAs (haloacetic acids) are the major non-volatile DBPs (Cunning and Jolley, 1993; U.S. Environmental Protection Agency (EPA), 1997b; Boorman et al., 1999). Other DBPs, such as haloacetonitriles (HANs), chloropicrine and chlorinated furanones are usually present at lower concentrations. Concentrations of 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) are usually in the ng/l range (Smeds et al. 1997). However, this compound is the strongest determinant of mutagenic activity of chlorinated drinking water in *Salmonella* assays (Kronberg and Vartiainen, 1988; Tuomisto and Vartiainen, 1990; Vartiainen et al., 1990; Wright et al., 2002).

Health effects of exposures to DBPs are thought to include various cancers and reproductive health effects, including spontaneous abortions, stillbirths, congenital malformations and retarded fetal development (Smallwood et al., 1993; Chiu et al., 1996; Swan and Waller, 1998; Nieuwenhuijsen et al., 2000a; Bove et al., 2002).

Concentrations of DBPs usually vary by season reflecting variability in source water composition and disinfection practices (Arora et al., 1997). DBP concentrations may also vary within the distribution system due to continuous formation and decomposition (LeBel et al., 1997; Chen and Weisel, 1998; Rossman et al., 2001).

Water boiling results in volatilization of chloroform and other THMs. These compounds are present at low concentrations in drinks prepared with boiled water and are not detectable in most foods. Thus, individual ingestion exposures are determined by consumption of non-boiled tap water. Inhalation is an important pathway of exposures to THMs as these compounds can accumulate in in-door air during showering, bathing and other activities associated with water use (Backer et al., 2000; Kerger et al., 2000; Lynberg et al., 2001). Dermal absorption during showering/bathing is another major route of exposure to THMs (Weisel, 1993; Weisel and Jo, 1996; Weisel et al., 1999; Nieuwenhuijsen et al., 2000b). Within the exposed population, individual dermal and inhalation exposures depend on showering/bathing frequency and duration, and other parameters, such as water temperature (which strongly affects dermal absorption of THMs), water flow, type of shower-head, and air exchange rate in the bathroom.

Polar molecules of HAAs, HANs, and MX (mutagen X) do not readily penetrate the skin (Xu et al., 2002). Inhalation exposures to these non-volatile and semi-volatile DBPs have also been demonstrated to be insignificant (Kim and Weisel, 1998). On the other hand, these compounds, especially dichloroacetic acid (DCAA), persist in boiled water and foods (Raymer et al., 2000; Wu et al., 2001). Thus, individual exposures to these compounds are determined by total ingestion of tap water (non-boiled and boiled), hot drinks and tap water-containing foods.

Point-of-use treatment of drinking water using activated carbon filters may reduce ingestion exposures to DBPs. However, the efficiency of home filters may vary depending on filter brand, age and characteristics of tap water.

The DBP exposure assessment study presented in this paper was conducted in the city of Cherepovets, Russia, by the Harvard School of Public Health and the Cherepovets Center for Sanitary and Epidemiological Control (Sanepid) in cooperation with the National Public Health Institute (Finland), and Research and Production Corporation Typhoon (Russia). Cherepovets (population of 320,000) is located 400 km to the North of Moscow in the sparsely populated area of coniferous forests. The city uses a major water artery in the area, the Sheksna River, as its sole water source. The single water treatment plant uses chlorination with high doses of liquid chlorine, which vary from 5 mg/l to 13 mg/l depending on the immediate chlorine demand of source water. No DBP precursor removal is practiced. Chlorination is followed by coagulation with aluminum sulfate and rapid upward filtration through sand filters (direct clarification). Most of the time, total residual chlorine concentration in effluent water varies from 1 mg/l to 2 mg/l (these limits are set by local water quality standards) with free chlorine accounting for two thirds and chloramines accounting for the remainder. In the spring of 1999, the mean free chlorine concentration in effluent water was 1.09 mg/l, the mean concentration of chloramines was 0.47 mg/l, while the mean pH was 6.85. Secondary chlorination in the distribution system is not practiced. According to the utility company, mean residence time of water in the distribution system is several hours, while exact water residence times for specific locations are unknown. The mean concentrations of free chlorine at point of use sites (a sample of residences in different parts of the city) were 0.06 mg/l in fall 1998 and 0.03 mg/l in spring 1999, while the mean concentrations of chloramines were correspondingly 0.43 mg/l and 0.26 mg/l (Egorov et al., 2002a).

According to the water utility's data, concentrations of chloroform in treatment plant effluent frequently exceed the Russian standard of 200 µg/l. Monitoring of chloroform at point-of-use sites is not practiced and other DBPs are not routinely monitored in Cherepovets.

Materials and methods

Water sampling and analysis

Water and air samples for DBP analysis were collected during several short visits of Harvard specialists to Cherepovets from the fall of 1999 through the spring of 2001. Samples were then transported to the chemistry laboratories at Harvard University or Typhoon Corp. Tests of mutagenicity were conducted at the National Public Health Institute (Kuopio, Finland), which also provided methodology for MX monitoring and analyzed replicate control samples.

Cold tap water samples were collected from local households for determination of HAAs, HANs, MX and mutagenicity, while warm water samples (at a temperature normally used for showering) were collected for determination of THMs. Several samples of boiled tap water and tea have also been analyzed.

Water samples for determination of THMs were collected into 40 ml bottles, acidified and preserved with sodium thiosulfate and transported in insulated containers with ice packs. Analysis was conducted using a gas chromatography/mass spectrometry (GC/MS) capillary column technique with head space sample introduction in accordance with the method developed by the Pacific Northwest National Laboratory (PNNL Method VOA-4, 1998). Water samples for determination of HAAs were collected, preserved, transported and analyzed in accordance with the US EPA Method 552.2 (US EPA, 1995a). Analysis of HANs was conducted using GC/MS in accordance with the US EPA method 551.1 (US EPA, 1995b).

For determination of MX, tap water samples of 2 l volume were collected into precleaned glass bottles, acidified and filtered through sorption columns with XAD-8 resin. MX was eluted from the sorbent with ethyl acetate. MX solution in ethyl acetate was evaporated to a non-volatile residue. MX was methylated with 2% H₂SO₄ in methanol and then extracted with hexane. MX concentrations were determined using GC/MS in accordance with the method described by Vartiainen et al. (1991) and Smeds et al. (1997).

Water samples for determination of mutagenic activity in the standard *Salmonella typhimurium* assay (Maron and Ames, 1983) were collected, processed and extracted following the procedure for determination of MX as described above. Tests were conducted using the tester strain TA100 without metabolic activation in accordance with the method used in previously conducted studies of tap water mutagenicity (Vartiainen and Liimatainen 1988; Wright et al. 2002).

Selection of home water filters to reduce ingestion exposures

To assess removal efficiency of THMs, HAAs, HANs and MX, we concurrently tested three commercially available inexpensive home filters: Brita™ and Aquaphor™ tabletop pitcher filters and a detachable faucet-tip Rodnik filter. Cartridges in all of these filters contained activated carbon. Brita filters also contained ion-exchange resins for removal of heavy metals, and, thus, a smaller amount of activated carbon. Filtered water samples were collected after filtration of a predefined quantity of tap water through these new filters (for example, from 1st, 50th, 100th, and 150th liters). Non-filtered tap water samples were collected concurrently to determine baseline concentrations. In addition, two previously used faucet-tip filters of different brands were tested by collecting filtered and non-filtered samples from apartments of Sanepid employees. Testing of water filters was conducted in April 2001.

Air sampling and analysis

Indoor air sampling for determination of THMs was conducted using an active sampling method. The sampling equipment included a portable pump, electronic flowmeter/totalizer, Tygon™ tubing, and sorption tubes packed with Carboxpack-B™ sorbent (Supelco Inc., Bellefonte, Pennsylvania, USA). Samples from shower rooms at industrial facilities were collected when workers were taking showers after work shifts. Bathroom, kitchen and bedroom air samples were collected from apartments of Sanepid employees. Bathroom samples were collected during showering activities at a distance of 20 cm from the water flow for 15 to 20 minutes (duration of normal showering in Cherepovets) at an average flow rate of approximately 10 ml/min. Bedroom samples were collected for 20 minutes at an average flow rate of approximately 100 ml/min and kitchen samples were collected at an average flow rate of 20 ml/min for 20 min. Sample volumes were measured using an electronic totalizer. In addition, to assess temporal variability of chloroform concentrations in air during long bathing activities, two Sanepid volunteers collected air samples during consecutive 10-minute intervals while taking 50 minute-long baths. To determine how ventilation affects accumulation of chloroform in breathing zone air, several samples were collected from bathrooms with all ventilation openings temporarily sealed. For determination of THMs in indoor air samples, analytes were thermally desorbed from Carboxpack-B™ sorption tubes in accordance with the US EPA Method TO-17 (US EPA, 1997a) and analyzed in accordance with the US EPA Method TO-15 (US EPA, 1999) using an automatic thermal desorption unit connected to GC/MS.

Air exchange rates (AER) were measured in several selected bathrooms of Sanepid employees with different ventilation types. AER were determined using air concentrations of a volatile tracer compound, perfluorinated methylcyclohexane (PMCH), under steady-state conditions. PMCH was allowed to permeate into bathrooms for several (six to eight) hours. Concentrations of PMCH

Table 1. Sampling schedule and number of samples analyzed.

Type of analyses	Number of samples				
	October-December 1999	February 2000	August 2000	April 2001	Total
THMs in tap water	—	—	4	10	14
HAAs in tap water	3	2	—	11	16
HANs and chloropicrin in tap water	—	—	—	3	3
MX in tap water	—	—	—	11	11
Mutagenicity of tap water	—	—	—	2	2
THMs in indoor air	17	—	13	5	35
THMs in exhaled air	—	—	—	9	9
Air exchange rates	—	—	—	4	4

were then measured using a passive sampling technique (open sorption tubes). Analysis was conducted using a gas chromatograph with electron capture detector (GC/ECD) by Mr. Robert Weker (Harvard School of Public Health).

Exhaled air concentrations of THMs were measured in samples collected from Sanepid employees before and within 1 minute after their routine showering and bathing activities. Samples were collected into five-liter Tedlar™ air sampling bags with mouthpieces and valves. All samples were collected in bedrooms, where inhaled air had low concentrations of THMs. Within 12 hours from sampling, analytes were transferred into Carboxen-B™ sorption tubes by pumping air from sampling bags at a flow rate of 50 ml/min. Sorption tubes were transported to the laboratory where sample processing and analysis were conducted as described above for indoor air samples.

Questionnaire and diary surveys in the general population

A cross-sectional questionnaire survey of the use of water filters and showering and bathing activities was conducted in randomly selected households in the fall of 1998 (500 families) and the spring of 1999 (750 families). These surveys were nested within a cross-sectional epidemiological study of health effects of microbiological water pollution in the distribution system (Egorov et al., 2002a). A daily diary survey of tap water consumption in 100 randomly selected households was conducted from June through November 1999. This survey was nested within a prospective epidemiological study of health effects of microbiological water pollution (Egorov et al., 2003).

Questionnaire and diary surveys in pregnant women

A cross-sectional questionnaire survey of 51 pregnant women in spring 2001 was designed specifically for assessment of exposures to DBPs. Participants of this survey were recruited by local health care specialists at one of the city's pregnancy consultation centers.

A two weeks-long diary survey of tap water consumption and water exposures was conducted in 27 women recruited from the cross-sectional survey population. Only pregnant women who did not have home water filters purchased through their own initiative were recruited for this survey. At baseline, 10 participants received free-of-charge pitcher-type home water filters and replacement cartridges. The remaining 17 participants contin-

ued to use non-filtered tap water for drinking. All survey participants recorded detailed information on water use and water consumption at home and outside the home. Daily DBP ingestion exposures for each woman were then estimated using the data on DBP concentrations in filtered and non-filtered tap water.

Results

Sampling schedule and numbers of air and water samples collected are presented in Table 1.

Concentrations of DBPs in water

The results of DBP measurements in Cherepovets tap water are presented in Table 2. Chloroform was the major THM species forming 96% of total THMs in water, while bromoform was below the detection limit in all samples collected. The concentration of total THMs in August 2000 was 50% higher than in April 2001 (270 µg/l vs. 180 µg/l). The mean total THM concentration in two samples of boiled tap water collected from teakettles in local residences was 7 µg/l (these samples are not included in Tables 1 and 2).

Total concentrations of five HAAs in Cherepovets tap water were rather stable over time: 157 µg/l in December 1999, 158 µg/l in February 2000 and 148 µg/l in April 2001.

Concentrations of MX at point-of-use sites (180 ± 51 ng/l; $N = 8$) were higher than concentrations in the treatment plant effluent (113 ± 12 ng/l; $N = 3$). Although MX is unstable in water at the neutral pH, the rate of MX decomposition is low with a half-life of more than seven days (Vartiainen et al., 1991). Thus, in this distribution system with a short water residence time, continuing formation of MX through reactions of residual chlorine with organic compounds appears to be more important than its decomposition. The concentration of MX in

Table 2. Concentrations of DBPs in tap water in Cherepovets ($\mu\text{g/l}$).

Parameter	Mean	SD	Method detection limit
Chloroform	198	70	0.1
Bromodichloromethane (BDCM)	6.7	2.0	0.1
Dibromochloromethane (DBCM)	0.5	0.5	0.1
Bromoform	ND	—	0.3
Total THMs	205	70	
Monochloroacetic acid (MCAA)	3.6	2.9	0.4
Dichloroacetic acid (DCAA)	62	19	0.01
Trichloroacetic acid (TCAA)	83	26	0.01
Bromochloroacetic acid (BCAA)	1.9	1.5	0.01
Bromodichloroacetic acid (BDCAA)	0.4	0.4	0.01
Total HAAs	150	31	
Dichloroacetonitrile (DCAN)	5.6	0.3	0.01
Bromochloroacetonitrile (BCAN)	0.3	0.2	0.02
Trichloroacetonitrile (TCAN)	0.1	0.01	0.01
Dibromoacetonitrile (DBAN)	0.2	0.1	0.02
Total HANs	6.2	0.2	
Chloropicrin	0.35	0.04	0.02
MX	0.16	0.05	0.004

Table 3. Removal of DBPs by various home water filters (manufacturer recommended capacity of cartridges is 150 liters of water for Brita™ and Aquaphor™ and 1,000 liters for Rodnik).

Filter	Made in	Compound	Percent removal of DBPs						
			1 st liter	50 th liter	100 th liter	150 th liter	300 th liter	600 th liter	1000 th liter
Brita	Germany	DCAA	95	48	49	2			
		TCAA	87	57	39	— 19			
		MX	NA	> 99	NA	> 99			
		Chloroform	94	96	92	90			
Aquaphor	Russia	DCAA	97	96	67	59			
		TCAA	95	88	67	63			
		MX	> 99	> 99	NA	> 99			
		Chloroform	94	95	95	95			
Rodnik	Russia	DCAA	80	NA	51	NA	47	45	31
		TCAA	81	NA	37	NA	45	40	18
		MX	95	NA	NA	NA	NA	73	60
		Chloroform	91	NA	88	NA	88	90	77

one sample of tea prepared by boiling tap water for approximately 1 minute was 84 ng/l.

In April 2001, the mutagenic activity of water extracts in the *Salmonella* TA-100 assay was $14,900 \pm 800$ net revertants/L ($N = 2$).

Removal of DBPs by point-of-use activated carbon filters

The results of testing home water filters for removal of major DBP species are presented in Table 3. Removal of MX and THMs was consistently higher than removal of HAAs. The latter limited the useful life of carbon cartridges. As suggested by negative TCAA removal by a Brita filter from the 150th liter,

longer use of a cartridge may result in elution of previously accumulated HAAs (probably due to HAA replacement by compounds with higher affinity to binding sites). At the same time, the metal removing capacity of Brita was underutilized as concentrations of heavy metals including lead were very low in Cherepovets (data not shown). The Russian-made Aquaphor™ filter, which employs a mixture of fibrous and granular absorbents (U.S. patents 5904854 and 5521008), demonstrated the highest removal rates of all DBP species.

Our tests of two faucet-mounted filters, which had been used for various amounts of time by Sanepid employees in their apartments, demonstrated practically zero removal of DBPs (data not shown).

Table 4. Results of indoor air chloroform monitoring in Cherepovets ($\mu\text{g}/\text{m}^3$).

Type of sampling site	N	Mean	SD	Min	Max
Bathrooms	15	330	310	75	900
Kitchens	4	86	91	ND	170
Bedrooms	5	2.1	2.3	ND	5.0
Hotel shower with enclosure	1	5,400	NA	5,400	5,400
Factory shower	5	2,600	1,100	1,900	4,900
Change room at a factory shower	1	18	NA	18	18
Bathrooms with all ventilation openings closed	4	7,800	6,300	2,400	15,600

Air concentrations of volatile DBPs

A summary of chloroform concentrations in indoor air by the type of sampling site is presented in Table 4. The method detection limits (MDL) for chloroform were $1.2 \mu\text{g}/\text{m}^3$ for samples of 2 l volume and $0.3 \mu\text{g}/\text{m}^3$ for 200 ml samples. Chloroform was the major species present in bathroom air forming almost 98% of total THMs. Chloroform concentrations in kitchens varied widely from non-detectable to a maximum of $170 \mu\text{g}/\text{m}^3$ depending on ventilation rate, cooking and washing activities. Its concentrations in bedrooms were invariably low. The concentration of bromodichloromethane (BDCM) in bathrooms during showering was $8.4 \pm 4.1 \mu\text{g}/\text{m}^3$. The MDLs for BDCM were $1.0 \mu\text{g}/\text{m}^3$ and $0.2 \mu\text{g}/\text{m}^3$ for 2 l and 200 ml samples respectively. Dibromochloromethane and bromoform were non-detectable in most samples.

Concentrations of chloroform in female shower rooms at the city's largest industrial factory, when workers were taking showers after their work shift, were almost an order of magnitude higher than in residential bathrooms ($2,600 \mu\text{g}/\text{m}^3$ vs. $330 \mu\text{g}/\text{m}^3$). The chloroform concentration in one sample collected in an adjacent changing room was only $18 \mu\text{g}/\text{m}^3$, suggesting that water used for showering was the main source of chloroform in indoor air. A hotel shower enclosure was another site with a very high chloroform concentration in breathing zone air.

The analysis of predictors of chloroform concentrations in bathroom air indicated that variability in bathroom volumes in typical apartment buildings of standard design is very low (from 5.2 m^3 to 7.0 m^3). This low variability in bathroom volumes could not substantially affect the rate of chloroform accumulation. However, air exchange rates in four bathrooms with different ventilation settings varied from 1.4 to 4.2 air exchanges per hour with an average of 2.9.

The results of multiple chloroform measurements in bathroom air during 50-minute bathing (not

included in Table 4) in two different bathrooms are presented in Figure 1. Figure 1 (left panel) shows that chloroform concentrations in air continued to increase throughout bathing in a bathroom with a low air exchange rate. Figure 1 (right panel) shows a decrease in chloroform concentration during bathing activity in a bathroom with a higher air exchange rate. This decrease followed an initial rise due to the use of the shower to fill the bathtub. Maximum BDCM concentrations in 10-minute samples from these two experiments were $14.5 \mu\text{g}/\text{m}^3$ and $5.4 \mu\text{g}/\text{m}^3$ respectively.

The mean chloroform concentration in breathing zone air in four bathrooms with all ventilation openings temporarily sealed was $7,800 \mu\text{g}/\text{m}^3$ (SD = $6,300 \mu\text{g}/\text{m}^3$; range from $2,400 \mu\text{g}/\text{m}^3$ to $15,600 \mu\text{g}/\text{m}^3$). Air exchange rates in these bathrooms were not measured. However, these rates were likely to be very low. The equilibrium concentration of chloroform in air for a $200 \mu\text{g}/\text{l}$ concentration in water at 40°C is $30,000 \mu\text{g}/\text{m}^3$. Thus, concentration of chloroform in air at the end of a 20 minute-long shower was likely to be close to the equilibrium point (the $15,600 \mu\text{g}/\text{m}^3$ average reflects accumulation of chloroform from near zero to the equilibrium concentration $30,000 \mu\text{g}/\text{m}^3$).

The mean chloroform concentration in exhaled air of local residents before showering was $3.2 \mu\text{g}/\text{m}^3$ (N = 3, SD $0.7 \mu\text{g}/\text{m}^3$, MDL $0.3 \mu\text{g}/\text{m}^3$) while after showering/bathing it increased to $110 \mu\text{g}/\text{m}^3$ (N = 6, range from 11 to $410 \mu\text{g}/\text{m}^3$, standard deviation $160 \mu\text{g}/\text{m}^3$). BDCM was non-detectable in all samples before showering (N = 3), while average concentration after showering was $0.8 \mu\text{g}/\text{m}^3$ (N = 6, range from non-detectable to $3.7 \mu\text{g}/\text{m}^3$, MDL $0.2 \mu\text{g}/\text{m}^3$). Bromoform and DBCM were non-detectable in all samples collected before and after bathing. Concentrations of benzene, toluene, o-xylene, m, p-xylenes, tetrachloroethene, ethylbenzene and tetrachloromethane in exhaled air before and after showering did not differ significantly (data not shown).

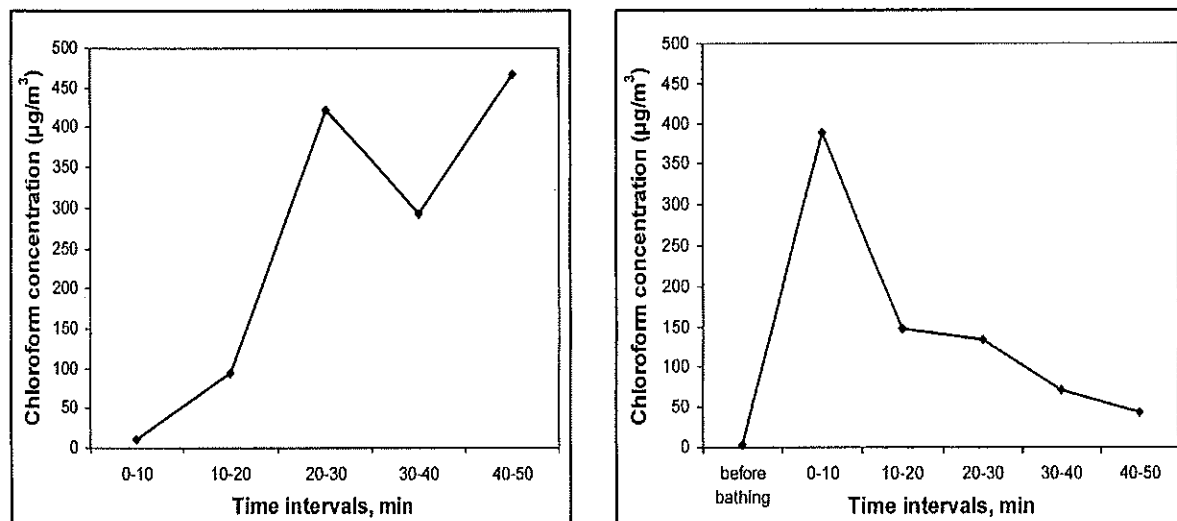


Fig. 1. Air concentrations of chloroform in two Cherepovets bathrooms during bathing. Left panel: Air exchange rate 1.4/hour; volunteer fills the bathtub using the faucet; then sits in the bathtub for 50 minutes. Right panel: Air exchange rate 3.4/hour; volunteer fills the bath using the shower head; then turns shower off and sits in the bath tub for 50 minutes.

Surveys of water exposures in the general population

The results of questionnaire surveys in the general population show that 15% of study participants used home water filters. These were predominantly (83%) faucet-mounted filters designed mainly for removal of suspended particles. Table-top pitcher-type filters were less popular, while the use of more expensive stationary in-line filters was very uncommon (only 3% of all filters used). The average frequency of showering and bathing in study participants was 0.7 times per day with a range from once per week to three times per day.

The results of the 5.5 month-long diary survey of 100 families (367 individuals; mean age 29.6 years) indicated that the majority of Cherepovets residents never drinks non-boiled tap water or drinks it rarely. Only 39% of study participants reported some episodes of non-boiled tap water consumption. Each day, from 3% to 13% of study participants (7% on average) reported consumption of non-boiled tap water, with higher rates corresponding to higher ambient air temperatures. This high rate of boiling is due to concerns about microbiological safety of tap water (the Cherepovets health officials advise local residents to boil their drinking water).

Questionnaire survey of water exposures in pregnant women

The age of 51 pregnant women who participated in the questionnaire survey (mean $\pm$ standard deviation) was 24.0 ± 4.6 years; their weight was 66.4 ± 12.4 kg; and the pregnancy term was 27.1 ± 8.1 weeks. Study participants had, on average, 1.20 previous pregnancies, including 0.31 live births, 0.12 miscarriages and 0.77 medical abortions. Only 10% were smokers. Prevalence of home water filter use in this group was 18%. Only one individual regularly attended a swimming pool with chlorinated water and two individuals reported attendance at public saunas. The average reported frequency of showering and bathing was 1.2 times per day, substantially higher than in the general population. The mean reported daily duration of showering and bathing in this group was 21.8 ± 11.1 min. There was no association between daily duration of showering/bathing and pregnancy term.

Diary survey of water exposures in pregnant women

The results of the two weeks-long diary survey involving 27 of these pregnant women are presented in Table 5. At the inception of the survey, 10 women received free-of-charge home filters and replacement cartridges while the remaining 17 women continued to use non-filtered tap water. The mean daily consumption of non-boiled tap water in both groups

Table 5. Daily consumption of water and drinks by a group of pregnant women in Cherepovets during a 14 days-long diary survey. Mean (standard deviation), liters.

Types of water	Did not use home water filters (17 women)	Used home water filters (10 women)
Non-boiled non-filtered tap water and drinks prepared of it	0.01 (0.03)	0.02 (0.04)
Non-boiled filtered tap water and drinks prepared of it	0 (0)	0.07 (0.13)
Boiled non-filtered tap water and drinks prepared of it	0.78 (0.16)	0.18 (0.23)
Boiled filtered tap water and drinks prepared of it	0 (0)	0.62 (0.21)
Non-chlorinated non-bottled water (wells at summer houses)	0.05 (0.08)	0.01 (0.01)
Bottled water (boiled and non-boiled) and drinks prepared of it	0.21 (0.16)	0.18 (0.13)
Total self-reported water intake	1.04 (0.23)	1.07 (0.13)

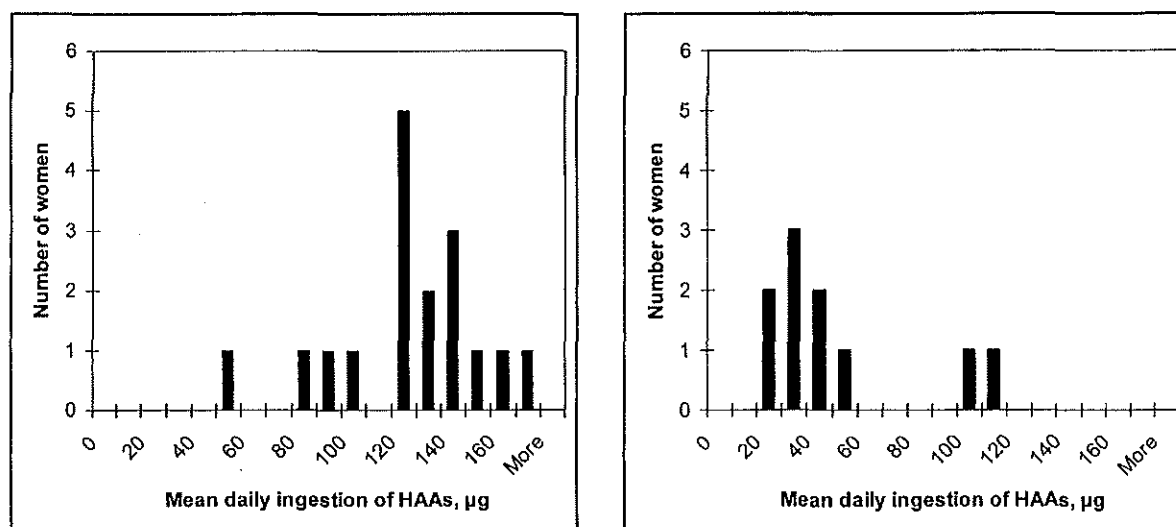


Fig. 2. Estimated daily ingestion of HAAs with water and drinks by pregnant women in Cherepovets. Left panel: Pregnant women without home water filters. Right panel: pregnant women with home water filters.

of pregnant women was very low, while consumption of boiled water and drinks that were prepared from boiled water (hot tea, coffee, etc.) was substantial. Average daily total intake of tap water (boiled and non-boiled) was 0.82 l/day. Women with filters continued to boil most of their water for drinking. They also consumed some non-filtered tap water outside their homes (mostly at work places). Survey participants in both groups also reported substantial consumption of milk (0.8 l/day) and natural juices (0.3 l/day), while consumption of bottled soft drinks was low (0.07 l/day).

Figure 2 shows approximate estimates of daily ingestion of HAAs with water and drinks by pregnant women with home water filters and without filters. The estimates assume a mean concentration of total HAAs in non-filtered tap water of 150 µg/l, 90% mean removal efficiency of filters

during the first two weeks of use (~ 75 liters of filtered water), no change in HAA concentration after boiling and preparation of hot drinks, and zero concentration of HAAs in bottled water, juices and soft drinks. These crude estimates, which do not account for ingestion of HAAs with foods that are prepared with tap water, indicate a substantial (approximately by a factor of three) reduction in exposures to HAAs in women using filtered water (42 µg/day vs. 117 µg/day).

In the group of pregnant women, the total daily duration of full-body water contact (mean $\pm$ standard deviation) was 15.5 ± 12.6 min. The daily duration of showering at home was 12.0 ± 7.8 min. The mean daily duration of showering at work places was 0.5 min (standard deviation 2.2 min) and bathing at home 3.0 min (standard deviation 3.9 min). The total daily duration of water

contact estimated from the diary data was lower than the duration reported by the same individuals in their questionnaires, suggesting a reporting bias (rounding up) in the questionnaire study.

Discussion

In the city of Cherepovets, Russia, high doses of chlorine are applied to poor quality source water with high concentrations of dissolved organic compounds. Concentrations of chlorination by-products, including THMs, HAAs, HANs and MX, as well as mutagenic activity of treated water are, therefore, very high.

The mean concentration of five HAAs in Cherepovets (150 µg/l) exceeds by far the 95th percentile of the distribution of HAAs concentrations in US municipalities of 86 µg/l (US EPA, 1997c). The mean concentration of five HAAs in Cherepovets exceeded the current US EPA standard, the annual running average of 60 µg/l (US EPA, 2001), by a factor of 2.5. The concentrations of DHAA in 11 out of 16 samples analyzed exceeded the provisional WHO guideline for this compound of 50 µg/l (WHO, 1993). The concentrations of TCAA exceeded the provisional WHO guideline of 100 µg/l in four out of 16 samples.

The mean concentration of total THMs in Cherepovets (205 µg/l) also exceeds the current US EPA standard (US EPA, 2001), the annual running average of 80 µg/l, and the 95th percentile of concentrations in the US water supply systems (104 µg/l; US EPA, 1997c), to a similar degree. The concentrations of total THMs were above the EU standard of 100 µg/l (Council of the European Union, 1998) in all but one sample. Chloroform concentrations in six out of 14 samples were above the WHO guideline of 200 µg/l, while concentrations of bromoform, DBCM and BDCM were well below the corresponding WHO guidelines of 100 µg/l, 100 µg/l and 60 µg/l in all samples.

MX concentrations in chlorinated waters in Massachusetts in 1997–1998 ranged from 4 ng/l to 80 ng/l (N = 88), with a mean value of 28 ng/l (Wright et al., 2002). Reported concentrations of MX in Finland, Japan and the UK are even lower (Kronberg and Vartiainen 1988; Smeds et al., 1997; Suzuki and Nakanishi, 1990; Fawell and Horth, 1990). Thus, the average concentration of MX in Cherepovets (160 ng/l) exceeded the highest previously reported concentration by two-fold.

Water extracts from Cherepovets also had very strong mutagenic activity in the *Salmonella* TA100

assay (14,900 net revertants/liter), which by far exceeds mutagenic activity of tap waters in Finland (from 230 to 3,250 rev/l, Smeds et al., 1997) and in Massachusetts (from 300 to 5,700 rev/l, with a mean of 1,450 rev/l, Wright et al., 2002). Determination of mutagenicity in these three studies was conducted by the same laboratory in Kuopio, Finland.

A characteristic feature of the Cherepovets population and especially of pregnant women in this city is low consumption of non-boiled tap water due to concerns over its microbiological safety. These concerns seem to be justified: surveys conducted by regional health authorities demonstrated the presence of hepatitis A and rotaviruses (A. Tereschenko and N. Drizhd, personal communication), while a survey conducted by the Harvard School of Public Health in cooperation with the local Sanepid demonstrated the presence of disinfection-resistant protozoan parasites in treated water (Egorov et al., 2002b). Epidemiological studies demonstrated associations between episodes of elevated effluent water turbidity and daily episodes of self-reported diarrheal illness (Egorov et al., 2003), and between deterioration of microbiological water quality in the distribution system and elevated rates of diarrheal illness in some areas of the city (Egorov et al., 2002a). Pregnant women in Cherepovets consumed 0.01 l/day of non-boiled tap water vs. 0.56 l/day reported by Shimokura et al. (1998) for pregnant women in the USA. This low consumption of non-boiled tap water in Cherepovets results in low ingestion exposures to THMs, as concentrations of these compounds are low in boiled water. Total tap water consumption (0.82 l/day) by pregnant women in Cherepovets was comparable to daily consumption by pregnant women in the USA (Shimokura et al. (1998), 0.78 l/day; Ershow et al. (1991), 1.19 l/day) and Italy (Barbone et al. (2002), 0.6 l/day). Most home water filters that were used by Cherepovets residents were likely to be inefficient for DBP removal. As concentrations of non-volatile DBPs, which persist in boiled water, are very high in Cherepovets, ingestion exposures to these compounds in pregnant women may result in non-trivial adverse health effects. Using simple exposure-reduction measures, such as more efficient home filters, can reduce these adverse effects.

This study demonstrated a high efficiency of activated carbon filters (AquaphorTM) for removal of DBPs. Application of these inexpensive filters to the sensitive subpopulation of pregnant women is a cost-effective method to reduce exposures to potentially fetotoxic DBPs. When this study was conducted, the total cost of an Aquaphor pitcher and 20 replacement cartridges was the Ruble equivalent of

approximately \$ 90, an affordable expense for most families in this city with a very low birth rate. In this pilot study, with filtered water used only at homes, ingestion exposures to HAAs were reduced by almost 3-fold. The use of filtered water both at home and outside the home could result in up to a 10-fold reduction in exposures to HAAs and even greater reduction in exposures to MX.

Exposures to volatile THMs occur predominantly through dermal absorption and inhalation during showering, bathing and other activities associated with water contact. In general, daily duration of bathing and showering in Cherepovets' pregnant women (15.5 min) was slightly higher than that reported by Shimokura et al. (1998) for US pregnant women (13.1 min). The Cherepovets distribution was substantially skewed to the right, probably due to fixed hot water fees and the centralized hot water supply, which is conducive to excessive use of hot water by some individuals.

As concentrations of THMs in indoor air depend on many factors, a precise assessment of inhalation exposures may require extensive THM measurements in bathrooms (where concentrations are the highest) and in kitchens (where individuals spend more time). Our results of chloroform measurements suggest that ventilation rate is an important determinant of chloroform concentrations in bathroom air during showering and bathing. The ratio of chloroform concentrations in bathroom breathing zone air and water in this study was approximately $1.6 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$, which is somewhat lower than $3.3 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$ reported by Kerger et al. (2000). The difference might be due to different construction of bathrooms (for example, the fact that many bathrooms in Cherepovets do not have shower enclosures and curtains).

This ratio was higher in the shower room of an industrial factory (approximately $13 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$) probably due to the continuous use of multiple showers resulting in a high rate of chloroform volatilization. Very high concentrations of chloroform in shower room air at the largest industrial factory in Cherepovets suggest substantial exposures in factory workers. In this industrial city, more than 50% of active age males and a substantial proportion of females are industrial workers who take regular showers in factories' shower rooms.

The results also suggest that inhalation exposures in kitchens may be another important determinant of total exposure. However, a larger exposure assessment study would be needed to assess the contribution of the various microenvironments.

Measurements of concentrations of THMs in exhaled air have been demonstrated to be informa-

tive bioindicators of dermal and inhalation exposures (Weisel et al., 1992; Pleil and Lindstrom, 1997; Gordon et al., 1998; Aggazzotti et al., 1998). Exhaled air sampling, which is much more acceptable to study participants than blood sampling, is a method of choice for population surveys. The average concentration of chloroform in exhaled air in Cherepovets volunteers after showering ($110 \mu\text{g}/\text{m}^3$ average) was higher than levels previously reported (Gordon et al., 1998: $45 \mu\text{g}/\text{m}^3$; Weisel et al., 1999: from 4 to $54 \mu\text{g}/\text{m}^3$) reflecting higher concentrations of chloroform in Cherepovets tap water. Similar exhaled air concentrations have been reported after swimming in indoor swimming pools (Aggazzotti et al., 1995: $94 \mu\text{g}/\text{m}^3$; Levesque et al., 1994: $89 \mu\text{g}/\text{m}^3$). A study of competitive swimmers (Lindstrom et al., 1997) reported an increase in chloroform concentrations in exhaled air of a male swimmer from about $3 \mu\text{g}/\text{m}^3$ before swimming to $148 \mu\text{g}/\text{m}^3$ at the eighth minute, to $371 \mu\text{g}/\text{m}^3$ at the 90th minute. The present study did not include assessment of chloroform exposures in swimming pools. However, the contribution of this pathway to developmental health risks in Cherepovets is likely to be very small as very few pregnant women attend swimming pools there.

THMs are fully metabolized by the liver after ingestion. Thus, biologically effective doses of these compounds depend on route of exposure and target organs. For the same amount of internalized chloroform, ingestion results in a higher dose to the liver, while inhalation and dermal absorption result in higher fetal exposure (Weisel and Jo, 1996). As inhalation and dermal absorption exposures to THMs in Cherepovets are high in pregnant women, these exposures may result in measurable fetotoxic and teratogenic effects.

HAAs, HANs and MX are not volatilized during boiling, which results in high ingestion exposures in Cherepovets pregnant women. Most epidemiological studies of pregnancy outcomes conducted to date relied on THMs measurements to characterize exposures. Thus, epidemiological data on developmental toxicity and teratogenicity of other classes of DBPs are extremely limited or non-existent (Neuwenhuijsen et al., 2000a and 2000b). However, toxicological studies have demonstrated fetotoxic and teratogenic effects of HAAs (Smith et al., 1989a and 1992; Hunter et al., 1996; Ward et al., 2002) and HANs (Smith et al., 1988 and 1989b). It would also be prudent to minimize exposures to MX and other unknown mutagenic DBPs that determine high mutagenic activity of Cherepovets tap water in the standard *Salmonella* assay.

Construction of a new more sophisticated water treatment plant that will minimize formation of

DBPs in treated water was under way in Cherepovets at the beginning of 2003. Meanwhile, application of home filters may be recommended to a sensitive subpopulation such as pregnant women as a temporary measure to reduce ingestion exposures to semi-volatile and non-volatile DBPs in Cherepovets and elsewhere.

Acknowledgements. This study was funded partly by a World Bank loan to the Russian Federation and partly by a seed grant from a National Institute of Environmental Health Sciences' Center at the Harvard School of Public Health. Andrey Egorov was partially supported through grant 2 P42 ES-05947 from the NIEHS with funding provided by EPA. The contents of this manuscript are the responsibility of the authors and do not necessarily represent the official views of the NIEHS or EPA. The authors acknowledge the administrative and organizational support of the Environmental Health Component of the Centre for Preparation and Implementation of International Projects on Technical Assistance (CPPI), Moscow, Russia.

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Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Thursday, March 12, 2015 10:53 AM
To: Brent Wright; Daugherty Johnson; Dayne Walling; donna. cole; gdn2@aol.com; Howard Croft; James Henry; jmikewright; JoAnne Herman; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Laura Sullivan; Michael Glasgow; Mike Lane; Prysby, Mike (DEQ); Natasha Henderson; Norb Birchmeier; Pete Levine; rob.nicholas@veolia.com; Robert Nicholas; rosejo@msu.edu; Russell Hudson; Samir Matta; Warren Green
Subject: Water Update

All,

We still have not received the violation notice from the DEQ although we expect it any day now. We continue to work on what additional documentation will accompany the letter and still plan to vet that through this group. We would like to have the notice in hand to verify how it reads before completing our draft copy of accompanying documents.

We are planing to have another community advisory group meeting next Thursday March 19th. I will wait to set the next **Technical Advisory Meeting** date and agenda until after that group meets.

Thank you,

--

Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Wednesday, March 11, 2015 9:19 AM
To: Prysby, Mike (DEQ)
Subject: RE: City of Flint February 2015 MOR

Follow Up Flag: Follow up
Flag Status: Flagged

I assume you are referring to the one confluence sample above 0.3 NTU. It would be a good idea to verify with the City their filter operation protocols. If they had the ability to filter to waste or move the filter(s) directly into backwash prior to hitting 0.3 that would have been preferable. It also be worth looking at the trending data for each filter to see if it was across the board or a particular filter and at what point it was at in the filter run cycle.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Prysby, Mike (DEQ)
Sent: Tuesday, March 10, 2015 1:47 PM
To: Busch, Stephen (DEQ)
Subject: FW: City of Flint February 2015 MOR

Steve,

The cold water and high flows challenged the city's ability to maintain acceptable treatment. Although they met standards according to our rules, the high treatment rate later in the month and low water temp did have some impact.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Michael Glasgow [<mailto:mglasgow@cityofflint.com>]
Sent: Tuesday, March 10, 2015 9:46 AM
To: Prysby, Mike (DEQ)
Subject: City of Flint February 2015 MOR

Mike,

Good morning, I just wanted to get you a copy of the February MOR. A copy will go out in the mail today.

Mike Glasgow
City of Flint Water Plant

Rennaker, Joanne (DEQ)

From: Benzie, Richard (DEQ)
Sent: Tuesday, March 10, 2015 6:15 PM
To: Busch, Stephen (DEQ)
Cc: Prysby, Mike (DEQ)
Subject: FW: Update: Call with White House Flint Liaison

I meant to ask you today if we (you) should forward a copy of the March 5th violation notice sent to Flint about their TTHM RAAs to Region 5 EPA to keep them informed. I did not see where they would otherwise receive a copy of that letter and I thought it might help Region 5 EPA staff to relay correct information when asked about the current status of this violation.

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Tuesday, March 10, 2015 5:52 PM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: Update: Call with White House Flint Liaison

Update on what's been happening here regarding Flint:

Paul Joice is the White House Flint Liaison for HUD, living in Flint and working in the mayor's office. He needed some background on the Flint drinking water issues, so Tom and I—along with 4 managers from Headquarters, briefed him. Tom prepared a summary of notes taken at the meeting FYI—see below.

Becki Clark for the Office of Ground Water and Drinking Water at HQ, requested that Dr. Michael Wright, toxicologist/epidemiologist, from Office of Research and Development, sit on the Flint Technical Advisory Counsel. I believe Mike Prysby is sitting on the committee too. Since Mike is out of the office until April, did you sit in on the first meeting of this Advisory Council, Steve? What did you think of the meeting?

I have also been inundated with controlled correspondence emails referred to me from the White House. Several have had some questions about the health effects, so I have been including a paragraph explaining the health effects, which I think provide exactly the right info related to TTHMs being a chronic contaminant. I have cc'd Mike and Steve on the letters, so you all will get them, but here is the paragraph FYI:

“In your e-mail, you noted concerns regarding the health effects of TTHMs. By law, the City must inform consumers of health standard exceedances. The TTHM health standard was exceeded so the City must let consumers know the potential risk, to give consumers the opportunity to make informed decisions. The risk of developing long-term health problems, such as liver, kidney, central nervous system, and cancer, is low for those in general good health and the concern for these illnesses are only after years of ingestion. The risk of developing health problems is higher for some sub-populations, such as the immune-compromised and pregnant women; therefore, this group may want to seek alternative sources of water, such as bottled water, or purchase a home water treatment device. Consumers may want to talk with their doctors to help them make individual health decisions.”

Thank you all for keeping us in the loop from your seat in Lansing.

Jennifer

From: Poy, Thomas
Sent: Monday, March 09, 2015 3:10 PM
To: Hyde, Tinka; Henry, Timothy
Cc: Crooks, Jennifer
Subject: Call with White House Flint Liaison

Tinka/Tim: We (R5 and OGWDW) had a call with the White House Strong Cities/Strong Communications Flint Liaison this morning. Below are my notes of the discussion.

Flint Drinking Water Conference Call – 3/9/15

Participants: R5/GWDWB – Tom Poy, Jennifer Crooks
 HQ/OGWDW – Eric Burneson, Elizabeth Corr, Becki Clark, Roy Simon
 White House Strong Cities/Strong Communications Flint Liaison – Paul Joice (HUD) (works directly with Flint's mayor)

Tom Poy summarized what has gone on with Flint's Drinking Water:

- Switching from finished Detroit water (Lake Huron source) to Flint River in April 2014.
- Karegondi pipeline will provide Flint with raw water from Lake Huron when completed in 2016.
- MDEQ has been working with Flint from the start to get their treatment plant running properly.
- Summer 2014, Flint had an E coli detect because of distribution system issues (broken valves causing stagnation of water).
 - o Chlorine levels increased which increases potential of forming disinfection byproducts when chlorine reacts with organic carbon.
 - o Flushing increased which can stir up sediment in the water mains.
- December 2014, Flint exceeded the MCL for TTHM which is based on a running annual average (RAA) (avg of 4 quarterly samples).
- MDEQ has worked with Flint since August 2014 when chlorine levels were increased, to tweak operations to reduce TTHM formation.
- February 2015 sampling has TTHM concentrations well below the MCL but since compliance is based on an RAA, it will take another quarter or two of lower concentrations to make the average go down below the MCL.
- Flint has hired a consultant to help with their PWS.
- Flint has formed a Technical Advisory Committee (TAC) to help with their PWS; Dr. Michael Wright (ORD toxicologist) is EPA's representative.
- The Technical Advisory Committee met last week for the first time.

Paul Joice said that he was at the TAC meeting but did not participate as there were not enough seats for the large crowd. He heard that it was a good meeting. Paul said that he would like Dr. Wright to be able to make a public statement about health effects. The public notice for the TTHM violations say that sensitive subpopulations should consult their physicians but the physicians don't have any info on TTHMs.

Paul had questions about Flint's drinking water:

- 1) What are the health effects of TTHMs and what level of exposure is a concern?
- 2) What message should be provided on TTHMs?
- 3) What can be done about Flint's aging infrastructure and falling population base?
- 4) What about citizen complaints about their water looking funny, tasting funny, and smelling funny?

Paul said that having Dr. Wright on the TAC will help resolve Q1 and Q2.

Paul said on Q4, that he lives in the city and his water looks and tastes fine. I said that taste and odor issues could be the result of the flushing that Flint had done due to the bacteria and TTHM problems. Flushing can stir up sediment in the pipes. I said that there have also been complaints about rashes from using the water but that this may not be solely due to high TTHM levels. It could be because of increased chlorine in the water, changes in water chemistry (pH, hardness, etc.). It would take some investigative work to determine what part of the distribution system is having these problems and would need additional health/medical data to try to

figure out a cause. Paul said that many of the people who complained did not want to give out their home addresses.

On Q3, I said that many systems across the country have aging infrastructure and while there is SRF monies available, this money does not cover the needs out there. Paul asked about regionalization. Eric Burneson acknowledged that there are economies of scale with regionalization but the benefits are realized more for smaller systems than ones the size of Flint. We could not generalize whether regionalization was a good idea for Flint and other communities in Genessee County because it is a very site specific issue.

Paul said that our conference call helped him under the Flint situation better.

Tom Poy
Chief, Ground Water and Drinking Water Branch
USEPA - Region 5
(312) 886-5991

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Tuesday, March 10, 2015 5:52 PM
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Cc: Benzie, Richard (DEQ)
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- MDEQ has been working with Flint from the start to get their treatment plant running properly.
- Summer 2014, Flint had an E coli detect because of distribution system issues (broken valves causing stagnation of water).
 - o Chlorine levels increased which increases potential of forming disinfection byproducts when chlorine reacts with organic carbon.
 - o Flushing increased which can stir up sediment in the water mains.
- December 2014, Flint exceeded the MCL for TTHM which is based on a running annual average (RAA) (avg of 4 quarterly samples).
- MDEQ has worked with Flint since August 2014 when chlorine levels were increased, to tweak operations to reduce TTHM formation.
- February 2015 sampling has TTHM concentrations well below the MCL but since compliance is based on an RAA, it will take another quarter or two of lower concentrations to make the average go down below the MCL.
- Flint has hired a consultant to help with their PWS.
- Flint has formed a Technical Advisory Committee (TAC) to help with their PWS; Dr. Michael Wright (ORD toxicologist) is EPA's representative.
- The Technical Advisory Committee met last week for the first time.

Paul Joice said that he was at the TAC meeting but did not participate as there were not enough seats for the large crowd. He heard that it was a good meeting. Paul said that he would like Dr. Wright to be able to make a public statement about health effects. The public notice for the TTHM violations say that sensitive subpopulations should consult their physicians but the physicians don't have any info on TTHMs.

Paul had questions about Flint's drinking water:

- 1) What are the health effects of TTHMs and what level of exposure is a concern?
- 2) What message should be provided on TTHMs?
- 3) What can be done about Flint's aging infrastructure and falling population base?
- 4) What about citizen complaints about their water looking funny, tasting funny, and smelling funny?

Paul said that having Dr. Wright on the TAC will help resolve Q1 and Q2.

Paul said on Q4, that he lives in the city and his water looks and tastes fine. I said that taste and odor issues could be the result of the flushing that Flint had done due to the bacteria and TTHM problems. Flushing can stir up sediment in the pipes. I said that there have also been complaints about rashes from using the water but that this may not be solely due to high TTHM levels. It could be because of increased chlorine in the water, changes in water chemistry (pH, hardness, etc.). It would take some investigative work to determine what part of the distribution system is having these problems and would need additional health/medical data to try to figure out a cause. Paul said that many of the people who complained did not want to give out their home addresses.

On Q3, I said that many systems across the country have aging infrastructure and while there is SRF monies available, this money does not cover the needs out there. Paul asked about regionalization. Eric Burneson acknowledged that there are economies of scale with regionalization but the benefits are realized more for smaller systems than ones the size of Flint. We could not generalize whether regionalization was a good idea for Flint and other communities in Genesee County because it is a very site specific issue.

Paul said that our conference call helped him under the Flint situation better.

Tom Poy
Chief, Ground Water and Drinking Water Branch
USEPA - Region 5
(312) 886-5991

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, March 10, 2015 1:47 PM
To: Busch, Stephen (DEQ)
Subject: FW: City of Flint February 2015 MOR
Attachments: February 2015 MOR.pdf

Steve,

The cold water and high flows challenged the city's ability to maintain acceptable treatment. Although they met standards according to our rules, the high treatment rate later in the month and low water temp did have some impact.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

From: Michael Glasgow [<mailto:mglasgow@cityofflint.com>]
Sent: Tuesday, March 10, 2015 9:46 AM
To: Prysby, Mike (DEQ)
Subject: City of Flint February 2015 MOR

Mike,

Good morning, I just wanted to get you a copy of the February MOR. A copy will go out in the mail today.

Mike Glasgow
City of Flint Water Plant

CITY of FLINT WATER TREATMENT PLANT MONTHLY OPERATION REPORT

SUPPLY NAME: CITY of FLINT WATER PLANT
 WSSN: 2310

Michael Glasgow

Operator-in-Charge

February 2015

Month/Year

F-1R, F-2

Certification of Operator-in-Charge

F-1

Water Plant Classification



Signature of Operator-in-Charge

Genesee

County

Treatment Rate and Filter Data

Maximum Treatment Rate:	<u>25.3</u>	Million Gallons per Day
Rated Plant Capacity:	<u>36</u>	Million Gallons per Day
Average Filter Run:	<u>86</u>	Hours
Average Head Loss:	<u>n/a</u>	Feet *(filter head loss meters not operational)
Average Filtration Rate:	<u>2.4</u>	Gallons Per Square Feet per Minute
Maximum Filtration Rate:	<u>3.3</u>	Gallons Per Square Feet per Minute
Average Wash Water Use:	<u>2.4%</u>	Percent of Treated Water

Chemical Data

Chlorine on hand:	<u>8,000</u>	lb.	Est. supply:	<u>8</u>	days
Primary Coagulant (Ferric Chloride) on hand:	<u>125,000</u>	lb.	Est. supply:	<u>3</u>	days
Lime (CaO) on hand:	<u>397</u>	tons	Est. supply:	<u>31</u>	days
Fluoride on Hand:	<u>26,600</u>	lb.	Est. supply:	<u>40</u>	days
Cost of All Chemicals per Million Gallons:	<u>n/a</u>	dollars			
Total Power Cost per Million Gallons:	<u>n/a</u>	dollars			

Remarks	Confluence Point # 1 (N)	Confluence Point # 2 (S)
Number of filter confluence samples > 0.3 NTU:	<u>1</u>	<u>0</u>
Number of filter confluence samples collected:	<u>218</u>	<u>218</u>
Percent of filter confluence samples > 0.3 NTU:	<u>0.5%</u>	<u>0.0%</u>
Number of filter confluence samples > 1 NTU	<u>0</u>	<u>0</u>
Did any individual filter exceed:		
1.0 NTU in two consecutive measurements taken 15 minutes apart?		<u>NO</u>
If yes, attach specific filter(s) information and indicate required follow-up status.		
0.5 NTU in two consecutive measurements taken 15 minutes apart after 4 hours of operation?		<u>NO</u>
If yes, attach specific filter(s) information and indicate required follow-up status.		
1.0 NTU in two consecutive measurements taken 15 minutes apart for 3 consecutive months?		<u>NO</u>
If yes, attach specific filter(s) information and indicate required follow-up status.		
2.0 NTU in two consecutive measurements taken 15 minutes apart for 2 consecutive months?		<u>NO</u>
If yes, attach specific filter(s) information and indicate required follow-up status.		
Was continuous (every 15 minutes) filter monitoring equipment off-line during the month?		<u>NO</u>
If yes, indicate date(s), duration, and individual filter grab sampling frequency on a separate sheet.		
Did POE disinfectant residual fall below 0.2 ppm during the month?		<u>NO</u>
If yes, indicate date(s) and duration on a separate sheet.		
Was minimum C*T credit achieved for the entire month?		<u>YES</u>
If no, indicate on a separate sheet the date(s) not achieved.		
Was continuous POE chlorine residual monitoring equipment off-line during the month?		<u>NO</u>
If yes, indicate date(s) and duration on a separate sheet.		

[illegible]

Filter turbidity

City of Flint Water Treatment Plant

February 2015 Page 3

WSSN: 2310

Date	Turbidity, Units												
	Confluence Point. No.1 (N) North						Confluence Point. No.2 (S) South						Point of Entry
	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	Plant Tap NTU
1	8	0.07	0.09	6	0	0	8	0.06	0.09	6	0	0	0.07
2	7	0.06	0.10	6	0	0	7	0.06	0.07	6	0	0	0.07
3	8	0.07	0.15	6	0	0	8	0.06	0.07	6	0	0	0.08
4	8	0.05	0.08	6	0	0	8	0.05	0.07	6	0	0	0.07
5	8	0.07	0.10	6	0	0	8	0.06	0.07	6	0	0	0.07
6	7	0.06	0.08	6	0	0	7	0.06	0.08	6	0	0	0.07
7	8	0.06	0.07	6	0	0	8	0.06	0.08	6	0	0	0.07
8	8	0.06	0.07	6	0	0	8	0.06	0.07	6	0	0	0.06
9	8	0.07	0.09	6	0	0	8	0.05	0.06	6	0	0	0.09
10	7	0.06	0.07	6	0	0	7	0.05	0.06	6	0	0	0.08
11	8	0.06	0.07	6	0	0	8	0.05	0.07	6	0	0	0.07
12	8	0.06	0.08	6	0	0	8	0.06	0.08	6	0	0	0.06
13	8	0.06	0.09	6	0	0	8	0.09	0.18	6	0	0	0.08
14	8	0.06	0.09	6	0	0	8	0.06	0.10	6	0	0	0.05
15	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
16	8	0.06	0.08	6	0	0	8	0.05	0.07	6	0	0	0.06
17	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
18	8	0.07	0.09	6	0	0	8	0.07	0.09	6	0	0	0.07
19	8	0.07	0.09	6	0	0	8	0.06	0.08	6	0	0	0.07
20	8	0.07	0.08	6	0	0	8	0.07	0.10	6	0	0	0.07
21	8	0.08	0.14	6	0	0	8	0.08	0.10	6	0	0	0.08
22	8	0.09	0.12	6	0	0	8	0.10	0.13	6	0	0	0.08
23	8	0.13	0.16	6	0	0	8	0.07	0.10	6	0	0	0.10
24	7	0.19	0.36	6	1	1	7	0.14	0.18	6	0	0	0.17
25	8	0.08	0.10	6	0	0	8	0.10	0.12	6	0	0	0.11
26	8	0.13	0.17	6	0	0	8	0.13	0.18	6	0	0	0.14
27	8	0.19	0.29	6	0	0	8	0.15	0.18	6	0	0	0.15
28	8	0.20	0.27	6	0	0	8	0.13	0.18	6	0	0	0.15
Avg.	8	0.08	0.12	6	0	0	8	0.07	0.10	6	0	0	
Max.	8	0.20	0.36	6	1	1	8	0.15	0.18	6	0	0	0.17
Min.	7	0.05	0.07	6	0	0	7	0.05	0.06	6	0	0	

Fluoridation &
ChlorinationCity of Flint Water Treatment Plant
WSSN: 2310

February 2015

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Date	Fluoride Applied as F- mg/L	Fluoride Analysis (mg/L)			Chlorine Application (mg/L)			Chlorine Residual (mg/L)					
					Intermediate Chlorine	Post Chlorine	Total Chlorine	Filtered		3 MG Well		Tap	
		Raw	Tap	Dist.				Free	Total	Free	Total	Free	Total
1	0.3	0.23	0.53		1.6	3.1	4.7	0.3	0.6	2.6	3.0	2.5	2.9
2	0.3	0.22	0.48		1.8	2.9	4.7	0.3	0.5	2.4	2.7	2.2	2.5
3	0.3	0.23	0.51	0.52	1.9	3.0	4.9	0.8	1.2	2.6	2.9	2.4	2.7
4	0.4	0.22	0.53		1.9	3.0	4.9	0.6	0.8	2.8	3.0	2.7	3.0
5	0.3	0.22	0.53		1.9	2.9	4.8	0.5	0.7	2.6	3.0	2.2	2.5
6	0.4	0.22	0.57		2.0	3.0	5.0	0.8	1.0	2.7	3.0	2.3	2.8
7	0.3	0.22	0.58		2.1	2.7	4.8	0.3	0.6	2.6	2.9	2.1	2.4
8	0.4	0.23	0.56		2.1	2.7	4.8	0.6	0.8	2.7	3.0	2.2	2.5
9	0.4	0.22	0.64		1.9	2.8	4.7	0.4	0.6	2.7	3.0	2.3	2.6
10	0.4	0.24	0.63	0.56	2.2	2.9	5.1	0.5	0.7	2.8	3.1	2.1	2.4
11	0.4	0.21	0.55		2.2	2.8	5.0	0.7	0.9	2.6	2.8	1.9	2.4
12	0.4	0.21	0.58		2.2	2.7	4.9	0.6	0.8	2.5	2.8	2.1	2.5
13	0.4	0.23	0.59		2.2	2.4	4.6	0.4	0.6	2.0	2.5	1.7	2.2
14	0.4	0.22	0.55		2.2	2.2	4.4	0.6	0.8	2.3	2.6	1.5	2.1
15	0.4	0.21	0.60		2.1	2.2	4.3	0.4	0.6	2.0	2.4	1.9	2.2
16	0.4	0.23	0.59		2.1	2.2	4.3	0.4	0.6	2.1	2.4	1.8	2.1
17	0.4	0.21	0.61	0.54	2.1	2.3	4.4	0.8	1.0	2.0	2.4	1.3	1.7
18	0.3	0.23	0.58		2.0	2.2	4.2	0.3	0.6	1.9	2.4	1.5	2.0
19	0.3	0.24	0.64		2.2	2.1	4.3	0.6	0.8	2.0	2.4	1.7	2.2
20	0.4	0.23	0.56		2.2	2.1	4.3	0.7	1.0	2.0	2.5	1.5	1.9
21	0.4	0.24	0.61		2.2	2.1	4.3	0.5	0.7	1.7	2.2	1.5	2.0
22	0.4	0.23	0.55		2.2	2.1	4.3	0.4	0.6	2.0	2.3	1.7	1.9
23	0.3	0.24	0.64		2.2	2.2	4.4	0.5	0.6	2.0	2.1	1.5	1.6
24	0.3	0.24	0.56	0.54	2.3	2.6	4.9	0.4	0.6	2.5	3.3	2.1	2.5
25	0.3	0.23	0.62		2.3	2.6	4.9	0.5	0.7	2.5	2.9	2.4	2.7
26	0.3	0.23	0.54		2.3	2.7	5.0	0.5	0.7	2.7	3.1	2.5	3.0
27	0.3	0.24	0.56		2.3	2.5	4.8	0.6	0.8	2.3	2.9	2.1	2.5
28	0.3	0.24	0.56		2.3	2.5	4.8	0.6	0.8	2.3	2.8	1.9	2.5
Avg.	0.35	0.23	0.57	0.54	2.1	2.6	4.7	0.5	0.7	2.4	2.7	2.0	2.4
Max.	0.40	0.24	0.64	0.56	2.3	3.1	5.1	0.8	1.2	2.8	3.3	2.7	3.0
Min.	0.30	0.21	0.48	0.52	1.6	2.1	4.2	0.3	0.5	1.7	2.1	1.3	1.6

Chemical Analyses

City of Flint Water Treatment Plant

February 2015

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WSSN: 2310

Date	pH (S.U.)		Total Hardness as CaCO ₃ (mg/L)		Total Alkalinity as CaCO ₃ (mg/L)		Non-Carbonate Hardness as CaCO ₃ (mg/L)		Calcium as Ca ²⁺ (mg/L)		Magnesium as Mg ²⁺ (mg/L)		Chloride as Cl ⁻ (mg/L)	
	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap
1	7.78	7.91	339	198	273	60	66	138	109.0	56.9	17.5	14.1	51	98
2	7.92	7.64	343	203	274	77	69	126	110.6	60.1	15.6	12.6	52	91
3	7.75	8.69	344	176	276	62	68	114	113.8	54.5	13.6	10.2	57	90
4	8.04	7.88	346	176	277	62	69	114	114.6	54.5	14.6	10.2	49	88
5	7.77	7.56	349	183	284	63	65	120	118.6	60.9	12.6	7.3	55	89
6	7.92	7.63	350	180	276	52	74	128	117.8	52.9	13.6	11.7	54	95
7	8.07	7.76	348	185	282	68	66	117	113.8	54.5	15.6	11.7	52	92
8	8.05	7.57	347	181	278	50	69	131	111.4	51.3	16.5	12.6	51	91
9	8.11	7.66	349	183	280	62	69	121	112.2	52.9	16.5	12.2	53	94
10	7.95	7.65	350	168	284	47	66	121	113.0	57.7	16.5	6.8	56	95
11	7.97	7.76	345	173	274	54	71	119	109.0	49.7	17.9	12.6	51	92
12	7.85	7.66	342	169	274	51	68	118	117.8	59.3	12.2	5.3	55	92
13	7.77	7.70	345	170	267	53	78	117	121.0	57.7	11.2	4.9	54	90
14	7.86	7.54	344	173	269	52	75	121	125.0	63.3	7.3	3.9	56	93
15	8.00	7.73	349	176	280	53	69	123	113.0	50.5	16.0	12.2	50	94
16	7.89	7.68	353	169	285	47	68	122	123.4	53.7	10.7	8.7	55	95
17	8.05	7.92	360	172	281	49	79	123	118.6	48.9	15.6	11.7	53	92
18	7.96	7.97	352	218	282	102	70	116	125.9	78.6	8.7	5.3	54	91
19	8.11	7.82	358	208	291	91	67	117	120.2	59.3	14.6	13.1	53	92
20	7.93	7.90	362	207	286	94	76	113	133.1	76.2	7.3	4.4	55	87
21	8.00	8.06	362	214	284	98	78	116	133.9	76.2	6.8	4.4	54	86
22	7.98	8.03	366	227	294	113	72	114	116.2	67.3	18.5	14.1	52	88
23	8.07	8.31	361	225	293	112	68	113	121.8	68.9	14.1	12.6	52	86
24	7.95	7.85	361	227	289	101	72	126	133.9	78.6	5.8	6.8	54	88
25	8.03	8.14	365	244	295	127	70	117	118.6	77.8	16.5	11.7	55	89
26	7.91	7.88	365	235	288	108	77	127	132.3	86.6	8.3	4.9	55	89
27	7.96	7.85	354	241	291	117	63	124	131.5	91.4	6.3	2.9	57	89
28	7.90	7.72	358	228	228	115	130	113	127.5	84.2	9.7	3.9	54	87
Avg.	7.95	7.84	352	197	280	76	73	120	119.9	63.7	12.9	9.0	54	91
Max.	8.11	8.69	366	244	295	127	130	138	133.9	91.4	18.5	14.1	57	98
Min.	7.75	7.54	339	168	228	47	63	113	109.0	48.9	5.8	2.9	49	86

Bacteriological &
Physical ParametersCity of Flint Water Treatment Plant
WSSN: 2310

February 2015

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Date	Total Coliform						Standard Plate Count (Simplate MPN)		Conductivity (mS)	Temp. C	Color		Odor	
	Raw (Colliert MPN)		Filter Confluence (N&S)		Plant Tap									
	# Samples	Count	# Samples	# pos	# Samples	# pos	Raw	Tap	Tap	Raw	Raw	Tap	Raw	Tap
1	1	41	12	0	1	0	150	< 2	0.53	4.0				
2	1	117	12	0	1	0	132	< 2	0.55	4.2				
3	1	96	12	0	1	0	146	< 2	0.49	4.3				
4	1	86	12	0	1	0	90	< 2	0.51	4.1				
5	1	105	12	0	1	0	183	< 2	0.51	3.5				
6	1	276	12	0	1	0	128	< 2	0.50	2.4				
7	1	124	12	0	1	0	97	< 2	0.50	3.8				
8	1	120	12	0	1	0	80	< 2	0.48	3.8				
9	1	104	12	0	1	0	90	< 2	0.51	4.2				
10	1	93	12	0	1	0	132	< 2	0.50	4.0				
11	1	115	12	0	1	0	83	< 2	0.47	4.3				
12	1	115	12	0	1	0	93	< 2	0.46	3.8				
13	1	153	12	0	1	0	80	< 2	0.50	4.5				
14	1	154	12	0	1	0	93	< 2	0.48	3.6				
15	1	138	12	0	1	0	83	< 2	0.52	0.5				
16	1	179	12	0	1	0	137	< 2	0.50	0.7				
17	1	365	12	0	1	0	166	< 2	0.50	1.2				
18	1	219	12	0	1	0	177	< 2	0.51	1.7				
19	1	153	12	0	1	0	112	< 2	0.45	2.2				
20	1	192	12	0	1	0	62	< 2	0.56	1.9				
21	1	142	12	0	1	0	116	< 2	0.51	4.1				
22	1	160	12	0	1	0	146	< 2	0.55	2.1				
23	1	129	12	0	1	0	112	< 2	0.58	1.0				
24	1	135	12	0	1	0	100	< 2	0.61	3.4				
25	1	145	12	0	1	0	156	< 2	0.61	2.0				
26	1	115	12	0	1	0	108	< 2	0.61	1.2				
27	1	86	12	0	1	0	74	< 2	0.61	3.3				
28	1	84	12	0	1	0	65	< 2	0.56	3.3				

Avg.									0.52	3.0				
Max.		365					183	0	0.61	4.5				
Min.									0.45	0.5				

**Distribution System
Monitoring**
**City of Flint Water Treatment Plant
WSSN: 2310**

February 2015

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Date	Free Chlorine Residual at Bacteriological Monitoring Stations mg/l										
	1	2	3	4	5	6	7	8	CS	WS	Number of Samples
1											0
2											0
3	0.7	1.5	1.5	1.5	1.5	0.2	1.7	1.7	1.3	2.0	10
4											0
5	1.0	1.7	1.7	1.7	1.1	0.2	1.8	2.0	0.7	1.4	10
6											0
7											0
8											0
9											0
10	1.0	1.2	1.5	1.3	1.0	0.2	2.0	1.9	0.7	1.0	10
11	1.0	1.3	1.7	1.7	0.9	0.3	1.7	2.3	0.5	0.9	10
12	0.4	1.4	2.3	1.8	0.7	0.2	1.9	2.2	0.5	1.2	10
13											0
14											0
15											0
16											0
17	1.1	0.7	1.2	1.5	0.7	0.2	1.1	1.3		1.5	9
18	1.2	0.8	1.6	1.2	0.8	0.2	1.8	1.7		1.4	9
19	0.9	0.7	1.3	1.0	0.7	0.2	0.8	1.3		1.0	9
20											0
21											0
22											0
23	1.3	0.8	1.3	1.1	0.6	0.2	0.6	1.5		0.8	9
24	1.5	1.1	1.7	1.2	1.0	0.2	2.5	2.2		2.3	9
25											0
26	1.7	1.4	2.0	1.5	1.1	0.3	1.8	1.8		2.1	9
27											0
28											0

Distribution Sample Summary	
Total # of routine distribution samples analyzed	104
Total # of routine distribution samples required	100

Distribution Bacteriological Summary	
Total # of positive routine distribution samples	0
Percent of routine distribution samples positive	0%

See page 9 for positive sample information.

Distribution Disinfectant Total Residual Summary	
Percentage of samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.22

Date	Total Chlorine Residual at Bacteriological Monitoring Stations mg/l										Number of Samples
	1	2	3	4	5	6	7	8	CS	WS	
1											0
2											0
3	1.0	1.8	1.8	1.9	1.8	0.3	2.0	1.9	1.7	2.4	10
4											0
5	1.3	2.1	2.0	2.0	1.3	0.4	2.1	2.3	1.0	1.6	10
6											0
7											0
8											0
9											0
10	1.3	1.5	1.9	1.6	1.3	0.4	2.4	2.2	1.0	1.3	10
11	1.2	1.5	1.8	1.9	1.1	0.4	1.9	2.6	0.7	1.2	10
12	0.5	1.6	2.4	2.0	0.9	0.4	2.1	2.4	0.6	1.4	10
13											0
14											0
15											0
16											0
17	1.3	1.0	1.4	1.8	0.9	0.3	1.5	1.8		1.7	9
18	1.5	1.0	1.9	1.5	1.0	0.3	2.1	2.0		1.7	9
19	1.3	1.1	1.6	1.5	1.0	0.3	1.0	1.7		1.3	9
20											0
21											0
22											0
23	1.5	1.0	1.6	1.3	0.8	0.3	0.8	1.8		1.2	9
24	1.7	1.3	1.9	1.4	1.2	0.4	2.8	2.4		2.5	9
25											0
26	1.9	1.6	2.4	1.7	1.4	0.5	2.1	2.0		2.5	9
27											0
28											0

Distribution Disinfectant Total Residual Summary	
Percent samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.5

Positive Distribution Samples

[illegible]

Rennaker, Joanne (DEQ)

From: Michael Glasgow <mglasgow@cityofflint.com>
Sent: Tuesday, March 10, 2015 9:46 AM
To: Prysby, Mike (DEQ)
Subject: City of Flint February 2015 MOR
Attachments: February 2015 MOR.pdf

Mike,

Good morning, I just wanted to get you a copy of the February MOR. A copy will go out in the mail today.

Mike Glasgow
City of Flint Water Plant

CITY of FLINT WATER TREATMENT PLANT MONTHLY OPERATION REPORT

SUPPLY NAME: CITY of FLINT WATER PLANT

WSSN: 2310

Michael Glasgow

Operator-in-Charge

February 2015

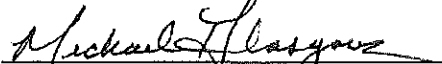
Month/Year

F-1R, F-2

Certification of Operator-in-Charge

F-1

Water Plant Classification



Signature of Operator-in-Charge

Genesee

County

Treatment Rate and Filter Data

Maximum Treatment Rate:	<u>25.3</u>	Million Gallons per Day
Rated Plant Capacity:	<u>36</u>	Million Gallons per Day
Average Filter Run:	<u>86</u>	Hours
Average Head Loss:	<u>n/a</u>	Feet *(filter head loss meters not operational)
Average Filtration Rate:	<u>2.4</u>	Gallons Per Square Feet per Minute
Maximum Filtration Rate:	<u>3.3</u>	Gallons Per Square Feet per Minute
Average Wash Water Use:	<u>2.4%</u>	Percent of Treated Water

Chemical Data

Chlorine on hand:	<u>8,000</u> lb.	Est. supply:	<u>8</u> days
Primary Coagulant (Ferric Chloride) on hand:	<u>125,000</u> lb.	Est. supply:	<u>3</u> days
Lime (CaO) on hand:	<u>397</u> tons	Est. supply:	<u>31</u> days
Fluoride on Hand:	<u>26,600</u> lb.	Est. supply:	<u>40</u> days
Cost of All Chemicals per Million Gallons:	<u>n/a</u> dollars		
Total Power Cost per Million Gallons:	<u>n/a</u> dollars		

Remarks

Confluence Point # 1 (N)

Confluence Point # 2 (S)

Number of filter confluence samples > 0.3 NTU:

10

Number of filter confluence samples collected:

218218

Percent of filter confluence samples > 0.3 NTU:

0.5%0.0%

Number of filter confluence samples > 1 NTU

00

Did any individual filter exceed:

1.0 NTU in two consecutive measurements taken 15 minutes apart?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

0.5 NTU in two consecutive measurements taken 15 minutes apart after 4 hours of operation?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

1.0 NTU in two consecutive measurements taken 15 minutes apart for 3 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

2.0 NTU in two consecutive measurements taken 15 minutes apart for 2 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

Was continuous (every 15 minutes) filter monitoring equipment off-line during the month?

NO

If yes, indicate date(s), duration, and individual filter grab sampling frequency on a separate sheet.

Did POE disinfectant residual fall below 0.2 ppm during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

Was minimum C*T credit achieved for the entire month?

YES

If no, indicate on a separate sheet the date(s) not achieved.

Was continuous POE chlorine residual monitoring equipment off-line during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

[illegible]

Filter turbidity

City of Flint Water Treatment Plant

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WSSN: 2310

Date	Turbidity, Units												Point of Entry
	Confluence Point. No.1 (N) North						Confluence Point. No.2 (S) South						
	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	
1	8	0.07	0.09	6	0	0	8	0.06	0.09	6	0	0	0.07
2	7	0.06	0.10	6	0	0	7	0.06	0.07	6	0	0	0.07
3	8	0.07	0.15	6	0	0	8	0.06	0.07	6	0	0	0.08
4	8	0.05	0.08	6	0	0	8	0.05	0.07	6	0	0	0.07
5	8	0.07	0.10	6	0	0	8	0.06	0.07	6	0	0	0.07
6	7	0.06	0.08	6	0	0	7	0.06	0.08	6	0	0	0.07
7	8	0.06	0.07	6	0	0	8	0.06	0.06	6	0	0	0.07
8	8	0.06	0.07	6	0	0	8	0.06	0.07	6	0	0	0.06
9	8	0.07	0.09	6	0	0	8	0.05	0.06	6	0	0	0.09
10	7	0.06	0.07	6	0	0	7	0.05	0.06	6	0	0	0.08
11	8	0.06	0.07	6	0	0	8	0.05	0.07	6	0	0	0.07
12	8	0.06	0.08	6	0	0	8	0.06	0.08	6	0	0	0.06
13	8	0.06	0.09	6	0	0	8	0.09	0.18	6	0	0	0.08
14	8	0.06	0.09	6	0	0	8	0.06	0.10	6	0	0	0.05
15	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
16	8	0.06	0.08	6	0	0	8	0.05	0.07	6	0	0	0.06
17	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
18	8	0.07	0.09	6	0	0	8	0.07	0.09	6	0	0	0.07
19	8	0.07	0.09	6	0	0	8	0.06	0.08	6	0	0	0.07
20	8	0.07	0.08	6	0	0	8	0.07	0.10	6	0	0	0.07
21	8	0.08	0.14	6	0	0	8	0.08	0.10	6	0	0	0.08
22	8	0.09	0.12	6	0	0	8	0.10	0.13	6	0	0	0.08
23	8	0.13	0.16	6	0	0	8	0.07	0.10	6	0	0	0.10
24	7	0.19	0.36	6	1	1	7	0.14	0.18	6	0	0	0.17
25	8	0.08	0.10	6	0	0	8	0.10	0.12	6	0	0	0.11
26	8	0.13	0.17	6	0	0	8	0.13	0.18	6	0	0	0.14
27	8	0.19	0.29	6	0	0	8	0.15	0.18	6	0	0	0.15
28	8	0.20	0.27	6	0	0	8	0.13	0.18	6	0	0	0.15
Avg.	8	0.08	0.12	6	0	0	8	0.07	0.10	6	0	0	
Max.	8	0.20	0.36	6	1	1	8	0.15	0.18	6	0	0	0.17
Min.	7	0.05	0.07	6	0	0	7	0.05	0.06	6	0	0	

Fluoridation &
ChlorinationCity of Flint Water Treatment Plant
WSSN: 2310

February 2015

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Date	Fluoride Applied as F- mg/L	Fluoride Analysis (mg/L)			Chlorine Application (mg/L)			Chlorine Residual (mg/L)					
					Intermediate Chlorine	Post Chlorine	Total Chlorine	Filtered		3 MG Well		Tap	
		Raw	Tap	Dist.				Free	Total	Free	Total	Free	Total
1	0.3	0.23	0.53		1.6	3.1	4.7	0.3	0.6	2.6	3.0	2.5	2.9
2	0.3	0.22	0.48		1.8	2.9	4.7	0.3	0.5	2.4	2.7	2.2	2.5
3	0.3	0.23	0.51	0.52	1.9	3.0	4.9	0.8	1.2	2.6	2.9	2.4	2.7
4	0.4	0.22	0.53		1.9	3.0	4.9	0.6	0.8	2.8	3.0	2.7	3.0
5	0.3	0.22	0.53		1.9	2.9	4.8	0.5	0.7	2.6	3.0	2.2	2.5
6	0.4	0.22	0.57		2.0	3.0	5.0	0.8	1.0	2.7	3.0	2.3	2.8
7	0.3	0.22	0.58		2.1	2.7	4.8	0.3	0.6	2.6	2.9	2.1	2.4
8	0.4	0.23	0.56		2.1	2.7	4.8	0.6	0.8	2.7	3.0	2.2	2.5
9	0.4	0.22	0.64		1.9	2.8	4.7	0.4	0.6	2.7	3.0	2.3	2.6
10	0.4	0.24	0.63	0.56	2.2	2.9	5.1	0.5	0.7	2.8	3.1	2.1	2.4
11	0.4	0.21	0.55		2.2	2.8	5.0	0.7	0.9	2.6	2.8	1.9	2.4
12	0.4	0.21	0.58		2.2	2.7	4.9	0.6	0.8	2.5	2.8	2.1	2.5
13	0.4	0.23	0.59		2.2	2.4	4.6	0.4	0.6	2.0	2.5	1.7	2.2
14	0.4	0.22	0.55		2.2	2.2	4.4	0.6	0.8	2.3	2.6	1.5	2.1
15	0.4	0.21	0.60		2.1	2.2	4.3	0.4	0.6	2.0	2.4	1.9	2.2
16	0.4	0.23	0.59		2.1	2.2	4.3	0.4	0.6	2.1	2.4	1.8	2.1
17	0.4	0.21	0.61	0.54	2.1	2.3	4.4	0.8	1.0	2.0	2.4	1.3	1.7
18	0.3	0.23	0.58		2.0	2.2	4.2	0.3	0.6	1.9	2.4	1.5	2.0
19	0.3	0.24	0.64		2.2	2.1	4.3	0.6	0.8	2.0	2.4	1.7	2.2
20	0.4	0.23	0.56		2.2	2.1	4.3	0.7	1.0	2.0	2.5	1.5	1.9
21	0.4	0.24	0.61		2.2	2.1	4.3	0.5	0.7	1.7	2.2	1.5	2.0
22	0.4	0.23	0.55		2.2	2.1	4.3	0.4	0.6	2.0	2.3	1.7	1.9
23	0.3	0.24	0.64		2.2	2.2	4.4	0.5	0.6	2.0	2.1	1.5	1.6
24	0.3	0.24	0.56	0.54	2.3	2.6	4.9	0.4	0.6	2.5	3.3	2.1	2.5
25	0.3	0.23	0.62		2.3	2.6	4.9	0.5	0.7	2.5	2.9	2.4	2.7
26	0.3	0.23	0.54		2.3	2.7	5.0	0.5	0.7	2.7	3.1	2.5	3.0
27	0.3	0.24	0.56		2.3	2.5	4.8	0.6	0.8	2.3	2.9	2.1	2.5
28	0.3	0.24	0.56		2.3	2.5	4.8	0.6	0.8	2.3	2.8	1.9	2.5
Avg.	0.35	0.23	0.57	0.54	2.1	2.6	4.7	0.5	0.7	2.4	2.7	2.0	2.4
Max.	0.40	0.24	0.64	0.56	2.3	3.1	5.1	0.8	1.2	2.8	3.3	2.7	3.0
Min.	0.30	0.21	0.48	0.52	1.6	2.1	4.2	0.3	0.5	1.7	2.1	1.3	1.6

Chemical Analyses

City of Flint Water Treatment Plant

February 2015

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WSSN: 2310

Date	pH (S.U.)		Total Hardness as CaCO ₃ (mg/L)		Total Alkalinity as CaCO ₃ (mg/L)		Non-Carbonate Hardness as CaCO ₃ (mg/L)		Calcium as Ca ²⁺ (mg/L)		Magnesium as Mg ²⁺ (mg/L)		Chloride as Cl ⁻ (mg/L)	
	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap
1	7.78	7.91	339	198	273	60	66	138	109.0	56.9	17.5	14.1	51	98
2	7.92	7.64	343	203	274	77	69	126	110.6	60.1	15.6	12.6	52	91
3	7.75	8.69	344	176	276	62	68	114	113.8	54.5	13.6	10.2	57	90
4	8.04	7.88	346	176	277	62	69	114	114.6	54.5	14.6	10.2	49	88
5	7.77	7.56	349	183	284	63	65	120	118.6	60.9	12.6	7.3	55	89
6	7.92	7.63	350	180	276	52	74	128	117.8	52.9	13.6	11.7	54	95
7	8.07	7.76	348	185	282	68	66	117	113.8	54.5	15.6	11.7	52	92
8	8.05	7.57	347	181	278	50	69	131	111.4	51.3	16.5	12.6	51	91
9	8.11	7.66	349	183	280	62	69	121	112.2	52.9	16.5	12.2	53	94
10	7.95	7.65	350	168	284	47	66	121	113.0	57.7	16.5	6.8	56	95
11	7.97	7.76	345	173	274	54	71	119	109.0	49.7	17.9	12.6	51	92
12	7.85	7.66	342	169	274	51	68	118	117.8	59.3	12.2	6.3	55	92
13	7.77	7.70	345	170	267	53	78	117	121.0	57.7	11.2	4.9	54	90
14	7.86	7.54	344	173	269	52	75	121	125.0	63.3	7.3	3.9	56	93
15	8.00	7.73	349	176	280	53	69	123	113.0	50.5	16.0	12.2	50	94
16	7.89	7.68	353	169	285	47	68	122	123.4	53.7	10.7	8.7	55	95
17	8.05	7.92	360	172	281	49	79	123	118.6	48.9	15.6	11.7	53	92
18	7.96	7.97	352	218	282	102	70	116	125.9	78.6	8.7	5.3	54	91
19	8.11	7.82	358	208	291	91	67	117	120.2	59.3	14.6	13.1	53	92
20	7.93	7.90	362	207	286	94	76	113	133.1	76.2	7.3	4.4	55	87
21	8.00	8.06	362	214	284	98	78	116	133.9	76.2	6.8	4.4	54	86
22	7.98	8.03	366	227	294	113	72	114	116.2	67.3	18.5	14.1	52	88
23	8.07	8.31	361	225	293	112	68	113	121.8	68.9	14.1	12.6	52	86
24	7.95	7.85	361	227	289	101	72	126	133.9	78.6	5.8	6.8	54	88
25	8.03	8.14	365	244	295	127	70	117	118.6	77.8	16.5	11.7	55	89
26	7.91	7.88	365	235	288	108	77	127	132.3	86.6	8.3	4.9	55	89
27	7.96	7.85	354	241	291	117	63	124	131.5	91.4	6.3	2.9	57	89
28	7.90	7.72	358	228	228	115	130	113	127.5	84.2	9.7	3.9	54	87

Avg.	7.95	7.84	352	197	280	76	73	120	119.9	63.7	12.9	9.0	54	91
Max.	8.11	8.69	366	244	295	127	130	138	133.9	91.4	18.5	14.1	57	98
Min.	7.75	7.54	339	168	228	47	63	113	109.0	48.9	5.8	2.9	49	86

Bacteriological &
Physical Parameters

City of Flint Water Treatment Plant

February 2015

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WSSN: 2310

Date	Total Coliform						Standard Plate Count (Simplate MPN)		Conductivity (mS)	Temp. C	Color		Odor	
	Raw (Colilert MPN)		Filter Confluence (N&S)		Plant Tap									
	# Samples	Count	# Samples	# pos	# Samples	# pos	Raw	Tap	Tap	Raw	Raw	Tap	Raw	Tap
1	1	41	12	0	1	0	150	< 2	0.53	4.0				
2	1	117	12	0	1	0	132	< 2	0.55	4.2				
3	1	96	12	0	1	0	146	< 2	0.49	4.3				
4	1	86	12	0	1	0	90	< 2	0.51	4.1				
5	1	105	12	0	1	0	183	< 2	0.51	3.5				
6	1	276	12	0	1	0	128	< 2	0.50	2.4				
7	1	124	12	0	1	0	97	< 2	0.50	3.8				
8	1	120	12	0	1	0	80	< 2	0.48	3.8				
9	1	104	12	0	1	0	90	< 2	0.51	4.2				
10	1	93	12	0	1	0	132	< 2	0.50	4.0				
11	1	115	12	0	1	0	83	< 2	0.47	4.3				
12	1	115	12	0	1	0	93	< 2	0.46	3.8				
13	1	153	12	0	1	0	80	< 2	0.50	4.5				
14	1	154	12	0	1	0	93	< 2	0.48	3.6				
15	1	138	12	0	1	0	83	< 2	0.52	0.5				
16	1	179	12	0	1	0	137	< 2	0.50	0.7				
17	1	365	12	0	1	0	166	< 2	0.50	1.2				
18	1	219	12	0	1	0	177	< 2	0.51	1.7				
19	1	153	12	0	1	0	112	< 2	0.45	2.2				
20	1	192	12	0	1	0	62	< 2	0.56	1.9				
21	1	142	12	0	1	0	116	< 2	0.51	4.1				
22	1	160	12	0	1	0	146	< 2	0.55	2.1				
23	1	129	12	0	1	0	112	< 2	0.58	1.0				
24	1	135	12	0	1	0	100	< 2	0.61	3.4				
25	1	145	12	0	1	0	156	< 2	0.61	2.0				
26	1	115	12	0	1	0	108	< 2	0.61	1.2				
27	1	86	12	0	1	0	74	< 2	0.61	3.3				
28	1	84	12	0	1	0	65	< 2	0.56	3.3				

Avg.									0.52	3.0				
Max.		365					183	0	0.61	4.5				
Min.									0.45	0.5				

Distribution System
MonitoringCity of Flint Water Treatment Plant
WSSN: 2310

February 2015

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Date	Free Chlorine Residual at Bacteriological Monitoring Stations mg/l										
	1	2	3	4	5	6	7	8	CS	WS	Number of Samples
1											0
2											0
3	0.7	1.5	1.5	1.5	1.5	0.2	1.7	1.7	1.3	2.0	10
4											0
5	1.0	1.7	1.7	1.7	1.1	0.2	1.8	2.0	0.7	1.4	10
6											0
7											0
8											0
9											0
10	1.0	1.2	1.5	1.3	1.0	0.2	2.0	1.9	0.7	1.0	10
11	1.0	1.3	1.7	1.7	0.9	0.3	1.7	2.3	0.5	0.9	10
12	0.4	1.4	2.3	1.8	0.7	0.2	1.9	2.2	0.5	1.2	10
13											0
14											0
15											0
16											0
17	1.1	0.7	1.2	1.5	0.7	0.2	1.1	1.3		1.5	9
18	1.2	0.8	1.6	1.2	0.8	0.2	1.8	1.7		1.4	9
19	0.9	0.7	1.3	1.0	0.7	0.2	0.8	1.3		1.0	9
20											0
21											0
22											0
23	1.3	0.8	1.3	1.1	0.6	0.2	0.6	1.5		0.8	9
24	1.5	1.1	1.7	1.2	1.0	0.2	2.5	2.2		2.3	9
25											0
26	1.7	1.4	2.0	1.5	1.1	0.3	1.8	1.8		2.1	9
27											0
28											0

Distribution Sample Summary

Total # of routine distribution samples analyzed	104
Total # of routine distribution samples required	100

Distribution Bacteriological Summary

Total # of positive routine distribution samples	0
Percent of routine distribution samples positive	0%

See page 9 for positive sample information.

Distribution Disinfectant Total Residual Summary

Percentage of samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.22

WSSN: 2310

Date	Total Chlorine Residual at Bacteriological Monitoring Stations mg/l										
	1	2	3	4	5	6	7	8	CS	WS	Number of Samples
1											0
2											0
3	1.0	1.8	1.8	1.9	1.8	0.3	2.0	1.9	1.7	2.4	10
4											0
5	1.3	2.1	2.0	2.0	1.3	0.4	2.1	2.3	1.0	1.6	10
6											0
7											0
8											0
9											0
10	1.3	1.5	1.9	1.6	1.3	0.4	2.4	2.2	1.0	1.3	10
11	1.2	1.5	1.8	1.9	1.1	0.4	1.9	2.6	0.7	1.2	10
12	0.5	1.6	2.4	2.0	0.9	0.4	2.1	2.4	0.6	1.4	10
13											0
14											0
15											0
16											0
17	1.3	1.0	1.4	1.8	0.9	0.3	1.5	1.8		1.7	9
18	1.5	1.0	1.9	1.5	1.0	0.3	2.1	2.0		1.7	9
19	1.3	1.1	1.6	1.5	1.0	0.3	1.0	1.7		1.3	9
20											0
21											0
22											0
23	1.5	1.0	1.6	1.3	0.8	0.3	0.8	1.8		1.2	9
24	1.7	1.3	1.9	1.4	1.2	0.4	2.8	2.4		2.5	9
25											0
26	1.9	1.6	2.4	1.7	1.4	0.5	2.1	2.0		2.5	9
27											0
28											0

Distribution Disinfectant Total Residual Summary

Percent samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.5

[illegible]

Rennaker, Joanne (DEQ)

From: Laura Sullivan <dr.laura2@gmail.com>
Sent: Tuesday, March 10, 2015 12:15 AM
To: Howard Croft
Cc: donna.cole; gdn2@aol.com; James Henry; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Mike Lane; Prysby, Mike (DEQ); Norb Birchmeier; Pete Levine; Russell Hudson; JoAnne Herman; Michael Glasgow; Daugherty Johnson; Brent Wright; Warren Green; Samir Matta; Robert Nicholas
Subject: Re: Literature
Attachments: Abstracts for references 1-6.pdf; Reference 7.pdf; Reference 8.pdf; Reference 9.pdf; Reference 10.pdf

All-

I want to thank Dr. Rose and Mr. Wright for providing these documents. I've read through them and made notes, and I thought I'd share my notes here. There are days when I just can't find the time to comb through references, so if you are having that kind of day, I hope that these notes will help.

Attachment #1 from the NRDC (1999) indicates that **bottled water isn't always safe**. One of the reasons why, interestingly, is that it sometimes contains Trihalomethanes. Two references notes in the article contain site 8 studies found **adverse health effects associated with TTHM** (in the 1990s).

- o R.D. Morris, "Chlorination, Chlorination By-Products, and Cancer: A Meta Analysis," *American Journal of Public Health*, vol. 82, no. 7, at 955-963 (1992); EPA, "Proposed National Primary Drinking Water Regulations for Disinfectants and Disinfection By-Products," 59 Fed. Reg. 38668 (July 29, 1994); NRDC, U.S. PIRG, and Clean Water Action, *Trouble on Tap: Arsenic, Radioactive Radon, and Trihalomethanes in Our Drinking Water* (1995)
- o S.H. Swan, et al., "A Prospective Study of Spontaneous Abortion: Relation to Amount and Source of Drinking Water Consumed in Early Pregnancy," *Epidemiology*, vol. 9, no. 2, pp. 126-133 (March 1998); K. Waller, S. H. Swan, et al. (1998). "Trihalomethanes in Drinking Water and Spontaneous Abortion," *Epidemiology*, vol. 9, no. 2, pp. 134-40 (1998); F. J. Bove, et al. "Public Drinking Water Contamination and Birth Outcomes," *Amer. J. Epidemiol.*, vol. 141, no. 9, pp. 850-862 (1995); *see also*, NRDC, U.S. PIRG, and Clean Water Action, *Trouble on Tap: Arsenic, Radioactive Radon, and Trihalomethanes in Our Drinking Water* (1995).

Attachment #2 is a 1995 article that finds no strong link between TTHM levels and abortion or low birth rate. In doing a quick google scholar search, I found numerous articles that have been published since 1995, some of which make a correlation between exposure and birth defects, such as:

- S. Kumar, et al. "Total trihalomethanes in public drinking water supply and birth outcomes: a cross-sectional study," *Journal of Maternal and Child Health*, vol 18, no. 4, 996-1006 (2014). **This article notes a small increase in risk for low birthweight and pre-term births for chronic low maternal exposure to THMs.**

Attachment #3 (2003) is a Russian study that evaluates the efficacy of home filters in removing TTHMs. The authors of this article do not seek to determine whether or not TTHM levels can result in adverse health effects... instead, **the article states that adverse health effects are likely for pregnant women**

who are exposed to TTHM. The focus of the article is on finding an effective method for ridding water of the TTHM.

Attachment #4 (1999) from the EPA provides information on the importance of removing cryptosporidium from tap water, especially for people with compromised immune system. I'm not aware of previous or current test of the Flint river that detected cryptosporidium. That's the only reason I can think of for adding the topic to this discussion.

Attachment #5 (2006) This Water Research Journal article discusses the effect of boiling on the level of TTHM in the water. Depending on which trihalomethane is being measured, the level increases or decreases.

Attachment #6 Author unknown - perhaps this is a draft document to be included with the upcoming notification. This TTHM fact sheet suggests that the risk of adverse health effects after exposure to TTHMs is small, or that the number of people affected by TTHM is minimal. The statements made are vague and aren't supported by the other papers included in this email message.

Attachment #7 Again, author unknown. This document addresses the risks of cryptosporidium in drinking water, and casts doubt on the benefit of bottled water. The article states that THM is known to increase the risk of certain chronic diseases after long term exposure (without defining exactly what "long term" means), and that TTHMs can cause immediate adverse health effects in vulnerable people. The article notes that TTHMs have been associated with birth defects and premature births.

Attachment #8 discusses the options that people with compromised immune systems have for dealing with water that may have bacteria in it. Adding chlorine is not listed as an option.

After reading the attachments, I still felt unclear regarding the health effects of TTHM, and wanted to see if more recent research has been conducted and published. I searched and was able to find a number of literature citations. I am pasting here a list of articles I found, and attaching a document that contains the abstracts for the first 6 of the references. The full articles for references 7-10 are attached. I am a materials engineer, and not familiar with the academic literature on water research. For that reason, I may have missed pertinent literature published in the past 8 years. Still, it seems that the research I did find supports a correlation between TTHM exposure adverse health effects.

1. J. Lee, et al. "Occurrence of disinfection by-products in tap water distribution systems and their associated health risk." *Environmental Monitoring and Assessment* Vol. 185, no. 9, pp 7675-91 (Sept 2013).
2. E. Rincón-Bedoya, et al. "Mutagenicity and genotoxicity of water treated for human consumption induced by chlorination by-products," *Journal of Environmental Health*, Vol. 75, no. 6, pp 28-36 (Jan/Feb, 2013)
3. S. S. Tsai, et al. "Trihalomethanes in drinking water and the risk of death from esophageal cancer: does hardness in drinking water matter?," *Journal of Toxicology and Environmental Health*, Vol 76, no. 2, 120-30. (Jan/Feb, 2013)
4. S. Chowdhury, "Disinfection byproducts in Canadian provinces: associated cancer risks and medical expenses," *Journal of Hazardous Materials*, Vol 187, pp. 574-84 (March, 2011)
5. M. Basu, "Multi-route risk assessment from trihalomethanes in drinking water supplies," *Environmental Monitoring and Assessment*, Vol 178, pp. 121-34, (Jul, 2011)

6. GE. Bove, et al, "Case-control study of the effects of trihalomethanes on urinary bladder cancer risk," *Archives of Environmental and Occupational Health*, Vol 62, no. 1, pp. 39-47 (Spring, 2007)
7. J. M. Wright, et al, "Effect of Trihalomethane Exposure on Fetal Development," *Occupational Environmental Medicine*, vol 60, pp. 173-80 (2003).
8. J. M. Wright, et al, "The Effect of Disinfection By-Products and Mutagenic Activity on Birth Weight and Gestational Duration," vol 112, pp. 920-25, (2004)
9. L. Stayner, et al, "Exposure to Brominated Trihalomethanes in Water During Pregnancy and Micronuclei Frequency in Maternal and Cord Blood Lymphocytes," *Environmental Health Perspective*, vol 122, pages 100-106. (2014)
10. M Rahman, et al. "Colon and rectal Cancer Incidence and Water Trihalomethane Concentrations in New South Wales, Australia," *BMC Cancer*, Vol 14, pp. 445 (2014).

I am glad to have the opportunity to serve on the technical advisory board, and I hope that the day I spent pulling this information together helps us all to become more familiar with the implications of elevated TTHM levels in water, and brings us all closer to a solution for the residents of Flint.

Sincerely,

Dr. Laura Sullivan

Kettering University

On Mon, Mar 9, 2015 at 2:10 PM, Howard Croft <hcroft@cityofflint.com> wrote:
All,

I am sending out the literature that I received from Dr. Rose and from Mr. Wright of the EPA. There is a lot of information to go through here and we will attempt to put together a new fact sheet from these documents.

We are working on a cover letter that will be mailed out with the DEQ notice and I still intend to send a draft copy to this group prior to the mailer going out. We are targeting this Wednesday to have the letter ready for

preview (along with a fact sheet) and we will potentially mail it out by this weekend or next Monday if the notice has been received.

Thank you,

--

Howard Croft

Public Works Director

City of Flint

1101 S. Saginaw Street

Flint, MI 48502

PH# 810.766.7135 Ext.2043

hcroft@cityofflint.com

--

Laura L. Sullivan, Ph. D.

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dr.laura2@gmail.com

Human(kind). Be both.

Environ Monit Assess. 2013 Sep;185(9):7675-91.

Occurrence of disinfection by-products in tap water distribution systems and their associated health risk.

Lee J, Kim ES, Roh BS, Eom SW, Zoh KD.

Seoul Metropolitan Government Research Institute of Public Health and Environment, Gwacheon, Gyeonggi Province 427070, South Korea.

The concentrations of trihalomethanes (THMs), including chloroform, bromodichloromethane, dibromochloromethane, and bromoform, and haloacetic acids (HAAs; monochloroacetic acid, monobromoacetic acid, dibromoacetic acid, dichloroacetic acid, and trichloroacetic acid) were measured in tap waters passing through water distribution systems of six water treatment plants in Seoul, Korea, and their associated health risks from exposure to THMs through ingestion, dermal contact, and inhalation were estimated using a probabilistic approach. The concentration ranges for total THMs and HAA5 were 3.9-53.5 and <LOD-49.5 µg/L, respectively. Among DBPs, chloroform, bromodichloromethane, dichloroacetic acid, and trichloroacetic acid were the most frequently detected. Spatial and seasonal variations in concentrations of THMs and HAAs in the six water distribution systems were significant ($P < 0.001$). The mean lifetime cancer risks through ingestion, dermal contact, and inhalation during showering ranged as $7.23-10.06 \times 10^{-6}$, $2.19-3.63 \times 10^{-6}$, and $5.22-7.35 \times 10^{-5}$, respectively. The major exposure route to THMs was inhalation during showering. **Sensitivity analysis showed that shower time and shower frequency had a great impact on the lifetime cancer risk by the exposure to THMs in tap water.**

J Environ Health. 2013 Jan-Feb;75(6):28-36.

Mutagenicity and genotoxicity of water treated for human consumption induced by chlorination by-products.

Rincón-Bedoya E, Velásquez N, Quijano J, Bravo-Linares C.

Universidad Austral de Chile, Facultad de Ciencias, Instituto de Química, Valdivia, Chile. elizabethrincon@uach.cl

Water used for human consumption may contain mutagens and carcinogens generated during the disinfection process with chlorine. In the study described in this article, the mutagenicity and genotoxicity of water samples taken from the San Cristobal treatment plant in Medellin, Colombia, were evaluated. Short-term mutagenic and genotoxic assays using the Ames test and comet assay, respectively, were employed to examine the genotoxic activity of the extracts of these water samples. Two samples were taken before and after the chlorination process. The treated water samples without chlorination did not show mutagenic effects using

the Ames test, while the chlorinated samples produced mutagenic activity in both strains. A dose-response relationship for the comet assay was obtained only in the chlorinated samples. MX(3-chloro-4-[dichloromethyl]-5-hydroxy-2[5H]-furanone), E-MX([E]-2-chloro-3-[dichloromethyl]-4-oxobutenoic acid), and some trihalomethanes were detected at low concentrations. **These concentrations were enough, however, to cause detectable mutagenic and genotoxic activity in the extracts of chlorinated water samples.**

J Toxicol Environ Health A. 2013;76(2):120-30.

Trihalomethanes in drinking water and the risk of death from esophageal cancer: does hardness in drinking water matter?

Tsai SS, Chiu HF, Yang CY.

Department of Health Care Administration, I-Shou University, Kaohsiung, Taiwan.

The objectives of this study were to (1) examine the relationship between total trihalomethanes (TTHM) levels in public water supplies and risk of esophageal cancer occurrence and (2) determine whether calcium (Ca) and magnesium (Mg) levels in drinking water modify the effects of TTHM on risk to develop esophageal cancer. A matched case-control study was used to investigate the relationship between the risk of death attributed to esophageal cancer and exposure to TTHM in drinking water in 53 municipalities in Taiwan. All esophageal cancer deaths in the 53 municipalities from 2006 through 2010 were obtained from the Bureau of Vital Statistics of the Taiwan Provincial Department of Health. Controls were deaths from other causes and were pair-matched to the cancer cases by gender, year of birth, and year of death. Each matched control was selected randomly from the set of possible controls for each cancer case. Data on TTHM levels in drinking water were collected from Taiwan Environmental Protection Administration. Information on the levels of Ca and Mg in drinking water was obtained from the Taiwan Water Supply Corporation. The municipality of residence for cancer cases and controls was presumed to be the source of the subject's TTHM, Ca, and Mg exposure via drinking water. Relative to individuals whose TTHM exposure level <4.9 ppb, the adjusted odds ratio (OR) with 95% confidence interval (CI) for esophageal cancer was 1.02 (0.84-1.23) for individuals who resided in municipalities served by drinking water with a TTHM exposure ≥ 4.9 ppb. There was evidence of an interaction between drinking-water TTHM levels and low Ca and Mg intake. Our findings showed that the correlation between TTHM exposure and risk of esophageal cancer development was influenced by Ca and Mg levels in drinking water. **This is the first study to report effect modification by Ca and Mg intake from drinking water on the correlation between TTHM exposure and risk of esophageal cancer occurrence.** Increased knowledge of the interaction between Ca, Mg, and TTHM in reducing risk of esophageal cancer

development will aid in public policymaking and standard setting for drinking water.

J Hazard Mater. 2011 Mar 15;187(1-3):574-84. doi: 10.1016/j.jhazmat.2011.01.085. Epub 2011 Jan 26.

Disinfection byproducts in Canadian provinces: associated cancer risks and medical expenses.

Chowdhury S, Rodriguez MJ, Sadiq R.

Department of Civil Engineering, King Fahd University of Petroleum and Minerals, Dhahran 31261, Saudi Arabia. SChowdhury@kfupm.edu.sa

Chlorination for drinking water forms various disinfection byproducts (DBPs). Some DBPs are probably linked to human cancer (e.g., bladder, colorectal cancers) and other chronic and sub-chronic effects. This emphasizes the need to understand and characterize DBPs in drinking water and possible risks to human health. In this study, occurrences of DBPs throughout Canada were investigated. Trihalomethanes (THMs) were observed to be highest in Manitoba followed by Nova Scotia and Saskatchewan, while haloacetic acids were highest in Nova Scotia followed by Newfoundland and Labrador. **Based on the characterization of DBPs, risk of cancer from exposure to THMs was predicted using ingestion, inhalation and dermal contact pathways of exposure. In Canada, approximately 700 cancer cases may be caused by exposure to THMs in drinking water.** Medical expenses associated with these cancer incidents are estimated at some \$140 million/year. Expense may be highest in Ontario (~\$47 million/year) followed by Quebec (~\$25 million/year) due to a greater population base. This paper suggests improvements in water treatment, source protection and disinfection processes, and caution in the use of alternative disinfectants to reduce DBPs. Finally, elements are provided to mitigate risks and reduce cost estimates in future studies.

Environ Monit Assess. 2011 Jul;178(1-4):121-34. doi: 10.1007/s10661-010-1677-z. Epub 2010 Sep 8.

Multi-route risk assessment from trihalomethanes in drinking water supplies.

Basu M, Gupta SK, Singh G, Mukhopadhyay U.

Department of Environmental Science & Engineering, Indian School of Mines, Dhanbad, 826004, India. mrittika.basu@gmail.com

The main objectives of this study were to investigate the concentration and lifetime cancer risk and hazard index of trihalomethanes (THMs) through multiple routes like oral ingestion, dermal absorption, and inhalation exposure in the water samples collected at water treatment plant endpoints. Bromoform has been found in highest concentration followed by chloroform. A lesser concentration of dibromochloromethane has been found than dichlorobromomethane in most of the studied water, which is an unusual scenario, in spite of the high concentration of bromide in the water which can be attributed to the formation, speciation, and distribution of THMs in the breakpoint chlorination curve. **Among the three pathways studied, inhalation contributed 80-90% of the total risk followed by oral exposure and dermal contact.** Chloroform was found to be the major THM which is having cancer risk in its gaseous form whereas bromoform contributed highest cancer risk through oral ingestion. The average hazard index of total THMs through oral route was higher than unity, indicating high noncarcinogenic risk. The discrepancy between the three exposure pathways may be attributed to different concentration and speciation of THMs present in the waters. The sensitivity analysis by tornado diagram confirmed the highest positive impact of chloroform to the total cancer risk and, indirectly, confirmed inhalation as the major pathway of exposure. This study suggests the modification of the regulatory issues related to THMs based on the health risk associated with each THM and exposure pathway.

Arch Environ Occup Health. 2007 Spring;62(1):39-47.

Case-control study of the effects of trihalomethanes on urinary bladder cancer risk.

Bove GE Jr, Rogerson PA, Vena JE.

Department of Geography, State University of New York, Buffalo, NY 14261, USA.

In this research, the authors examined the relation between the estimated concentrations in drinking water of disinfectant byproduct (DBP) trihalomethanes (THMs) and the risk for urinary bladder cancer in a case-control study of 567 white men aged 35 to 90 years, in western New York State. They used logistic regression to estimate odds ratios (ORs) and to assess the effects of THM consumption on cancer risk. **Higher levels of consumption of THMs led to increased risk for cancer of the urinary bladder** (total 551, a composite measure of THMs based upon method 551 developed by the US Environmental Protection Agency: OR = 2.34; 95% confidence interval [CI] = 1.01-3.66). Results were most significant for bromoform (OR = 3.05; 95% CI = 1.51-5.69), and risk was highest (OR = 5.85; 95% CI = 1.93-17.46) for those who consumed the greatest amount of water at points within the distribution system with the oldest postdisinfected tap water.

The Effect of Disinfection By-products and Mutagenic Activity on Birth Weight and Gestational Duration

J. Michael Wright,¹ Joel Schwartz,² and Douglas W. Dockery²

¹Office of Research and Development, U.S. Environmental Protection Agency, National Center for Environmental Assessment, Cincinnati, Ohio, USA; ²Exposure, Epidemiology, and Risk Program, Department of Environmental Health, Harvard School of Public Health, Boston, Massachusetts, USA

Epidemiologic studies of disinfection by-products have traditionally focused on total trihalomethane (TTHM) concentration as a surrogate for maternal exposure during pregnancy. We used birth certificate data on 196,000 infants to examine the effect of third-trimester exposures on various indices of fetal development. We examined the effect of town-average concentrations of TTHM and additional exposure metrics in relation to mean birth weight, mean gestational age, small for gestational age (SGA) infancy, and preterm delivery. Trihalomethane data (TTHM, chloroform, and bromodichloromethane) from 1995–1998 were available for 109 towns in Massachusetts. Data from 1997–1998 on haloacetic acid (total haloacetic acids, dichloroacetic acid, and trichloroacetic acid), 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX), and mutagenicity were available for a limited number of towns. We observed reductions in mean birth weight (12–18 g) for maternal trihalomethane exposures > the 90th percentile compared with those < the 50th percentile. Birth weight reductions were detected for chloroform exposures > 20 µg/L and TTHM exposures > 40 µg/L. Elevated trihalomethanes were associated with increases in gestational duration and a reduced risk of preterm delivery. We found evidence of an exposure–response effect of trihalomethanes on risk of SGA, with odds ratios (ORs) ranging from 1.09 to 1.23 for bromodichloromethane exposures > 5 µg/L. Elevated mutagenic activity was associated with SGA [OR = 1.25; 95% confidence interval (CI), 1.04 to 1.51] and mean birth weight (–27 g; 95% CI, –54 to –1). Although smaller in magnitude, our findings are consistent with previous studies reporting associations between trihalomethanes and SGA. These data also suggest a relationship between fetal development indices and mutagenic activity independent of exposure to trihalomethanes, haloacetic acids, and MX. **Key words:** birth weight, bromodichloromethane, chloroform, gestational age, haloacetic acids, mutagenic activity, MX, preterm delivery, small for gestational age, trihalomethanes. *Environ Health Perspect* 112:920–925 (2004). doi:10.1289/ehp.6779 available via <http://dx.doi.org/> [Online 18 February 2004]

Disinfection by-products (DBPs) are formed when organic and inorganic matter react with disinfectants used to treat drinking water. Some DBPs are known reproductive and developmental toxins. Teratogenicity has been reported in animals exposed to haloacetic acids (HAAs) (Epstein et al. 1992; Smith et al. 1989a, 1992) and haloacetoneitriles (Smith et al. 1988, 1989b), and there is evidence that 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) may be a direct-acting teratogen *in vitro* (Teramoto et al. 1998). The trihalomethanes (THMs) are not considered teratogenic, but growth retardation has been reported in mice exposed to chloroform (Murray et al. 1979; Ruddick et al. 1983; Schwetz et al. 1974; Thompson et al. 1974). Growth retardation has also been reported in mice exposed to dichloroacetic acid (Smith et al. 1992) and trichloroacetic acid (Smith et al. 1989a) and in rats exposed to dichloroacetoneitrile (Smith et al. 1989b) and trichloroacetoneitrile (Smith et al. 1987).

Epidemiologic data suggest an association between DBPs and adverse developmental outcomes (Graves et al. 2001; Nieuwenhuijsen et al. 2000; Reif et al. 1996). Bove et al. (1995) observed a 42% increased risk of low birth weight associated with total THM (TTHM)

concentrations > 100 µg/L compared with those ≤ 20 µg/L. Savitz et al. (1995) reported a 30% increased risk of low birth weight for TTHM exposures ≥ 82.8 µg/L compared with those < 40.8 µg/L but found no effect for maternal dose estimated from TTHM concentration and the number of glasses of water consumed per day. Gallagher et al. (1998) reported associations between > 60 µg/L TTHM (vs. ≤ 20 µg/L) and low birth weight in term births [odds ratio (OR) = 5.9; 95% confidence interval (CI), 2.0 to 17.0] and all births (OR = 2.1; 95% CI, 1.0 to 4.8). Wright et al. (2003) found an increased risk of infants' being small for gestational age (SGA) associated with TTHM concentrations > 80 µg/L (OR = 1.14; 95% CI, 1.02 to 1.26) compared with ≤ 60 µg/L. A 50% increased risk of SGA was reported by Bove et al. (1995) for TTHM concentrations > 100 µg/L (OR = 1.50; 95% CI, 1.14 to 1.94) compared with ≤ 20 µg/L. An 8% increased risk (OR = 1.08; 95% CI, 0.99 to 1.18) of SGA was reported by Dodds et al. (1999) for TTHM ≥ 100 µg/L compared with < 50 µg/L. No associations between preterm delivery and DBP concentrations have been reported (Bove et al. 1995; Dodds et al. 1999; Gallagher et al. 1998; Kramer et al. 1992; Savitz et al. 1995; Wright et al. 2003).

TTHM concentration is the most common surrogate of DBP exposure used in epidemiologic studies, but independent effects of individual THMs have been reported. Waller et al. (1998) found an increased risk of spontaneous abortions in women drinking five or more glasses per day of cold tap water containing ≥ 75 µg/L TTHM (OR = 1.8; 95% CI, 1.1 to 3.0) and ≥ 18 µg/L bromodichloromethane (BDCM; OR = 3.0; 95% CI, 1.4 to 6.6). King et al. (2000) detected a 98% (OR = 1.98; 95% CI, 1.23 to 3.49) increased risk for stillbirths among mothers exposed to ≥ 20 µg/L BDCM (vs. < 5 µg/L) and a 66% increased risk (OR = 1.66; 95% CI, 1.09 to 2.54) for TTHM ≥ 100 µg/L (vs. < 50 µg/L). Few epidemiologic studies have evaluated the impact of non-volatile DBPs on fetal development. Kramer et al. (1992) examined the impact of total organic halides but reported difficulty distinguishing between the effects of this surrogate with highly correlated DBPs. The relationship between fetal development outcomes and individual nonvolatile DBPs has not been examined, but these DBPs are likely even less correlated with TTHM concentrations (Wright et al. 2002). We previously detected high levels of MX and mutagenic activity in drinking water from Massachusetts (Wright et al. 2002), as well as associations between TTHM and different fetal development indices (Wright et al. 2003). In the present study, we used several years of birth certificate data to examine the relationship between indices of fetal development and various town average exposure metrics. Exposure measures included previously collected MX and

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We thank the individual water departments and the Massachusetts Department of Public Health for their interest and cooperation in this study. Special thanks to D. Guterman, J. Dillon, A. Zaharias, and P. Caron at the Massachusetts Department of Environmental Protection for their assistance in the data collection effort.

This work was supported in part by a pilot study grant from the Kresge Center for Environmental Health (National Institute of Environmental Health Sciences grant ES-00002).

The authors declare they have no competing financial interests.

Received 1 October 2003; accepted 18 February 2004.

mutagenicity data, as well as TTHM, BDCM, chloroform, total HAA, dichloroacetic acid, and trichloroacetic acid concentrations.

Materials and Methods

Study population. The Massachusetts Department of Public Health (Boston, MA) supplied 1995–1998 birth certificate data ($n = 282,645$) for towns with populations $> 10,000$. These data contained detailed maternal and infant information including birth weight and gestational age. We excluded infants with implausible values for birth weight (< 200 g) and gestational age (< 22 or > 45 weeks) and those born to nonresidents. The remaining birth data were linked with drinking water DBP and mutagenicity measurements to examine the effect of maternal third-trimester exposure on mean birth weight and SGA in term births and preterm delivery and mean gestational age in all births.

Outcome data. Gestational age recorded on the birth certificates was based on clinician estimate. SGA infancy was defined as the lowest decile of birth weight for each gestational week stratified by infant sex and maternal race. We restricted the SGA and birth weight analyses to term births from 37–45 gestational weeks. Preterm delivery was defined as < 37 gestational weeks, whereas very preterm was defined as < 34 weeks. Infants at least 37 gestational weeks and weighing at least 2,500 g served as the comparison group for the estimated ORs.

Exposure data. We used town-specific aggregate data to estimate maternal exposure to THMs, HAAs, MX, and mutagenic activity in drinking water. We abstracted 1995–1998 THM data from the Massachusetts Department of Environmental Protection (Boston, MA) records. Community systems that use disinfectants and serve populations $> 10,000$ were required to monitor THMs on a quarterly basis. Of the 109 towns with THM data, nine towns were granted waivers allowing annual monitoring. The THM samples collected by each town were analyzed by laboratories certified by the U.S. Environmental Protection Agency (EPA) or the Massachusetts Department of Environmental Protection, by means of gas chromatography (U.S. EPA method 502.2) and gas chromatography/mass spectrometry (U.S. EPA Method 524.2; U.S. EPA 1995). TTHM concentration was defined as the sum of chloroform, BDCM, dibromochloromethane, and bromoform. Dibromochloromethane and bromoform rarely exceeded the detection limit in these sampled communities, so we restricted the data analysis to chloroform, BDCM, and TTHM.

HAA samples were collected by 17 towns on a weekly to quarterly basis from 1997 to 1998 and were analyzed using gas chromatography (U.S. EPA method 552; U.S. EPA 1995).

Total HAAs included monochloroacetic, dichloroacetic, trichloroacetic, monobromoacetic, and dibromoacetic acids. Monochloroacetic acid, monobromoacetic acid, and dibromoacetic acid rarely exceeded the detection limit in these sampled communities, so we restricted the data analysis to dichloroacetic acid, trichloroacetic acid, and total HAAs.

We previously measured MX and mutagenic activity in Massachusetts' surface water systems described in detail elsewhere (Wright et al. 2002). Briefly, we collected 88 tap water samples from 36 towns during the fall and spring of 1997 and 1998. The tap water samples were collected in 4-L bottles, extracted, and evaporated to 1 mL ethyl acetate. The extracts were analyzed at the Laboratory of Chemistry of the National Public Health Institute in Kuopio, Finland. MX concentrations were measured using gas chromatography/mass spectroscopy (Fawell and Horth 1990). Mutagenicity, measured as the number of net revertants (rev) per liter, was determined by the plate incorporation method of Maron and Ames (1983). The Ames test was conducted on *Salmonella typhimurium* tester strain TA100, which has been shown to be the most sensitive strain for detecting mutagenicity caused by MX (Daniel et al. 1991). MX is a direct-acting mutagen, so no metabolic activation was required. After linkage with the birth certificate data, MX and mutagenicity measurements for 34 towns were available for use in the present study.

Exposure assessment. Maternal ZIP code and infant month of birth were used to assign third-trimester town-specific DBP and mutagenicity data. Quarterly town averages were calculated from all available samples for the different sampling locations. Towns with annual THM measurements were assigned the same concentration for each quarter. To estimate third-trimester exposures, each mother with an infant born in the second or third month of a quarter was assigned the mean quarterly value for her town of residence. For infants born in the first month of a quarter, the third-trimester exposure was determined from the previous quarterly average concentration. Mothers delivering before 29 gestational weeks were not assigned a third-trimester value. We divided maternal exposures into approximately the lowest 50th percentile (reference), 50th–90th percentile, and > 90 th percentile. We also examined exposure–response gradients based on equal increments of THM concentration.

Statistical methods. Statistical Analysis Systems software (SAS, version 6.11; SAS Institute, Inc., Cary, NC) was used for the statistical analyses. We used linear regression to estimate changes in birth weight and gestational age associated with exposure to DBPs and mutagenic activity. We used logistic regression to estimate ORs for preterm delivery and SGA

infancy. To indicate the precision of the effect estimates, 95% CIs were calculated. Pearson correlation coefficients were used to examine the relation between the town-specific exposure metrics. We included the categorical THM variables as continuous regressors in the final models as a test of trend for the exposure–response analyses.

The regression models were adjusted for the following dichotomous maternal risk factors: diabetes, lung disease, renal disease, chronic hypertension, marital status, previous preterm delivery, and previous birth to an infant weighing $> 4,000$ g. We also included categorical variables for maternal education, parity, prenatal care, and the number of cigarettes smoked per day based on a previous analysis of nonparametric smooth functions (Hattis D. et al., unpublished data). The adequacy of prenatal care classification (no care, inadequate care, intermediate care, and adequate) was based on the Kessner index, which incorporates gestational age, timing of the first prenatal visit, and total number of prenatal visits (Alexander and Kotelchuck 1996). A quadratic polynomial for maternal age and categorical variables for maternal race (Caucasian, African American, Asian, Native American, and other) were included in all of the regression models. Except for the SGA analyses, all of the regression models were adjusted for infant sex. Median household incomes specific to ZIP code obtained from 1990 U.S. Census data (Geolytics, Inc., East Brunswick, NJ) and weight gain during pregnancy were included as continuous variables. Weight gain during pregnancy and marital status were not available on birth certificates before 1997, so we could not adjust for these covariates in the THM analyses.

Results

As shown in Table 1, the study population included Massachusetts residents with singleton infants 22–45 gestational weeks and ≥ 200 g ($n = 196,000$). Of the 194,827 births with recorded gestational age and THM measurements, 11,580 (6%) were classified as preterm deliveries (< 37 gestational weeks). Among the 183,247 term births, 17,359 (9%) were classified as SGA. Prenatal care and maternal smoking were the strongest risk factors for the three outcomes. Mothers without prenatal care had infants that weighed an average of 250 g less than those with adequate prenatal care. Similar reductions in infant birth weight were observed among mothers smoking > 10 cigarettes per day compared with nonsmokers. Third-trimester TTHM exposure was weakly associated with mean birth weight and SGA infancy in these unadjusted analyses.

Table 2 shows the distribution of third-trimester DBP and mutagenic activity exposure for residents of towns with populations

> 10,000. The average third-trimester TTHM exposure was 38 µg/L, with 7% of the maternal exposures exceeding 80 µg/L. The maximum total HAA concentration was 58 µg/L, and the average maternal exposure was 31

µg/L. The average third-trimester exposure was 25 ng/L for MX and 1,400 rev/L for mutagenicity.

Birth weight. Reductions in mean birth weight were observed for individual THMs,

MX, and mutagenic activity (Table 3). Compared with TTHM levels < 50th percentile (≤ 33 µg/L), exposures in the 50th–90th percentiles (> 33 to 74 µg/L) and those > 90th percentile (> 74 µg/L) were associated with 12-g (95% CI, –16 to –7) and 18-g (95% CI, –26 to –10) reductions in birth weight, respectively. Similar associations were observed for chloroform, whereas smaller effects were observed for BDCM. Statistically significant tests for trend ($p < 0.001$) were detected suggesting an exposure–response relationship between birth weight and THM exposures. Although a monotonic gradient was not evident for any of the THM exposure metrics (Figure 1), reductions in mean birth weight were observed for chloroform concentrations > 20 µg/L and TTHM exposures > 40 µg/L.

The number of towns with MX, mutagenicity, and HAA data was limited. Nevertheless, exposure to high MX concentrations resulted in mean birth weight reductions similar to those observed for THMs (Table 3). Elevated mutagenicity (> 2,250 rev/L) was associated with a 27-g (95% CI, –54 to –1) reduction compared with the reference population ($\leq 1,250$ rev/L). No associations were detected for high third-trimester HAA exposures, but birth weight increases > 20 g were observed for intermediate total haloacetic and trichloroacetic acids.

Gestational age. We detected an association between mean gestational age and exposure to THMs and mutagenicity (Table 3). Mothers exposed to high THM concentrations had slightly longer gestational periods (0.4–0.5 days) than did those with lower exposures. Mutagenicity > 2,250 rev/L was associated with longer gestation (1.1 days; 95% CI, 0.4 to 1.7) compared with $\leq 1,250$ rev/L. Trichloroacetic acid > 27 µg/L was associated with shorter gestational duration (–0.9 days; 95% CI, –1.7 to –0.1) compared with ≤ 18 µg/L.

SGA births. Statistically significant tests for trend ($p \leq 0.002$) suggested an exposure–response relationship between SGA and categorical THM exposures. We detected a monotonic increase in risk of SGA for chloroform exposures > 20 µg/L (Figure 2). A monotonic gradient was not evident between SGA and BDCM, but associations were detected for exposures > 5 µg/L (ORs = 1.09–1.23). We found similar ORs (1.05–1.15) for intermediate and high THM exposures based on the 50th and 90th percentile cut points (Table 4). Relative risks similar in magnitude were observed for elevated exposures to MX (OR = 1.14; 95% CI, 0.95 to 1.37) and mutagenic activity (OR = 1.25; 95% CI, 1.04 to 1.51). We did not detect an increased risk of SGA infancy for high HAA exposures, but inverse associations were detected for intermediate trichloroacetic and dichloroacetic acid exposures.

Table 1. Characteristics of singleton infants born 1995–1998 in Massachusetts towns with populations > 10,000 with TTHM data available.

Characteristics	Study population [no. (%)]	Mean birth weight [g] ^a	SGA (%) ^{a,b}	Preterm delivery (%) ^c
Total births (no.)	196,000	3,463	17,359 ^d	11,580 ^d
Maternal race				
Caucasian	138,381 (70.8)	3,509	8.5	5.5
African American	19,213 (9.8)	3,346	9.8	11.0
Other	27,106 (13.9)	3,370	12.6	8.7
Asian	10,357 (5.3)	3,283	15.4	7.1
American Indian	360 (0.2)	3,434	10.6	9.0
Maternal age [years]				
12–20	24,794 (12.7)	3,322	14.2	9.1
21–25	36,093 (18.4)	3,409	11.2	6.8
26–30	56,799 (29.0)	3,481	8.7	5.9
31–35	54,094 (27.6)	3,520	7.6	5.7
36–40	21,234 (10.8)	3,514	8.2	6.8
41–53	2,984 (1.5)	3,484	10.5	8.3
Maternal education				
$\leq$ 9th grade	14,743 (7.6)	3,329	14.8	9.8
10th grade	9,192 (4.7)	3,333	14.0	8.8
11th grade	10,536 (5.4)	3,345	13.7	8.8
High school graduate	160,649 (82.3)	3,489	8.5	6.0
Maternal smoking (cigarettes/day)				
0	168,463 (86.3)	3,491	8.2	6.1
1–5	8,711 (4.5)	3,323	15.1	8.7
6–10	10,134 (5.2)	3,271	17.9	9.1
> 10	7,888 (4.0)	3,238	20.7	10.2
Prenatal care (Kessner index)				
No prenatal care	464 (0.2)	3,233	19.9	25.1
Inadequate	6,582 (3.4)	3,333	14.1	10.6
Intermediate	33,860 (17.5)	3,399	11.5	9.1
Adequate	152,305 (78.8)	3,483	8.8	5.7
No. of previous births				
0	87,278 (44.5)	3,412	11.6	7.3
1	64,149 (32.7)	3,508	7.5	5.3
2 or 3	38,878 (19.8)	3,502	8.2	6.4
≥ 4	5,636 (2.9)	3,450	10.1	10.1
Infant sex				
Male	100,428 (51.2)	3,525	9.3	6.9
Female	95,572 (48.8)	3,398	9.7	6.2
Third-trimester TTHM (µg/L)				
0–20	63,138 (32.2)	3,484	8.6	6.7
> 20–40	48,623 (24.8)	3,468	9.3	6.5
> 40–60	44,218 (22.6)	3,442	10.3	6.6
> 60–80	25,562 (13.0)	3,440	10.2	6.6
> 80–163	14,459 (7.4)	3,454	10.5	5.8

^aInfants 22–45 gestational weeks and ≥ 200 g. ^bSGA defined as lowest 10% of birth weight per gestational age, sex, and race.

^cInfants < 37 gestational weeks and ≥ 200 g. ^dAmong 194,827 infants with recorded clinical estimates of gestational age.

Table 2. Maternal third-trimester exposure to DBPs and mutagenic activity for residents of Massachusetts towns with populations > 10,000 during 1995–1998.

	No. of towns	No. of births	10th ^a	Median	90th ^a	Maximum	Mean $\pm$ SD
THMs (µg/L) ^b							
TTHM	109	196,000	8	33	74	163	38.2 $\pm$ 27.0
Chloroform	109	195,506	4	25	63	135	31.0 $\pm$ 23.6
BDCM	109	195,506	1	4	12	46	5.7 $\pm$ 5.1
HAAs (µg/L) ^c							
Total HAAs	17	18,750	13	30	49	58	31.4 $\pm$ 13.6
Trichloroacetic acid	15	14,151	9	19	28	37	16.9 $\pm$ 7.5
Dichloroacetic acid	15	14,151	8	15	24	24	15.3 $\pm$ 5.7
MX (ng/L) ^c	34	16,378	13	20	45	80	24.6 $\pm$ 12.8
Mutagenicity (rev/L) ^c	34	16,378	820	1,260	2,040	5,710	1,410 $\pm$ 700

^aPercentile. ^b1995–1998 data. ^c1997–1998 data.

Preterm delivery. The risk of preterm delivery (< 37 gestational weeks) was significantly lower for mothers with intermediate and high THM exposures (ORs = 0.88–0.95; Table 4). Elevated levels of HAAs, MX, and mutagenicity were not associated with preterm delivery. No associations were detected between very preterm infants (< 34 gestational weeks) and THMs, MX, mutagenicity, or dichloroacetic acid (data not shown), but an increased risk was observed for high trichloroacetic (OR = 1.33; 95% CI, 0.77 to 2.30) and total HAAs (OR = 1.48; 95% CI, 0.84 to 2.61).

Discussion

Low birth weight and preterm delivery are strongly associated with infant morbidity and mortality (Branum and Schoendorf 2002;

Infant Health and Development Program 1990; McCormick 1985), especially in the United States, where infant mortality rates are largely attributable to preterm delivery (Wilcox et al. 1995). Although many important risk factors have been identified, the underlying etiology of approximately 60% of preterm deliveries and 40% of low-birth-weight infants remains unclear (Wollmann 1998). There is increasing interest in the role of environmental exposures, including ambient air pollution (Bobak 2000; Maisonet et al. 2001; Ritz and Yu 1999; Rogers et al. 2000; Wang et al. 1997) and DBPs in drinking water (Graves et al. 2001; Nieuwenhuijsen et al. 2000; Reif et al. 1996).

Consistent with previous term birth analyses (Bove et al. 1995), we found associations

between TTHM exposures > 40 µg/L and mean birth weight. Reductions in birth weight were also observed for low third-trimester chloroform (> 20 µg/L) and BDCM (> 5 µg/L) concentrations. Exposure to high levels of mutagenic activity resulted in the largest reduction in birth weight (–27 g; 95% CI, –54 to –1). The reductions in mean birth weight associated with DBPs and mutagenicity were an order of magnitude less than those observed for maternal smoking and other risk factors.

We evaluated SGA infancy as a measure of fetal growth restriction, because birth weight is a function of gestational duration and rate of fetal growth. We found evidence of exposure-response effects of THMs on SGA and a monotonic increase in risk for chloroform. Increased risks of SGA were observed for TTHM > 40 µg/L, chloroform > 20 µg/L, BDCM > 5 µg/L, and mutagenic activity

Table 3. The effect of third-trimester DBP and mutagenicity exposure on mean birth weight among term births and gestational age among all births.^a

Exposure	No. of births ^b	Birth weight		No. of births	Gestational age	
		Δ Birth weight (g) ^b	95% CI		Δ Gestational age (days)	95% CI
THMs (µg/L)						
TTHM						
0–33	89,881	Reference		95,630	Reference	
> 33–74	70,567	–12	–16 to –7	74,956	0.0	–0.1 to 0.1
> 74–163	16,729	–18	–26 to –10	17,627	0.5	0.3 to 0.7
Per 66 µg/L		–18	–23 to –13		0.3	0.1 to 0.4
Chloroform						
0–26	91,277	Reference		97,040	Reference	
> 26–63	69,285	–14	–19 to –9	73,637	0.0	–0.2 to 0.1
> 63–135	16,153	–18	–26 to –10	17,054	0.4	0.2 to 0.6
Per 59 µg/L		–19	–25 to –14		0.1	0.0 to 0.3
BDCM						
0–5	101,564	Reference		108,457	Reference	
> 5–13	60,873	–12	–17 to –8	64,215	0.6	0.5 to 0.7
> 13–46	14,278	–12	–20 to –3	15,059	0.5	0.3 to 0.8
Per 11 µg/L		–9	–13 to –4		0.5	0.4 to 0.6
HAAs (µg/L) ^c						
Total HAA						
4–30	7,853	Reference		8,360	Reference	
> 30–49	6,599	25	9 to 40	7,005	0.1	–0.3 to 0.5
> 49–58	881	7	–25 to 39	934	0.7	–1.5 to 0.1
Per 36 µg/L		25	6 to 45		0.2	–0.2 to 0.6
Trichloroacetic acid						
0–18	5,175	Reference		5,494	Reference	
> 18–27	4,953	21	3 to 39	5,264	0.2	–0.3 to 0.6
> 27–37	1,031	–4	–35 to 27	1,093	–0.9	–1.7 to –0.1
Per 19 µg/L		16	–9 to 40		0.1	–0.6 to 0.8
Dichloroacetic acid						
2–15	5,135	Reference		5,457	Reference	
> 15–22	4,346	15	–4 to 34	4,587	0.0	–0.5 to 0.5
> 22–24	1,678	12	–14 to 38	1,807	–0.3	–0.9 to 0.4
Per 16 µg/L		29	4 to 55		0.1	–0.4 to 0.6
MX (ng/L) ^c						
4–20	7,368	Reference		7,804	Reference	
> 20–46	5,542	–2	–17 to 14	5,879	–0.4	–0.8 to 0.0
> 46–80	1,484	–18	–44 to 8	1,552	0.1	–0.5 to 0.8
Per 32 ng/L		–14	–33 to 5		0.2	–0.3 to 0.7
Mutagenicity (rev/L) ^c						
330–1,250	6,414	Reference		6,763	Reference	
> 1,250–2,250	6,476	–19	–35 to –2	6,909	–0.5	–0.9 to 0.0
> 2,250–5,710	1,504	–27	–54 to –1	1,563	1.1	0.4 to 1.7
Per 1,450 rev/L		–16	–32 to –1		0.5	0.1 to 0.9

^aRegression coefficients adjusted for median household income, infant sex, adequacy of prenatal care, maternal race, maternal education, maternal cigarette consumption, maternal age, parity, previous infant weighing ≥ 4,000 g, previous preterm delivery, and maternal medical history (diabetes, chronic hypertension, lung disease, and renal disease). ^bAmong term births only. ^c1997–1998 analyses included adjustment for marital status and weight gain during pregnancy.

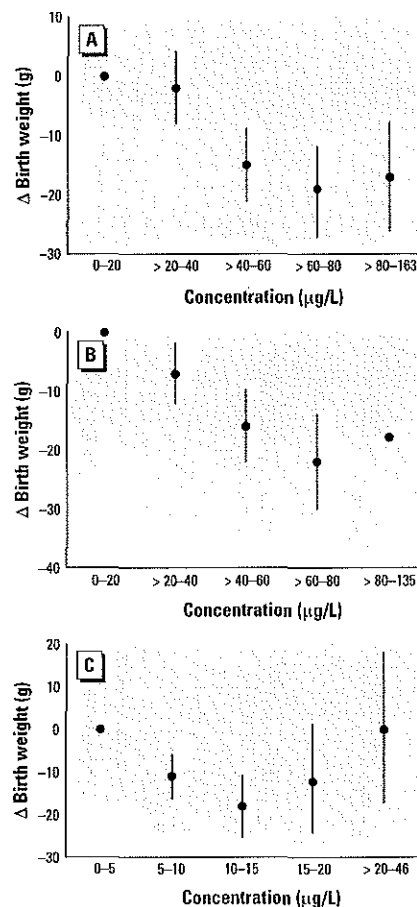


Figure 1. Change in mean birth weight and 95% CIs for third-trimester THM exposures: regression coefficients for (A) TTHM, (B) chloroform, and (C) BDCM adjusted for median household income, infant sex, adequacy of prenatal care, maternal race, maternal education, maternal cigarette consumption, maternal age, parity, previous infant weighing ≥ 4,000 g, previous preterm delivery, and maternal medical history (diabetes, chronic hypertension, lung disease, and renal disease).

> 2,250 rev/L. The effects of DBPs and mutagenicity on SGA and birth weight were smaller than previously reported for THMs.

Elevated TTHM and chloroform exposures were associated with a reduced risk of preterm delivery (< 37 gestational weeks). We found similar reductions in the risk of very preterm delivery (< 34 gestational weeks), although an increased risk was detected for total HAAs and trichloroacetic acid. It is unclear whether these differences are due to less misclassification among very preterm infants than among preterm infants or result from inaccurate gestational age estimates. We confirmed previous findings of associations between high THM exposures and increases in mean gestational age (Wright et al. 2003), but we are cautious in our interpretation given the likelihood of errors in gestational age estimates (David 1980; Gjessing et al. 1999). Although the clinical significance of small changes in gestational duration and

birth weight is unclear, the potential public health impact is considerable given widespread exposure to DBPs.

The modest effects that were detected reinforce the need for adequate control of confounding in environmental epidemiologic studies. Because of the comprehensive birth certificate data in Massachusetts, we were able to adjust for many potential confounders previously not considered. Moreover, nonparametric smoothing of confounders allowed for better control of established maternal risk factors for fetal growth retardation. Gestational age was a strong predictor of birth weight, but it is unclear whether gestational age is an intermediate in the causal pathway of DBPs and birth weight. Because bias may be introduced by adjusting for a causal intermediate (Rothman and Greenland 1998), we did not include gestational age in the final regression models. We had similar concerns regarding several maternal medical conditions including eclampsia, hydramnios, hypertension during pregnancy, and uterine bleeding, despite their being strong risk factors for infant birth

weight. Adjustment for these covariates had minimal effect on the results, so they were not included in the final regression models.

The main limitation of our study is the potential for exposure misclassification, because we relied on town average data to estimate individual exposures. Although we were unable to assess within-town variability because of the use of the aggregate exposure measures, between-town variability accounts for most of the total variation in DBP concentrations (Keegan et al. 2001). Interindividual variability in water use (e.g., showering, water consumption) is an important determinant of overall DBP exposure. Incorporating individual information such as water consumption rates should limit the amount of exposure misclassification, but previous studies have reported equivocal findings compared with the use of town average exposure measures (Klotz and Pyrch 1999; Savitz et al. 1995; Waller et al. 1998). The lack of information on maternal water use limited our ability to assess the impact of specific routes of exposure. Although inhalation and dermal absorption

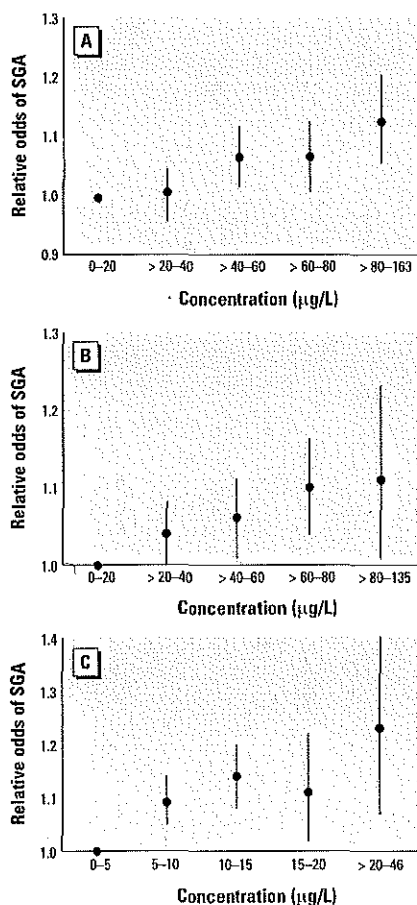


Figure 2. ORs and 95% CIs for SGA infancy and third-trimester THM exposures: ORs for (A) TTHM, (B) chloroform, and (C) BDCM adjusted for median household income, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, previous infant weighing $\geq 4,000$ g, previous preterm delivery, and maternal medical history (diabetes, chronic hypertension, lung disease, and renal disease).

Table 4. Adjusted ORs and 95% CIs for SGA and preterm delivery by third-trimester DBP and mutagenicity exposure.^a

Exposure	SGA ^{b,c} OR (95% CI)	Preterm delivery ^d OR (95% CI)
THMs (µg/L)		
TTHM		
0–33	1.0	1.0
> 33–74	1.06 (1.02 to 1.10)	0.95 (0.91 to 0.99)
> 74–163	1.13 (1.07 to 1.20)	0.88 (0.81 to 0.94)
Chloroform		
0–26	1.0	1.0
> 26–63	1.05 (1.02 to 1.09)	0.95 (0.91 to 0.99)
> 63–135	1.11 (1.04 to 1.17)	0.90 (0.84 to 0.97)
BDCM		
0–5	1.0	1.0
> 5–13	1.1 (1.07 to 1.14)	0.89 (0.85 to 0.93)
> 13–46	1.15 (1.08 to 1.22)	0.92 (0.85 to 0.99)
HAAs (µg/L)^e		
Total HAAs		
4–30	1.0	1.0
> 30–49	0.90 (0.81 to 1.01)	0.95 (0.83 to 1.10)
> 49–58	0.97 (0.77 to 1.23)	1.03 (0.77 to 1.39)
Trichloroacetic acid		
0–18	1.0	1.0
> 18–27	0.87 (0.76 to 0.99)	0.91 (0.77 to 1.07)
> 27–37	0.95 (0.76 to 1.19)	1.07 (0.81 to 1.42)
Dichloroacetic acid		
2–15	1.0	1.0
> 15–22	0.86 (0.75 to 0.99)	0.85 (0.71 to 1.01)
> 22–24	0.90 (0.75 to 1.09)	0.99 (0.79 to 1.23)
MX (ng/L)^e		
4–20	1.0	1.0
> 20–46	0.97 (0.86 to 1.09)	1.03 (0.89 to 1.19)
> 46–80	1.14 (0.95 to 1.37)	0.87 (0.66 to 1.14)
Mutagenicity (rev/L)^e		
330–1,250	1.0	1.0
> 1,250–2,250	0.98 (0.87 to 1.11)	1.09 (0.94 to 1.27)
> 2,250–5,710	1.25 (1.04 to 1.51)	0.79 (0.59 to 1.05)

^aORs adjusted for median household income, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, previous infant weighing $\geq 4,000$ g, previous preterm delivery, and maternal medical history (diabetes, chronic hypertension, lung disease, and renal disease). ^bSGA defined as lowest 10% of birth weight per gestational age, sex, and race. ^cAmong term births only. ^dPreterm (< 37 gestational weeks) analyses adjusted for infant sex. ^e1997–1998 analyses adjusted for marital status and weight gain during pregnancy.

are important determinants of exposure to volatile DBPs such as THMs (Weisel and Jo 1996), mothers exposed to high THM levels via drinking water also likely receive high exposures from other routes. The contribution of dermal and inhalation exposures to overall dose is considered minimal for nonvolatile DBPs such as HAAs and MX (Xu et al. 2002).

Residential mobility can lead to additional misclassification of exposures that are based on maternal ZIP codes at time of birth. Although an estimated 20–25% of women move during pregnancy (Khouri et al. 1988; Shaw and Malcoe 1992; Speare et al. 1976), only 8% of mothers of infants with birth defects reported moving to a different county during pregnancy (Khouri et al. 1988). Klotz and Pyrch (1999) conducted a sensitivity analysis addressing the impact of residential mobility on risk of neural tube defects for DBP exposures during the first month of pregnancy. Slightly stronger associations were detected among mothers with known residences at conception compared with those with confirmed and unconfirmed residences. The impact of mobility may depend on the critical period of exposure, because women may be less likely to move late in pregnancy. Among women who moved during pregnancy, Schulman et al. (1993) reported that 40% chose to move during the first trimester. This suggests that misclassification due to residential mobility is less likely to influence third-trimester exposure estimates. Although exposure misclassification is present to some degree in our study, these errors are unlikely to be associated with the birth outcomes. Random exposure misclassification will typically bias effect estimates toward the null and may explain the modest effects that we observed.

THM concentration may be of limited value as a surrogate of DBP exposure because the degree of correlation with individual THMs and nonvolatile DBPs can vary dramatically by water system (King et al. 2000; Whitaker et al. 2003; Wright et al. 2002). We observed effects similar in magnitude for individual THMs such as chloroform and BDCM, although most of the water systems in our study had low levels of brominated THMs. The associations that we detected between mutagenicity with birth weight and risk of small for gestational age infancy suggest an effect of mutagenic compounds on fetal development. These associations are not likely attributable to HAAs or THMs, because these DBPs are not considered strong mutagens (Daniel et al. 1993; Rosenthal 1987). MX was strongly correlated with mutagenic activity ($r = 0.86$) in drinking water samples from Massachusetts (Wright et al. 2002), but adjustment for MX in the regression models did not substantially alter the effect of mutagenic activity on mean birth weight (data not shown). Mutagenicity may be a better indicator of the complex mixture of mutagenic

compounds present in drinking water than are traditional DBP surrogates, but additional research is needed to determine the correlation between mutagenicity and individual DBP concentrations.

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ORIGINAL ARTICLE

Effect of trihalomethane exposure on fetal development

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Aims: To examine the effect of trimester specific and pregnancy average total trihalomethane (TTHM) exposure on infant birth weight, low birth weight, and intrauterine growth retardation in term births, as well as gestational age and preterm delivery in all births.

Methods: Cross sectional analysis of 56 513 singleton infants born to residents of Massachusetts during 1990. City specific aggregate data were used to estimate maternal exposure to TTHM concentration; individual maternal information was used to adjust for confounding.

Results: Increased pregnancy average and second trimester TTHM exposure were associated with small for gestational age and reductions in birth weight after adjusting for potential confounding variables. Compared to ≤ 60 $\mu\text{g/l}$, pregnancy average TTHM exposure over 80 $\mu\text{g/l}$ was associated with a 32 g reduction in birth weight. There was a 23 g reduction in birth weight in infants born to mothers exposed to greater than 80 $\mu\text{g/l}$ TTHM during the second trimester. For each 20 $\mu\text{g/l}$ increase in TTHM, the estimated reduction in birth was 2.8 g for pregnancy average exposure and 2.6 g for second trimester exposure. An increased risk of small for gestational age births was found for pregnancy average (odds ratio (OR) 1.14; 95% CI 1.02 to 1.26) and second trimester (OR 1.13, 95% CI 1.03 to 1.24) TTHM levels greater than 80 $\mu\text{g/l}$. There was no evidence of an association between preterm delivery and increased TTHM levels, but there were slight increases in gestational duration associated with TTHM concentrations.

Conclusions: Maternal exposure to THMs may be associated with fetal growth retardation. Our findings are consistent with most previous work, although we generally found smaller effects of TTHMs on low birth weight and intrauterine growth retardation.

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Disinfection of drinking water results in the formation of numerous disinfection byproducts (DBPs). The trihalomethanes are typically the most prevalent class of DBPs found in treated water and include chloroform, bromodichloromethane, dibromochloromethane, and bromoform. Chloroform is the most abundant trihalomethane and was the first DBP to be identified as a carcinogen in animals.¹ Other DBPs reported to be carcinogenic in animal studies include the brominated trihalomethanes,²⁻³ haloacetic acids,⁴ haloacetonitriles,⁵ bromate,⁶ and 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX).⁷ Epidemiological studies provide further evidence,⁸⁻¹⁵ with the most consistent findings for bladder and rectal cancer.¹⁶ While most research on DBPs has focused on carcinogenic endpoints, reproductive effects have received recent attention.¹⁷⁻¹⁸

Birth defects have been reported in animals exposed to chloroform,¹⁹⁻²⁰ but chloroform is generally not considered a strong teratogen.²¹⁻²² Chloroform appears to have a subtle effect on fetal development, as growth retardation has been reported in mice exposed to chloroform.¹⁹⁻²² Chloroform may directly affect the health of the fetus, since transplacental migration has been shown to occur in humans.²³ There is little evidence of teratogenicity associated with the brominated THMs.²¹⁻²²

Epidemiological studies provide further evidence that exposure to increased levels of DBPs may be associated with adverse developmental effects. Mothers exposed to water with increased trihalomethane concentrations have been shown to be at greater risk for a variety of pregnancy related complications including birth defects, stillbirths, spontaneous abortions, and fetal growth retardation.¹⁷⁻¹⁸ Total trihalomethane (TTHM) has been the most common measure of DBP exposure in epidemiological studies (table 1). Two studies²⁴⁻²⁵ have shown that mothers with high TTHM exposures were 30% more likely to have low birth weight (<2500 g) infants compared to those with low TTHM exposures. Kramer and

colleagues²⁶ reported a similar effect (odds ratio (OR) 1.3; 95% confidence interval (CI) 0.8 to 2.2) for chloroform levels greater than 10 $\mu\text{g/l}$ (compared to non-detectable levels). Gallagher and colleagues²⁷ reported more than a twofold increase in risk of low birth weight (OR 2.1; 95% CI 1.0 to 4.8) following exposure to TTHMs >60 $\mu\text{g/l}$ (compared to ≤ 20 $\mu\text{g/l}$). This effect was more pronounced when restricted to term births (OR 5.9; 95% CI 2.0 to 17.0). Dodds and colleagues²⁸ found little evidence of an association (OR 1.04; 95% CI 0.92 to 1.18) between low birth weight and maternal TTHM exposure >100 $\mu\text{g/l}$ (compared to < 50 $\mu\text{g/l}$).

No associations between maternal TTHM exposure and very low birth weight (<1500 g)²⁷⁻³⁰ or preterm delivery²⁴⁻²⁵⁻³⁰ have been reported. The effect of DBPs on the frequency of small for gestational age (SGA) births has been examined less frequently. Bove²⁷ reported a 50% (OR 1.50; 95% CI 1.14 to 1.94) excess risk of SGA among mothers in the highest TTHM exposure group (>100 $\mu\text{g/l}$ compared to ≤ 20 $\mu\text{g/l}$) during pregnancy. Dodds and colleagues²⁸ did not detect as strong an association (OR 1.08; 95% CI 0.99 to 1.18) between SGA and increased third trimester TTHM exposure, while Kramer and colleagues²⁸ reported an independent effect of chloroform (OR 1.8; 95% CI 1.1 to 2.9) and bromodichloromethane (OR 1.7; 95% CI 0.9 to 2.9).

The effect of water source and treatment on adverse developmental outcomes has been evaluated in Massachusetts. Tuthill and colleagues³¹ found no effect of disinfection practice (chlorine dioxide versus chlorine) on birth defects, mean birth

Abbreviations: BDCM, bromodichloromethane; CHCl₃, chloroform; CI, confidence interval; DBP, disinfection byproducts; EPA, Environmental Protection Agency; IUGR, intrauterine growth retardation; LBW, low birth weight; MX, 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone; ND, non-detectable; OR, odds ratio; SGA, small for gestational age; TTHM, total trihalomethane

Main messages

- Maternal exposure to disinfection byproducts (total trihalomethanes) in tap water was associated with decreased birth weight and an increased risk of low birth weight and intrauterine growth retardation.
- The small effect estimates reinforce the importance of minimising bias due to confounding and exposure misclassification.
- The large sample size and detailed birth data allowed control for presumed confounding by gestational age, maternal demographics, smoking, prenatal care, and maternal reproductive and medical history.

weight, or prematurity (<37 gestational weeks), but did report an association between chlorine dioxide use and prematurity determined by physician assessment. Aschengrau and colleagues investigated the role of type of water supply¹² and type of disinfection¹³ on spontaneous abortions, stillbirths, congenital anomalies, and neonatal deaths in Massachusetts. They reported an excess risk of spontaneous abortions in mothers using surface water (OR 2.2; 95% CI 1.3 to 2.6) compared to ground water users. They also found a higher frequency of stillbirths among mothers using chlorinated surface water (OR 2.6; 95% CI 0.9 to 7.5) compared to those using chloraminated surface water. The authors could not evaluate the role of specific trihalomethane concentrations, since the study periods preceded routine DBP monitoring. In the present study, we evaluated the effect of maternal TTHM exposure on several indices of fetal development. Using data recorded in the Massachusetts birth registry, we were able to adjust for many important risk factors for adverse birth outcomes in a large study population.

METHODS

Study design

We conducted a cross sectional analysis of the relation between adverse birth outcomes and TTHMs in Massachusetts drinking water. We used a semi-individual study design,¹⁴ estimating maternal exposure to DBPs from city specific aggregate monitoring data while utilising individual information on potential confounding variables and the outcomes of interest. Data extracted from birth records and hospital worksheets during 1990 (n = 94 407) were supplied by the

Policy implications

- There were associations for TTHM levels above 80 µg/l, the current maximum contaminant level allowed in the USA.
- While the effect of DBPs on fetal growth retardation may be small in magnitude, this remains an important public health issue due to widespread exposure.
- Further research is needed to evaluate the effects of specific disinfection byproducts, including non-volatile compounds.

Massachusetts Department of Public Health. The study population included singleton infants born to residents of communities that routinely monitored trihalomethanes (n = 57 378). We restricted the analyses to infants between 22 and 45 gestational weeks weighing more than 200 g at birth (n = 56 513).

Birth data

Infant birth weight and gestational age were abstracted from birth records. The recorded gestational age was determined from maternal recall of the date of last menses. Prematurity was defined as less than 37 gestational weeks and low birth weight as less than 2500 g. Infants were considered small for gestational age if they were in the lowest 10th centile of birth weight for each gestational week stratified by infant gender and maternal race (African American versus all other races combined). Gender and race specific deciles were determined from the complete dataset of all births in Massachusetts during 1990. The dichotomous outcomes (low birth weight, small for gestational age, and preterm delivery) were not mutually exclusive. For example, an infant could be classified as both preterm and small for gestational age. Term normal weight infants (>37 gestational weeks and >2500 g) served as the comparison group when calculating exposure odds ratios in the logistic regression models.

Exposure data

Drinking water is supplied by local water systems in Massachusetts, although multiple towns may share a common source. Utilities that disinfect their water and serve populations greater than 10 000 are required to monitor trihalomethane concentrations every quarter. Some towns with historically low trihalomethane levels are only required to monitor DBPs annually. We abstracted trihalomethane data

Table 1 Odds ratios and 95% CI from previous studies of fetal development and trihalomethane (THM) exposure

Study	Odds ratio (95% CI)			THM (µg/l) exposure group	
	Low birth weight	SGA	Preterm delivery	Highest level	Reference
Dodds <i>et al</i> ¹⁰	1.04 (0.92 to 1.18)	1.08 (0.99 to 1.18)*	0.97 (0.87 to 1.09)	>100	<50
Bove <i>et al</i> ²⁵⁻²⁷	1.3 (1.1 to 1.5)		1.0 (0.9 to 1.1)	>80	≤20
		1.22 (1.07 to 1.40)†		80-100	≤20
	1.42 (1.22 to 1.65)‡	1.50 (1.14 to 1.94)‡		>100	≤20
Gallagher <i>et al</i> ²⁹	2.1 (1.0 to 4.8)§		1.0 (0.3 to 2.8)	>60	≤20
	5.9 (2.0 to 17.0)¶			>60	≤20
Savitz <i>et al</i> ⁴	1.5 (1.0 to 2.3)		1.2 (0.8 to 1.8)	63.4-82.7	40.8-63.3
	1.3 (0.8 to 2.1)		0.9 (0.6 to 1.5)	>82.8	40.8-63.3
Kramer <i>et al</i> ²⁸	1.3 (0.8 to 2.2)	1.8 (1.1 to 2.9)†	1.1 (0.7 to 1.6)	>10 CHCl ₃	ND
	1.0 (0.7 to 1.5)	1.7 (0.9 to 2.9)‡	1.0 (0.6 to 1.5)	>10 BDCM	ND

Abbreviations: CHCl₃, chloroform; ND, non-detectable; BDCM, bromodichloromethane.

*SGA defined as lowest 10% of birth weight for each gestational week.

†SGA defined as lowest 5% of birth weight for each gestational week.

‡50% CI.

§Estimate for elevated third trimester exposure among all births.

¶Estimate for elevated third trimester exposure among term births.

Table 2 Total trihalomethane ($\mu\text{g/l}$) data for 96 Massachusetts communities

Period	25th centile	Median	75th centile	90th centile
1989				
April-June	9.7	25.5	40.5	59.0
July-September	11.0	34.8	53.0	81.6
October-December	9.5	27.9	51.0	64.5
1990				
January-March	9.1	25.5	47.6	61.3
April-June	13.0	26.5	51.8	64.8
July-September	14.2	32.7	55.8	83.7
October-December	11.5	28.3	50.3	67.7

Table 3 Characteristics of singleton infants greater than 200 g and between 22 and 45 gestational weeks born in Massachusetts in 1990

	Study population	Preterm	SGA*	LBW*	Mean birth weight (g)*
Total births	56513	3173	5310	1325	3458
Maternal race					
Caucasian	42047 (74.4%)	5.0%	9.2%	2.2%	3503
African-American	6025 (10.7%)	11.6%	9.2%	4.9%	3310
Other	5907 (10.5%)	8.6%	13.6%	3.2%	3359
Asian	2428 (4.3%)	9.0%	17.3%	4.0%	3263
American Indian	106 (0.2%)	8.9%	16.3%	5.8%	3336
Maternal age (y)					
11-22	11024 (19.5%)	8.7%	14.0%	3.7%	3346
23-34	38456 (68.1%)	5.5%	9.1%	2.4%	3482
35-45	7033 (12.4%)	6.4%	8.7%	2.8%	3504
Maternal education					
9th grade or less	5192 (9.2%)	9.8%	16.2%	4.7%	3324
10th or 11th grade	5947 (10.5%)	10.1%	14.7%	4.5%	3333
High school graduate	18752 (33.2%)	6.5%	10.6%	3.0%	3443
At least 1 year of college	26622 (47.1%)	4.6%	7.4%	1.8%	3521
Maternal smoking					
0 cigarettes/day	44986 (79.6%)	5.7%	8.1%	2.0%	3502
1-5 cigarettes/day	2404 (4.3%)	8.2%	13.9%	4.8%	3338
6-10 cigarettes/day	4409 (7.8%)	8.4%	17.2%	5.6%	3287
11 or more cigarettes/day	4714 (8.3%)	8.6%	19.7%	6.1%	3259
Prenatal care (Kessner index)					
No prenatal care	320 (0.6%)	31.8%	28.0%	14.9%	3117
Inadequate	2115 (3.7%)	13.4%	15.6%	5.6%	3300
Intermediate	10142 (18.0%)	9.0%	12.8%	3.9%	3378
Adequate	43936 (77.7%)	5.1%	9.7%	2.2%	3485
Number of previous births					
0	25029 (44.3%)	6.4%	11.7%	3.1%	3414
1	17915 (31.7%)	5.2%	8.2%	2.1%	3498
2 or 3	11764 (20.8%)	6.5%	8.8%	2.5%	3493
4 or more	1774 (3.1%)	11.6%	11.2%	4.1%	3454
Infant gender					
Male	28904 (51.2%)	5.9%	10.0%	2.2%	3524
Female	27609 (48.9%)	6.5%	10.0%	3.2%	3390
Average TTHM ($\mu\text{g/l}$) during pregnancy					
0-60	44232 (78.3%)	6.2%	9.7%	2.7%	3463
>60-80	7588 (13.4%)	6.1%	10.2%	2.5%	3458
>80	4693 (8.3%)	6.2%	12.0%	2.9%	3416

Abbreviations: SGA, small for gestational age; LBW, low birth weight.

*Term births only.

(1987-93) from the Massachusetts Department of Environmental Protection records for 99 communities. Recorded trihalomethane concentrations were measured using gas chromatography (Environmental Protection Agency (EPA) Method 502.2) and gas chromatography/mass spectrometry (EPA Method 524.2).¹⁹ Trihalomethane samples were analysed at the Massachusetts state laboratory (William Wall Experimental Station) until the third quarter of 1990 and at individual Massachusetts or EPA certified laboratories thereafter.

Eighty nine of the 99 towns collected quarterly samples, while the remaining 10 collected annual measurements. Groundwater was the primary water source for the towns with

annual monitoring requirements. Groundwater that is not under the influence of surface water has minimal levels of organic matter and typically requires less disinfection than surface water. This results in fewer DBPs and limited seasonal fluctuations in communities which rely on groundwater.

Table 2 presents the quarterly TTHM concentrations in the study population. In communities with multiple sampling sites in the distribution system ($n = 64$), we calculated a quarterly average across locations to assign maternal exposure scores. Three of the original 99 towns were excluded from the study because of considerable missing data. Twenty eight of the remaining 96 communities were missing some quarterly TTHM measurements. We imputed data for the missing values

Table 4 The frequency of maternal exposure to total trihalomethane (TTHM) concentration during pregnancy

TTHM ($\mu\text{g/l}$)	First trimester	Second trimester	Third trimester	Pregnancy average
0-60	46366 (82%)	45746 (81%)	44556 (79%)	44232 (78%)
>60-80	5308 (9%)	5085 (9%)	5964 (11%)	7588 (13%)
>80	4339 (9%)	5682 (10%)	5721 (10%)	4693 (8%)

based on the city specific quarterly averages from data available from adjacent years (1987-93).

Exposure assessment

Maternal trihalomethane exposure was estimated from the average TTHM concentration for the town of residence. Maternal residence reported on birth certificates was assumed to be constant for the entire pregnancy. Towns with annual trihalomethane measurements were assumed to have constant levels throughout the year, therefore residents were assigned the annual value for each trimester. Trimester specific and pregnancy average exposures were assigned based on the month of birth. Third trimester TTHM exposure was determined from the current quarterly average if the infant was born in the second or third month of that quarter. If the infant was born in the first month of a quarter, the third trimester exposure was assigned the value from the previous quarter. First and second trimester exposures were determined from the two quarters preceding the third trimester designation. We calculated an average maternal pregnancy exposure from the trimester specific values. Premature infants less than 29 gestational weeks were not assigned a third trimester value, so pregnancy average scores were based on exposures during the first and second trimesters.

Data analysis

The Massachusetts birth data included individual information on numerous potential confounding variables. The following maternal risk factors were included in the regression models as dichotomous variables: diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, uterine bleeding, previous preterm delivery, and previous birth of an infant weighing greater than 4000 g. We also controlled for gestational age (cubic polynomial) in the birth weight analyses. Adequacy of prenatal care was determined by the Kessner Index, which incorporates gestational age, timing of the first prenatal visit, and total number of prenatal visits.³⁶ We included dummy variables for prenatal care (none, inadequate, intermediate, and adequate), maternal race (Caucasian, African American, Asian, Native American, and other) and parity (0, 1, 2 or 3, and 4 or more children). For maternal education, we included indicators for 9th grade or less, 10th grade, 11th grade, completion of high school, and completion of at least one year of college. The effect estimates (and standard errors) for 10th and 11th grade education were similar in the regression analyses, so we combined them to improve precision.

We relied on findings from a previous analysis to determine the best modelling approach for continuous maternal risk factors.³⁷ In that analysis, non-parametric smooth functions were used to model the potential non-linear dependence of birth weight on maternal age and smoking. The authors found an inverted U shaped relation of birth weight and maternal age, so we included a quadratic polynomial for maternal age in the regression models. They also found a strong inverse relation between smoking and infant birth weight. That relation became less steep with increasing cigarette use, so we grouped mothers into the following categories: non-smokers,

light smokers (1-5 cigarettes per day), moderate smokers (6-10 cigarettes per day), and heavy smokers (11 or more cigarettes per day).

Alcohol consumption is another important risk factor for adverse developmental outcomes.³⁸ The Massachusetts Department of Public Health had advised that the birth certificate data on maternal alcohol use were considered of poor quality and validity. Preliminary analyses indicated that alcohol was not associated with birth weight, so we did not include maternal alcohol consumption in the analyses. We merged 1990 US census data with the birth data to provide further adjustment of socioeconomic status. We adjusted for median household income by census tract for every county but Barnstable County. The Massachusetts Department of Public Health did not code the birth data by census tract for Barnstable County, so we adjusted for median household income based on mother's zip code of residence.

Statistical methods

Linear regression was used to evaluate the association between TTHMs and gestational age for all births and the association between TTHMs and birth weight for term births. We used logistic regression to estimate odds ratios and 95% confidence intervals for the dichotomous outcomes. Pearson correlation coefficients were used to describe the relation between different periods of exposure. All linear and logistic regression analyses were performed using SAS PC statistical software.

RESULTS

There were 1325 low birth weight, 5310 SGA, and 3173 premature infants in the study population (table 3). Fifty one per cent of the infants in the study were male. Seventy four per cent of the mothers were Caucasian and 11% were African American. Racial differences were evident, with a lower frequency of adverse developmental endpoints occurring among Caucasian infants. The average age of mothers in the study population was 28 years, with 68% of the pregnancies occurring between 23 and 34 years of age. Younger mothers (aged 11-22) were more likely to give birth to premature, small for gestational age and low birth weight infants. Other determinants of adverse reproductive outcomes controlled for in the analyses included infant gender, parity, adequacy of prenatal care, maternal education, and maternal cigarette use.

Table 4 presents trimester specific and pregnancy average TTHM exposures. On average, 80% of the study population resided in towns with TTHM concentrations of 60 $\mu\text{g/l}$ or less across the four exposure windows. Eight per cent of women had a pregnancy average TTHM exposure greater than 80 $\mu\text{g/l}$, with slightly higher frequencies for trimester specific exposures. Average TTHM exposure was 39 $\mu\text{g/l}$ during the first and second trimesters and 38 $\mu\text{g/l}$ during the third trimester. These exposure indices were correlated between successive trimesters ($r = 0.50$ to 0.66) and between the specific trimesters and the pregnancy average values ($r = 0.81$ to 0.91).

Birth weight

We observed associations between pregnancy average and trimester specific TTHM exposures and birth weight among term

Table 5 The effect of trimester specific and pregnancy average total trihalomethane (TTHM) exposure on birth weight among term births

TTHM ($\mu\text{g/l}$)	Δ Birth weight (g)			
	First trimester	Second trimester	Third trimester	Pregnancy average
Crude				
0-60	Reference	Reference	Reference	Reference
>60-80	-3 [-18 to 11]	-7 [-22 to 8]	-3 [-17 to 11]	-5 [-18 to 7]
>80	-21 [-36 to -6]	-29 [-43 to -15]	-22 [-36 to -8]	-47 [-62 to -31]
Per each 20 $\mu\text{g/l}$	-1.6 [-3.8 to 0.5]	-2.9 [-5.3 to -0.6]	-3.3 [-6.0 to -0.6]	-3.4 [-6.1 to -0.6]
p value	0.14	0.01	0.02	0.02
Adjusted*				
0-60	Reference	Reference	Reference	Reference
>60-80	-4 [-18 to 9]	-5 [-19 to 9]	-9 [-22 to 4]	-1 [-12 to 11]
>80	-17 [-31 to -3]	-23 [-36 to -10]	-11 [-24 to 2]	-32 [-47 to -18]
Per each 20 $\mu\text{g/l}$	-1.8 [-3.8 to 0.2]	-2.6 [-4.8 to -0.4]	-1.8 [-4.4 to 0.8]	-2.8 [-5.5 to -0.2]
p value	0.08	0.02	0.17	0.03

*Regression coefficients adjusted for gestational age, infant gender, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, median household income, previous infant weighing 4000 g or more, previous preterm delivery, and maternal medical history (diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, and uterine bleeding).

Table 6 Crude and adjusted odds ratios and 95% CI of low birth weight for trimester specific and pregnancy average total trihalomethane (TTHM) exposure among term births

TTHM ($\mu\text{g/l}$)	Low birth weight			
	First trimester	Second trimester	Third trimester	Pregnancy average
Crude OR (95% CI)				
0-60	1.0	1.0	1.0	1.0
>60-80	1.06 [0.89 to 1.28]	0.87 [0.71 to 1.07]	0.97 [0.81 to 1.16]	0.91 [0.77 to 1.08]
>80	0.93 [0.75 to 1.13]	1.09 [0.92 to 1.30]	1.11 [0.93 to 1.32]	1.08 [0.89 to 1.31]
Adjusted OR (95% CI)*				
0-60	1.0	1.0	1.0	1.0
>60-80	1.13 [0.93 to 1.38]	0.93 [0.75 to 1.15]	1.08 [0.90 to 1.31]	0.97 [0.81 to 1.26]
>80	0.98 [0.79 to 1.21]	1.14 [0.95 to 1.38]	1.09 [0.91 to 1.31]	1.05 [0.85 to 1.29]

*Odds ratios adjusted for gestational age, infant gender, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, median household income, previous infant weighing 4000 g or more, previous preterm delivery, and maternal medical history (diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, and uterine bleeding).

Table 7 Crude and adjusted relative risks of small for gestational age for trimester specific and pregnancy average total trihalomethane (TTHM) exposure among term births

TTHM ($\mu\text{g/l}$)	Small for gestational age			
	First trimester	Second trimester	Third trimester	Pregnancy average
Crude OR (95% CI)				
0-60	1.0	1.0	1.0	1.0
>60-80	1.06 [0.97 to 1.17]	1.05 [0.95 to 1.16]	1.03 [0.94 to 1.13]	1.06 [0.98 to 1.15]
>80	1.11 [1.09 to 1.23]	1.20 [1.10 to 1.31]	1.09 [1.05 to 1.26]	1.27 [1.15 to 1.40]
Adjusted OR (95% CI)*				
0-60	1.0	1.0	1.0	1.0
>60-80	1.00 [0.89 to 1.10]	0.99 [0.89 to 1.10]	0.98 [0.89 to 1.09]	1.00 [0.92 to 1.09]
>80	1.09 [0.98 to 1.21]	1.13 [1.03 to 1.24]	1.03 [0.94 to 1.14]	1.14 [1.02 to 1.26]

*Odds ratios adjusted for adequacy of prenatal care, maternal education, maternal smoking, maternal age, parity, median household income, previous infant weighing 4000 g or more, previous preterm delivery, and maternal medical history (diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, and uterine bleeding).

births (table 5). After adjusting for gestational age and other covariates, a 2.8 g (95% CI -5.5 to -0.2) decrease in birth weight was observed for every 20 $\mu\text{g/l}$ increase in pregnancy average TTHM exposure. A similar effect was observed for second trimester TTHM exposure (-2.6 g; 95% CI -4.8 to -0.4 per 20 $\mu\text{g/l}$). Compared to the reference group (≤ 60 $\mu\text{g/l}$ TTHM), we found a 32 g (95% CI -47 to -18) reduction in birth weight among infants whose mothers had pregnancy average exposures greater than 80 $\mu\text{g/l}$. Mothers in the highest

exposure group during the second trimester had infants that weighed 23 g (95% CI -36 to -10) less than the comparison group.

Low birth weight

No consistent associations were detected for TTHM exposure and low birth weight among term births (table 6). Increased risks were detected for intermediate first trimester (OR 1.13; 95% CI 0.93 to 1.38) and high second trimester exposures (OR

Table 8 The effect of trimester specific and pregnancy average total trihalomethane (TTHM) exposure on gestational age among all births

TTHM ($\mu\text{g/l}$)	Δ Gestational age (weeks)			
	First trimester	Second trimester	Third trimester	Pregnancy average
Crude				
0-60	Reference	Reference	Reference	Reference
>60-80	0.05 [-0.01 to 0.11]	0.06 [0.00 to 0.13]	0.05 [0.00 to 0.10]	0.07 [0.02 to 0.12]
>80	0.00 [-0.07 to 0.06]	0.08 [0.02 to 0.14]	0.07 [0.02 to 0.13]	0.07 [0.03 to 0.11]
Per each 20 $\mu\text{g/l}$	0.02 [0.01 to 0.03]	0.03 [0.02 to 0.04]	0.02 [0.01 to 0.03]	0.02 [0.01 to 0.02]
p value	0.001	<0.0001	<0.0001	0.003
Adjusted*				
0-60	Reference	Reference	Reference	Reference
>60-80	0.02 [-0.04 to 0.09]	0.06 [0.00 to 0.13]	0.04 [-0.02 to 0.09]	0.04 [-0.01 to 0.09]
>80	-0.02 [-0.09 to 0.04]	0.09 [0.02 to 0.15]	0.05 [0.00 to 0.11]	0.08 [0.01 to 0.14]
Per each 20 $\mu\text{g/l}$	0.01 [0.00 to 0.02]	0.02 [0.01 to 0.03]	0.01 [0.00 to 0.02]	0.02 [0.01 to 0.03]
p value	0.07	<0.0001	0.008	0.003

*Regression coefficients adjusted for infant gender, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, median household income, previous infant weighing 4000 g or more, previous preterm delivery, and maternal medical history (diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, and uterine bleeding).

Table 9 Crude and adjusted odds ratios and 95% CI of preterm delivery for trimester specific and pregnancy average total trihalomethane (TTHM) exposure among all births

TTHM ($\mu\text{g/l}$)	Preterm delivery			
	First trimester	Second trimester	Third trimester	Pregnancy average
Crude OR [95% CI]				
0-60	1.0	1.0	1.0	1.0
>60-80	0.97 [0.86 to 1.10]	1.03 [0.91 to 1.17]	1.00 [0.88 to 1.13]	0.90 [0.80 to 1.01]
>80	1.00 [0.88 to 1.13]	0.92 [0.81 to 1.04]	1.01 [0.89 to 1.14]	0.93 [0.85 to 1.01]
Adjusted OR [95% CI]*				
0-60	1.0	1.0	1.0	1.0
>60-80	0.96 [0.84 to 1.10]	1.02 [0.89 to 1.16]	0.99 [0.87 to 1.13]	1.00 [0.89 to 1.12]
>80	1.01 [0.88 to 1.16]	0.90 [0.79 to 1.03]	0.97 [0.85 to 1.11]	0.90 [0.77 to 1.04]

*Odds ratios adjusted for infant gender, adequacy of prenatal care, maternal race, maternal education, maternal smoking, maternal age, parity, median household income, previous infant weighing 4000 g or more, previous preterm delivery, and maternal medical history (diabetes, eclampsia, hydramnios, chronic hypertension, hypertension during pregnancy, incompetent cervix, lung disease, renal disease, and uterine bleeding).

1.14; 95% CI 0.95 to 1.38). Similar effects were observed for intermediate and high third trimester TTHM exposures.

Small for gestational age

We found a higher frequency of SGA births among mothers with pregnancy average TTHM exposures greater than 80 $\mu\text{g/l}$ (OR 1.14; 95% CI 1.02 to 1.26) compared to the reference group (table 7). Increased risk of SGA was also detected for first (OR 1.09; 95% CI 0.98 to 1.21) and second (OR 1.13; 95% CI 1.03 to 1.24) trimester TTHM exposures.

Gestational duration

We observed small increases in gestational age per 20 $\mu\text{g/l}$ TTHM during the entire pregnancy and for each trimester (table 8). Statistically significant associations were detected for mothers in the highest TTHM exposure group (>80 $\mu\text{g/l}$) during the second trimester (0.09 gestational weeks; 95% CI 0.02 to 0.15) and over the entire pregnancy (0.08 gestational weeks; 95% CI 0.01 to 0.14). There was little evidence of an association between TTHM exposure and preterm delivery. In fact, the data indicate that mothers with higher exposures during the second trimester (OR 0.90; 95% CI 0.79 to 1.03) and the entire pregnancy (OR 0.90; 95% CI 0.77 to 1.04) were less likely to deliver prematurely (table 9).

DISCUSSION

Our findings indicate that exposure to high trihalomethane levels during pregnancy is associated with reductions in birth

weight among term births. After adjusting for gestational age and other covariates, we observed reductions of 2.8 g for each 20 $\mu\text{g/l}$ increase in pregnancy average TTHM concentration and 2.6 g for each 20 $\mu\text{g/l}$ increase in second trimester TTHM concentration (table 5). Maternal exposure to increased TTHMs (>80 $\mu\text{g/l}$) was associated with lower birth weight when compared to the reference group (≤ 60 $\mu\text{g/l}$). The largest effects were observed for pregnancy average (-32 g; 95% CI -47 to -18) and second trimester (-23 g; 95% CI -36 to -10) exposures. Bove²⁷ was the only investigator to examine the effect of TTHM on birth weight as a continuous measure, reporting a 70 g (95% CI -106 to -35) decrease in birth weight for each 100 $\mu\text{g/l}$ increase in TTHM. This is considerably larger than the pregnancy average estimate from this study, which would have predicted a 14 g decrease if extrapolated to 100 $\mu\text{g/l}$. However, birth weight deficits were only found in the highest exposure category, suggesting a non-linear response in our data.

Overall, we found weaker associations between TTHMs and adverse developmental outcomes than previously reported. Our data indicate that exposure to TTHMs may shift the birth weight distribution downward among term births without significantly impacting the prevalence of low birth weight infancy. We found a small increased risk for term low birth weight among mothers with increased second trimester TTHM exposures (OR 1.14; 95% CI 0.95 to 1.38). In contrast to findings from Gallagher and colleagues,²⁹ we found a similar effect of TTHM on low birth weight among all births (data not presented).

Since low birth weight is a function of fetal growth rate and gestational duration, we evaluated the impact of TTHM on both small for gestational age and premature infants. We observed an increased risk of SGA among mothers with high second trimester (OR 1.13; 95% CI 1.03 to 1.24) and pregnancy average (OR 1.14; 95% CI 1.02 to 1.26) TTHM exposures. These relative risks are similar in magnitude to the study by Dodds and colleagues,³⁰ but are substantially smaller than reports by Kramer and colleagues²⁸ and Bove.³⁷ Consistent with other studies, we did not detect an association between TTHM exposure and preterm delivery. Therefore, DBPs do not appear to adversely impact length of gestation. In fact, our data indicate that TTHMs are associated with small increases in gestational duration. The clinical significance of such a small increase in gestational duration is unclear, especially given the poor precision of gestational age estimates.³⁹

The third trimester is considered the most critical period of exposure for a developing fetus. While fetal growth tends to peak between 43 and 44 weeks, second trimester exposures may be important as well. Ninety five per cent of fetal growth occurs after the 20th gestational week,⁴⁰ with increases in fetal growth rate beginning after 34 gestational weeks.⁴¹ Compared to the third trimester, we saw slightly stronger effects of second trimester TTHM exposure on fetal growth indices. Our estimates of maternal exposure between successive trimesters are highly correlated ($r = 0.50$ to 0.65), so we may not be able to differentiate the effect of DBPs between the different trimesters.

One of the strengths of our study was the comprehensive information on individual pregnancy risk factors available from birth records and hospital worksheets. The large study population allowed us to control for important maternal risk factors not considered in previous studies. Confounding by gestational age and other maternal risk factors had the largest impact on the association of TTHMs and birth weight (tables 5–9) but did not have much of an effect on the relation between TTHMs and the other outcomes. Nevertheless, the potential for residual confounding remains, since we were not able to control for other reproductive risk factors (marital status, weight gain during pregnancy, maternal nutrition, alcohol use, etc). These risk factors would have to be associated with TTHMs as well as the reproductive outcomes to be confounders.

A potential limitation of our study is exposure misclassification, since we relied on the address of residence at time of birth to assign exposure status. Previous reports indicate that a considerable number of women move during pregnancy (10–37%).³⁸ An additional limitation of our study is the inability to distinguish the impact of specific routes of exposure (ingestion, inhalation, and dermal absorption) to volatile compounds such as the trihalomethanes.⁴² Although the findings are inconsistent, a few studies have been able to evaluate the impact of water consumption⁴³ and showering.⁴⁴ While these sources of exposures are important, any resulting misclassification errors in our study are likely to be independent of the outcome measures. Non-differential exposure misclassification typically biases effect estimates towards the null, which may explain the smaller relative risks in this study compared to previous reports. Despite the potential for non-differential misclassification, the aggregate measures of exposure should reflect the gross temporal and spatial differences in the exposure experience of our study population.

Variability in DBP formation has been noted in distribution systems given adequate chlorine residual. Trihalomethanes can increase further out in the distribution system, with more variation observed in the brominated compounds (compared to chloroform).⁴⁵ In contrast, haloacetic acids may undergo biological degradation since maximum values have been found at the closest sampling locations.⁴⁶ Understanding these relations is important for exposure assessment strategies that rely on limited DBP monitoring data. While we were able to capture some of the temporal variability associated with DBP

formation through the use of routinely monitored exposure data, our inability to account for spatial variability may also result in misclassification. Gallagher and colleagues³⁹ were able to address seasonal and spatial variation in trihalomethane concentrations by using specific sampling dates and incorporating hydraulic characteristics in a computer simulation model of residential exposures. They reported the largest relative risk for low birth weight (OR 2.1; 95% CI 1.0 to 4.8) and term low birth weight (OR 5.9; 95% CI 2.0 to 17.0) despite low TTHM concentrations.

Only one study has explored the role of other DBPs on adverse reproductive outcomes. Klotz and colleagues⁴⁶ reported an OR of 1.2 (95% CI 0.5 to 2.6) for total haloacetic acids >35 $\mu\text{g/l}$ compared to <3 $\mu\text{g/l}$ and an OR of 1.3 (95% CI 0.6 to 2.5) for haloacetonitriles >3.0 $\mu\text{g/l}$ compared to <0.5 $\mu\text{g/l}$. Kramer and colleagues²⁸ reported an 80% (OR 1.8; 95% CI 0.9 to 3.4) increased risk of SGA for exposure to total organic halides >100 $\mu\text{g/l}$. Total organic halides were highly correlated with trihalomethane concentrations, so the authors were not able to determine the independent effect of each DBP marker. More research is needed to identify the specific compounds that DBP surrogates represent. If TTHM concentration (or another surrogate marker) is a poor proxy for specific DBPs, even the most elaborate exposure modelling will not be able to fully elucidate the potentially harmful effects of DBPs on fetal development. Our results add to the body of literature indicating that there are such effects, but further research is needed to better delineate them.

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Exposure to Brominated Trihalomethanes in Water During Pregnancy and Micronuclei Frequency in Maternal and Cord Blood Lymphocytes

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BACKGROUND: Water disinfection by-products have been associated with an increased cancer risk. Micronuclei (MN) frequency in lymphocytes is a marker of genomic damage and can predict adult cancer risk.

OBJECTIVE: We evaluated maternal exposure to drinking water brominated trihalomethanes (BTHM) in relation to MN frequency in maternal and cord blood lymphocytes.

METHODS: MN frequency was examined in 214 mothers and 223 newborns from the Rhea mother-child cohort in Crete, Greece, in 2007–2008. Residential BTHM water concentrations were estimated during pregnancy using tap water analyses and modeling. Questionnaires on water related habits were used to estimate BTHM exposure from all routes. Associations between BTHM and MN frequency were estimated using negative binomial regression.

RESULTS: BTHM concentrations in residential tap water during pregnancy ranged from 0.06 to 7.1 µg/L. MN frequency in maternal binucleated lymphocytes was found to increase with BTHM concentrations in residential water for exposure during the first [rate ratio (RR) for 1 µg/L = 1.05; 95% CI: 1.00, 1.11] and second trimesters (RR for 1 µg/L = 1.03; 95% CI: 1.00, 1.06), and through all routes of BTHM exposure during the first trimester (RR for 1 µg/week = 3.14; 95% CI: 1.16, 8.50).

CONCLUSIONS: These findings suggest that exposure to BTHM may increase the frequency of MN in maternal binucleated lymphocytes.

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Introduction

Disinfection of water reduces pathogenic infection; however, water disinfectants also react with organic materials to generate disinfection by-products (DBP). Several hundred DBPs have been identified. Trihalomethanes (THM) are one of the most frequent classes of DBP detected in residential water (Richardson et al. 2007).

Several DBP compounds, such as brominated THM (BTHM), are carcinogenic in rodents and are mutagenic in several tests [International Agency for Research on Cancer (IARC) 2004; Richardson et al. 2007]. There is epidemiologic evidence of an association between bladder cancer and exposure to DBP from residential water (Villanueva et al. 2004) and from bathing, showering, or swimming (Villanueva et al. 2006).

Micronuclei (MN) frequency is a well-established biomarker of DNA damage (Fenech 2007). MN frequency in peripheral blood lymphocytes has been associated in a large prospective study with an increased risk of cancer among adults (Bonassi et al. 2011).

The frequency of MN has been reported to increase in exfoliated urine cells with THM exposures (Villanueva et al. 2006). BTHM concentrations in exhaled breath have been associated with an increased frequency of MN in lymphocytes and increased urinary mutagenicity in adults swimming in indoor pools (Kogevinas et al. 2010).

Little is known about potential mutagenic or carcinogenic effects of *in utero* exposures to DBP. The fetus may be more susceptible to environmental mutagens and carcinogens (Wild and Kleinjans 2003), and certain cancers may have a fetal origin (Gluckman et al. 2008). With this in mind, we assessed the potential associations between exposure to BTHM during pregnancy and MN frequency in maternal and cord blood lymphocytes.

Methods

Study population. This study includes mothers and newborns from the island of Crete, Greece, who were part of the Rhea cohort (Chatzi et al. 2009; Patelarou et al. 2011). Women who became pregnant during

February 2007–February 2008 were asked to participate in the study. The first contact with potential participants was made at around 10–13 weeks of pregnancy, at the time of the first ultrasound examination. Women were invited to provide blood and urine samples and complete face-to-face interviews if they were residents of the study area, > 16 years of age, visiting a participating hospital or private clinic during the 10th–13th week of gestation, and did not have communication limitations. Participating women were contacted again during the 14th–18th and 28th–32nd weeks of pregnancy and at birth. During recruitment, 1,610 eligible women agreed to participate, and 1,459 (91%) were followed through delivery. A subset of 408 participants donated maternal and/or cord blood for biomarker measurements as part of the NewGeneris study (Merlo et al. 2009). A total of 214 mothers and 223 newborns with MN analysis of maternal and cord blood lymphocytes from singleton pregnancies were included in this study. Of these, 162 were mother-child pairs.

A comparison of those who did and did not participate in the current study revealed

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a small but significantly lower percentage of Greek women among those who participated in the study (87%) than among those who did not (92%). Otherwise the groups were very similar with regard to the study covariates (data not shown). Questionnaires elicited information on maternal characteristics including ethnicity, age, prepregnancy body mass index (BMI), parity (none or ≥ 1), smoking, secondhand tobacco smoke (SHS), supplement use, education, and water-related habits during pregnancy (Patelarou et al. 2011). A food frequency questionnaire was used to assess dietary habits and adherence to a Mediterranean diet (Chatzi et al. 2012). Information on diabetes, gestational hypertension, and anthropometric measurements at birth was obtained from medical records. Gestational age was based on the interval between the last menstrual period and the date of delivery for 84% of the women. When the last menstrual estimate was inconsistent by ≥ 7 days with the ultrasound measurement taken in the first trimester of pregnancy (16%), a quadratic regression formula describing the relation between crown-rump length and gestational age was used (Westerway et al. 2000).

The Ethics Committee of the University Hospital in Heraklion, Crete, Greece, approved the study. All participants provided written, informed consent for themselves and their child after having received a complete description of the study.

DBP exposure assessment. As part of the European project HIWATE (Health Impacts of long-term exposure to disinfection byproducts in drinking Water), residential and maternal exposure to DBP during pregnancy was estimated using standardized methods (Nieuwenhuijsen et al. 2009; Patelarou et al. 2011). Briefly, on the basis of information provided by the water company that supplies Heraklion, the city was divided into six zones according to the source of underground water used in each area that corresponded to the six water treatment plants supplying water. In total, 18 sampling points were selected (12 areas in Heraklion and 6 in rural areas), which covered geographically the residences of participating women. One household in each of the 18 areas, which was randomly selected, was visited four times at home to collect tap water samples between the months of September 2007 and January 2009 (72 tap water samples in total). Samples were analyzed by gas chromatography/mass spectrometry for the four specific THMs: chloroform, bromoform, bromodichloromethane, and dibromochloromethane. BTHM constituted $> 80\%$ of the total THM (Patelarou et al. 2011), so we decided to concentrate this analysis on exposures to BTHM. Residential addresses were assigned to a water supply

zone based on the maternal address early in pregnancy. BTHM concentrations in residential water were estimated based on the residential water supply zone, and individual residential concentrations of BTHM (micrograms per liter of residential water) were predicted using generalized additive models for each month of pregnancy.

Average residential water BTHM concentrations were calculated for the entire pregnancy and for each trimester for both mothers and newborns. BTHM concentrations were assumed to be uniform within the water supply zones, so the potential spatial variation of BTHM concentrations within the water systems was not considered in the analysis. However, the areas covered by these systems were small, and little variation within the systems was expected (Symanski et al. 2004).

Information on maternal water usage habits during pregnancy was combined with estimated residential water concentrations to estimate maternal and prenatal BTHM exposures through all routes, including ingestion, dermal absorption, and inhalation (micrograms per week) (Patelarou et al. 2011).

MN frequency in maternal and cord blood lymphocytes. Maternal peripheral blood was collected by venipuncture 1 day after delivery, and cord blood was collected by umbilical puncture from the placenta immediately after delivery (Merlo et al. 2009). The blood for the cytokinesis-block micronuclei assay was kept in heparin tubes at 4°C . Whole-blood cultures with phytohemagglutinin (PHA) stimulation were initiated within 24 hr after collection (Vande Loock et al. 2011). After 44 hr of incubation, cytochalasin B was added to the cultures to block the cell division and enable scoring of binucleated (BN; i.e., cells that have divided once, having two nuclei) lymphocytes. At 72 hr following PHA stimulation, the cultures were harvested. A hypotonic treatment was used to remove the red blood cells; cells were fixed in freshly prepared methanol-acetic acid, and cell suspensions were dropped onto clean slides. Slides were stained and were examined in the Laboratory of Cell Genetics, Vrije Universiteit Brussel.

A semi-automated scoring procedure of the lymphocytes was carried out, using the PathFinder platform installed by Imstar (version 6; Paris, France). At the end of the automatic screening, lymphocytes containing detected MN were visually evaluated. After validation, the total numbers of BN and mononucleated (MONO) lymphocytes with MN, and the total number of lymphocytes counted for each participant, were recorded. The cytokinesis-block proliferation index (CBPI) for each participant was calculated as follows: $\text{CBPI} = (\text{number of MONO} + 2 \times \text{number of BN} + 3 \times \text{number}$

of polynucleated lymphocytes)/total number of lymphocytes counted (Decordier et al. 2009). The design of the MN protocol aims at maximizing the number of BN lymphocytes, which results on average in a CBPI of 2. Lower CBPI frequencies reflect cell cycle delay due to toxicity or cell immaturity, and higher CBPI frequencies result from excessive mitogenic activation.

Statistical analyses. Descriptive analyses of the study population characteristics, exposures, and outcomes were conducted. Negative binomial regression was used to model the MN counts using the GLM (generalized linear models) procedure in STATA 11.0 and 13.0 (StataCorp, College Station, TX, USA). A natural log link was used, and the model included the number of either BN or MONO cells as an offset to control for the number of lymphocytes counted. We also evaluated Poisson regression as an alternative to negative binomial regression, but the latter provided a better fit to the data (data not shown). MN frequencies in maternal BN and MONO, and cord blood BN and MONO, were evaluated as outcomes using separate models to estimate associations of each outcome with BTHM concentrations in residential water (micrograms per liter; categorized into quartiles), and BTHM exposures through all routes (micrograms per week and as quartiles), for each trimester and for the entire pregnancy. In addition, we used separate models to estimate associations of the outcomes with maternal water habits during early pregnancy, including bathing and showering [evaluated separately according to frequency (times per week), duration (minutes), or frequency $\times$ duration (minutes/week); and as shower only, bath only, or both], use of a swimming pool during pregnancy (any or none), hand dishwashing only (vs. any use of a dishwashing machine), and type of drinking water consumed (public, bottled, or spring water). Models were also fitted to evaluate the possible effect of clustering by the water systems by including a random effect for water systems using the VCE (variance covariance estimation) option in the STATA GLM procedure.

Covariates for control of potential confounding included a set of variables that were believed *a priori* to be determinants of MN. For mothers, the models included maternal age at birth (years), smoking during pregnancy (nonsmoker/ex-smoker/active smoker), workplace and home exposure to SHS (no/yes), residence in an urban area (no/yes), education (low: ≤ 9 years education; medium: 10–14 years education; high: university degree or higher), and ethnicity (Greek/non-Greek). For newborns, the same covariates were included, except that gestational age (weeks) was substituted for

maternal age. Nonsmokers reported not smoking at any time for at least 3 months before pregnancy or during pregnancy; ex-smokers reported smoking sometime within the 3 months before pregnancy and/or during the first 12 weeks of gestation, but not after then; and active smokers reported smoking 3 months before pregnancy and at approximately 12 weeks of gestation (the time of interview). In addition, potential confounding by prepregnancy maternal BMI (kilograms per meter squared), prior births (yes/no), Mediterranean diet (low, moderate, high), use of dietary supplements (yes/no),

diabetes (yes/no), gestational hypertension (yes/no), and small for gestational age (yes/no) was evaluated by fitting models with and without these covariates and monitoring changes in the regression coefficient of the exposure variables. Statistical testing and 95% CIs were estimated using robust standard errors. Restricted cubic spline models with 3 knots were fitted based on Harrell's recommended percentiles to evaluate the linearity of associations. Statistical interactions between the exposure variables and all of the covariates were assessed by fitting models with cross-product terms and testing their significance

using a Wald test. The cross-product terms corresponding to categorical covariates with > 2 levels were tested as a group. Any interactions that were found to be statistically significant at the $p < 0.05$ level were included in the models.

The inclusion of numerous potential confounders in the analysis resulted in a large amount of missing data. To increase efficiency and reduce selection bias, we applied multiple imputation methods. The imputation used all the available information on the individual characteristics of the entire study population and included all individuals who had MN data for either the mother or the child. To make the missing-at-random (MAR) assumption more plausible, we included many variables in the imputation model and used the chained equations procedure (White et al. 2011) under the MAR assumption. Categorical variables were modeled using logistic or ordinal models; non-normally distributed variables were log-transformed or imputed using predictive mean matching. All of the covariates were included in the model. We generated 30 complete data sets that were analyzed individually to obtain a set of parameters and then combined into overall estimates using Rubin's rule (Rubin 1987).

Results

Study population characteristics. A summary of the variables used in the analysis for the combined population ($n = 240$) of mothers and newborns with complete MN and BTHM information for all and stratified by quartiles of BTHM exposure averaged over the pregnancy is presented in Table 1. Most of the mothers were Greek (86%) and ≤ 35 years of age (88%). Most mothers did not smoke during pregnancy (61%), but were exposed to SHS either at home or work (89%), had moderate education (53%), and lived in urban areas (72%). Most women drank bottled water (73%) and only used showers (vs. baths) (95%) during pregnancy. Six percent of the children were born before 37 weeks of gestation. The mean ($\pm$ SD) gestational age was 38.4 ± 1.3 weeks, and mean birth weight was $3,225 \pm 412$ g.

All of the study covariates had missing data for some participants except sex and gestational age. The percentage of missing values ranged from 0.4% (delivery mode) to 31% (Mediterranean diet). The percentage of participants missing data for at least one of the final model covariates was 3%.

Maternal residence in an urban area ($p < 0.001$), and drinking-water source ($p < 0.001$) were the only covariates that were significantly associated with BTHM (Table 1). The percentage of women who were in the highest quartile of BTHM was higher for those living in an urban area (27%) than those

Table 1. Study population characteristics [n (%)]^a for all and by quartiles of the residential exposure to brominated trihalomethanes during the full pregnancy.^b

Characteristic	All ($n = 240$)	Quartile 1	Quartile 2	Quartile 3	Quartile 4	p -Value ^c
Ethnicity						0.82
Greek	205 (86.3)	60 (88.2)	43 (84.3)	50 (83.3)	30 (88.1)	
Other	33 (13.9)	8 (11.8)	8 (15.7)	10 (16.7)	7 (11.9)	
Missing	2	1	0	0	1	
Maternal age (years)						0.24
≤ 35	210 (87.8)	65 (94.2)	44 (88.0)	50 (83.3)	51 (85.0)	
> 35	29 (12.1)	4 (5.8)	6 (12.0)	10 (16.7)	9 (15.0)	
Missing	1	0	1	0	0	
Maternal smoking						0.06
Nonsmokers	145 (61.2)	45 (65.2)	33 (68.9)	28 (46.7)	39 (65.0)	
Ex-smokers	44 (18.6)	16 (23.2)	5 (10.4)	14 (23.3)	9 (15.0)	
Active smokers	48 (20.2)	8 (11.6)	10 (20.8)	18 (30.0)	12 (20.0)	
Missing	3	0	3	0	3	
SHS ^d						0.42
Not exposed	26 (10.9)	5 (7.3)	5 (10.0)	6 (10.0)	10 (16.7)	
Exposed	213 (89.1)	64 (92.8)	45 (90.0)	54 (90.0)	50 (83.3)	
Missing	1	0	1	0	0	
Maternal education						0.68
Low	55 (23.0)	19 (27.5)	11 (22.0)	13 (21.7)	12 (20.0)	
Moderate	126 (52.7)	36 (52.2)	30 (60.0)	30 (50.0)	30 (50.0)	
High	58 (24.3)	14 (20.3)	9 (18.0)	17 (28.3)	18 (30.0)	
Missing	1	0	0	0	0	
Residence						< 0.001
Urban	171 (72.1)	38 (55.9)	26 (52.0)	55 (91.7)	52 (88.1)	
Rural	66 (27.9)	30 (44.1)	24 (48.0)	5 (8.3)	7 (11.9)	
Missing	3	1	1	0	0	
Gestational age (weeks)						0.98
≥ 37	225 (93.8)	64 (92.8)	48 (94.1)	57 (95.0)	56 (93.3)	
< 37	15 (6.3)	5 (7.3)	3 (5.9)	3 (5.0)	4 (6.7)	
Missing	0	0	0	0	0	
Drinking water						< 0.001
Bottled	174 (72.8)	40 (58.0)	31 (62.0)	53 (88.3)	50 (83.3)	
Public	49 (20.5)	23 (33.3)	15 (30.0)	6 (10.0)	5 (8.3)	
Spring	16 (6.7)	6 (8.7)	4 (8.0)	1 (1.7)	5 (8.3)	
Missing	1	0	1	0	0	
Type of bathing						0.91
Shower only	221 (94.5)	63 (94.0)	48 (98.0)	55 (84.8)	55 (91.7)	
Bath only	5 (2.1)	2 (3.0)	0 (0.0)	1 (1.7)	2 (3.3)	
Both	8 (3.4)	2 (3.0)	1 (2.0)	2 (3.5)	3 (5.0)	
Missing	6	2	2	2	0	
Swimming pool use						0.24
Ever	229 (98.7)	67 (100.0)	47 (97.9)	57 (100.0)	58 (96.7)	
Never	3 (1.3)	0 (0.0)	1 (2.1)	0 (0.0)	2 (3.3)	
Missing	8	2	3	3	0	
Hand dishwashing						0.21
No	82 (35.2)	25 (37.3)	13 (27.1)	26 (44.8)	18 (30.0)	
Yes	151 (64.8)	42 (62.7)	35 (72.9)	32 (55.2)	42 (70.0)	
Missing	7	2	3	2	0	

All variables correspond to maternal characteristics during pregnancy.

^aNumber of subjects with micronuclei analyses (either mother or newborn). ^bBrominated trihalomethanes in residential water quartiles: 0.06–0.15; > 0.15 –0.74; > 0.74 –4.44; > 4.44 –7.09 $\mu\text{g/L}$. ^c p -Value based on Fisher exact test for table frequencies (excluding the missing values). ^dExposed to secondhand smoke either at work or at home.

living in a rural area (10%). The percentage of women in the highest quartile of BTHM who consuming bottled water only (28%) was greater than those who consumed public (9%) or spring (4%) water.

Residential exposure to BTHMs during pregnancy. For the entire pregnancy, the mean concentration of BTHM in residential water was 2.1 ± 2.6 µg/L and the median was 0.8 µg/L. The minimum residential concentration was 0.06 µg/L and the maximum was 7.1 µg/L. Average BTHM concentrations over pregnancy were strongly correlated for the first and second trimester [Pearson correlation coefficient (r) = 0.70] and the second and third trimester (r = 0.73), but the correlation between the first and third trimester was weaker (r = 0.31). The mean maternal exposure through all routes was estimated to be 0.06 ± 0.10 µg/week. There was a strong positive correlation between mean residential water BTHM concentrations and estimated maternal BTHM exposure through all routes (r = 0.74, p < 0.001). Data for residential water concentrations and all route exposure estimates were missing and imputed for 25 (12%) mothers and 28 (13%) newborns.

MN frequency distribution. The mean MN frequency per 1,000 BN was 2.85 ± 2.20 (range, 0.00–15.88) in the 214 maternal blood samples and 1.80 ± 1.51 (range, 0.00–8.47) in the 223 cord blood samples (p < 0.001, paired t -test comparing mother and newborn counts based on the 162 paired samples). The mean frequency of MN per 1,000 MONO was 0.71 ± 1.04 (range, 0.00–6.79) for the mothers and 0.62 ± 0.72 (range, 0.00–4.19) for the newborns (p = 0.37, paired t -test for mother–newborn comparison). The mean CBPI was 1.64 ± 0.25 (range, 1.08–2.16) for maternal cultures and 1.57 ± 0.20 (range, 1.03–1.98) for the cord blood cultures (p = 0.99, for paired t -test for mother–newborn comparison). A trend of increasing mean MN frequencies with increasing pregnancy mean BTHM exposures was observed for both BN (p = 0.07) and MONO (p = 0.02) in mothers only (see Supplemental Material, Table S1).

Regression model findings. Compared with taking showers only, taking baths only was associated with an increased frequency of MN in maternal BN [rate ratio (RR) = 2.08; 95% CI: 1.09, 3.98] and MN in maternal MONO (RR = 6.72; 95% CI: 3.21, 14.05) based on five mothers who only used a bath (Table 2). The frequency of MN in maternal MONO also increased with the number of baths per week (RR = 1.30; 95% CI: 1.08, 1.55 per bath), and with the product of duration and the frequency of bathing per week (RR = 1.65; 95% CI: 1.23, 2.21 for 60 min of bathing per week). Conversely, the frequency of MN in maternal MONO decreased with frequent showering (RR = 0.88; 95% CI: 0.82, 0.95

for each additional shower per week) and with the product of duration and the frequency of showering per week (RR = 0.72; 95% CI: 0.52, 1.00 for 60 min of showering per week). Similar findings were observed for the analyses of the MN in maternal BN for bathing and showering duration and times per week except that these findings were not statistically significant. Compared with public water as a drinking source, maternal consumption of spring water only was associated with decreasing MN frequency in maternal MONO lymphocytes (RR = 0.26; 95% CI: 0.10, 0.70, based on 16 women who used spring water), and nonsignificantly related to decreased MN in maternal BN and MONO in newborns.

The results from modeling the frequency of MN in BN in mothers and newborns using continuous exposure variables

are presented in Table 3. Associations were closer to the null when adjusted for covariates compared with unadjusted estimates (see Supplemental Material, Tables S2–S4). The frequency of MN in maternal BN increased with BTHM concentrations in residential water during the first and second trimesters (RR = 1.05; 95% CI: 1.00, 1.11 p = 0.06 and RR = 1.03; 95% CI: 1.00, 1.06 p = 0.04 per 1-µg/L increase in BTHM, respectively) and with the average concentration during pregnancy (RR = 1.03; 95% CI: 0.99, 1.07, p = 0.13). When residential BTHM concentrations were categorized into quartiles (data not shown), adjusted RRs for the frequency of MN in maternal BN in the highest quartile relative to the first quartile were 1.28 (95% CI: 0.97, 1.70) and 1.24 (95% CI: 0.95, 1.61) for concentrations during the first

Table 2. Associations between maternal water usage habits and micronuclei frequency per 1,000 BN and MONO lymphocytes from maternal blood and newborns cord blood samples [RR (95% CI)].

Variable	Maternal blood cells ^a		Newborns cord blood cells ^b	
	BN	MONO	BN	MONO
Type of bathing				
Showers only	1.00	1.00	1.00	1.00
Baths only	2.08 (1.09, 3.98)*	6.72 (3.21, 14.1)*	1.07 (0.80, 1.42)	1.13 (0.62, 2.07)
Both	0.79 (0.54, 1.16)	0.20 (0.04, 1.05)	1.17 (0.70, 1.78)	1.13 (0.59, 2.14)
Showering				
Times per week	0.98 (0.95, 1.00)	0.88 (0.82, 0.95)**	0.98 (0.96, 1.01)	1.03 (0.99, 1.07)
Duration ^c	0.96 (0.86, 1.08)	0.86 (0.66, 1.12)	0.86 (0.75, 1.00)*	0.93 (0.77, 1.13)
Times × duration ^d	0.95 (0.87, 1.05)	0.72 (0.52, 1.00)**	0.84 (0.73, 0.97)*	1.06 (0.91, 1.24)
Bathing				
Times per week	1.09 (0.97, 1.23)	1.30 (1.08, 1.55)**	1.09 (0.99, 1.19)	1.06 (0.95, 1.18)
Duration ^c	1.06 (0.92, 1.23)	1.30 (0.97, 1.74)	1.07 (0.93, 1.22)	1.02 (0.82, 1.26)
Times × duration ^d	1.19 (0.96, 1.47)	1.65 (1.23, 2.21)**	1.15 (0.92, 1.44)	1.15 (0.90, 1.48)
Swimming pool use ^e	0.88 (0.32, 2.42)	1.19 (0.49, 2.88)	1.08 (0.32, 3.66)	1.74 (0.29, 10.41)
Drinking water source				
Public water	1.00	1.00	1.00	1.00
Bottled	0.88 (0.68, 1.13)	0.75 (0.43, 1.33)	1.12 (0.82, 1.52)	0.78 (0.55, 1.09)
Spring	0.79 (0.54, 1.16)	0.26 (0.10, 0.70)**	1.09 (0.68, 1.74)	0.75 (0.37, 1.51)
Hand dishwashing ^f	1.11 (0.89, 1.37)	0.76 (0.44, 1.34)	0.89 (0.70, 1.15)	0.89 (0.66, 1.21)

RRs and 95% CIs of the micronuclei frequency from negative binomial models.

^aModels for mothers controlled for maternal age at birth (years), maternal active smoking (nonsmokers/ex-smokers/active smokers), workplace and home SHS (no/yes), living in an urban area (no/yes), maternal education (low/middle/high), and maternal Greek ethnicity (yes/no). ^bModels for newborns controlled for the same variables as the maternal models except that maternal age was replaced by gestational age (weeks). ^cResults presented are for 10 min of showering or bathing. ^dResults presented are for 60 min of showering or bathing per week. ^eResults presented are for comparison of never (reference group) and ever used swimming pool during pregnancy. ^fResults presented are for comparison of dishwashing by machine (reference group) and hand. * p < 0.05. ** p < 0.01. ^g p < 0.001.

Table 3. Associations between brominated trihalomethanes and micronuclei frequency in BN cells from maternal and cord blood samples [RR (95% CI)].

Exposure	Mothers ^a	Newborns ^b
Residential tap water (µg/L)		
1st trimester	1.05 (1.00, 1.11)	1.02 (0.95, 1.08)
2nd trimester	1.03 (1.00, 1.06)	0.99 (0.96, 1.02)
3rd trimester	1.00 (0.98, 1.03)	0.98 (0.95, 1.01)
Full pregnancy	1.03 (0.99, 1.07)	0.98 (0.94, 1.03)
All routes of exposure (µg/week)		
1st trimester	3.14 (1.16, 8.50)	0.90 (0.23, 1.48)
2nd trimester	1.68 (0.76, 3.73)	0.56 (0.26, 1.21)
3rd trimester	0.76 (0.40, 1.45)	0.59 (0.28, 1.24)
Full pregnancy	1.55 (0.59, 4.09)	0.51 (0.19, 1.36)

RRs and 95% CI of the micronuclei frequency in maternal mononucleated cells from negative binomial models (per 1 unit of exposure increment).

^aAdjusted for maternal age at birth, maternal tobacco smoking, maternal exposure to workplace and home SHS, living in an urban area, maternal education, and Greek ethnicity. ^bModels for newborns controlled for the same variables as the maternal models except that maternal age was substituted by gestational age at birth (weeks).

and second trimesters, respectively. However, residential BTHM concentrations during the third trimester were not associated with MN in maternal BN ($p = 0.95$).

A 1- $\mu\text{g}/\text{week}$ increase in BTHM exposures from all routes during the first trimester also was associated with higher frequency of MN in maternal BN (RR = 3.14; 95% CI: 1.16, 8.50 $p = 0.03$) (Table 3). The association with BTHM exposures from all routes during the second trimester was also associated with elevated MN frequency in maternal BN, but this association was statistically nonsignificant (RR = 1.68; 95% CI: 0.76, 3.73 $p = 0.2$).

Plots of the model-predicted exposure-response relationships between residential BTHM water concentrations and the frequency of MN in maternal BN from unadjusted models are presented in the Supplemental Material, Figure S1. A restricted cubic spline with 3 knots is also included in the plots as a means of assessing the linearity of the exposure-response trends. These plots indicate that the linear models provide a reasonable fit to the estimates from the categorical and cubic spline models. Similar trends were evident when models with adjustment for the *a priori* covariates (results not shown).

There was no evidence of associations between any of the BTHM exposure measures and the frequency of MN in cord blood BN (see Supplemental Material, Table S2). For both mothers and newborns, there was no evidence of an association between any of the BTHM exposure estimates and the MN frequency in MONO (see Supplemental Material, Table S3 and Table S4).

Inclusion of additional covariates had little influence on model estimates (data not shown). Estimates were comparable to those shown when the analysis was restricted to the subset of study population with complete data (i.e., without the use of multiple imputation to impute missing data) (data not shown).

Mixed models that included a random effect for water systems had no influence on the exposure regression coefficients, but increased the precision and reduced the p -values for the estimated effect of BTHM exposures during the first trimester for residential exposures (from $p = 0.03$ to $p = 0.01$) and for all routes of exposure (from $p = 0.01$ to $p < 0.001$). Only minor changes were observed in the results for the other BTHM regression parameters.

A statistically significant interaction was observed between maternal smoking (nonsmokers/ex-smokers/active smokers) and BTHM exposures experienced during the first trimester for both residential water concentrations ($p < 0.001$) and all routes of exposure ($p = 0.02$) for MN frequency in maternal BN. Stratified analyses revealed that BTHM exposures during the first trimester were not

associated with MN in maternal BN among the 145 nonsmokers for either residential water (RR = 0.99; 95% CI: 0.93, 1.04) or for all routes of BTHM exposure (RR = 1.23; 95% CI: 0.34, 4.50) (see Supplemental Material, Table S5). A highly significant ($p = 0.002$) association was estimated for residential BTHM contaminants among the 48 active smokers (RR = 1.11; 95% CI: 1.04, 1.18). A borderline significant ($p = 0.07$) association was estimated for all routes of exposure among the 48 active smokers (RR = 3.97; 95% CI: 0.88, 17.99) and for residential water contaminants among the 44 ex-smokers (RR = 1.18; 95% CI: 0.99, 1.42).

Statistically significant ($p < 0.01$) interactions were also observed in the models for MN in maternal BN between maternal education and the all routes of exposure variables for second and third trimesters, and for the average over the pregnancy. The interaction for maternal education and all routes of exposure during the first trimester was nearly statistically significant ($p = 0.10$). Stratified analyses indicated that positive associations with all routes of BTHM exposure were only evident among the 47 women with low education (1st trimester: RR = 18.09; 95% CI: 1.31, 250.04; 2nd trimester: RR = 7.98; 95% CI: 1.17, 37.17; 3rd trimester: RR = 1.59; 95% CI: 0.55, 4.63; and pregnancy average: RR = 10.88; 95% CI: 1.70, 69.48) (see Supplemental Material, Table S6).

Discussion

To our knowledge, the present study is the first to examine the relationship between exposure to BTHM and MN frequency in maternal and cord blood lymphocytes. We found evidence of a significant increase of MN frequency in maternal BN with BTHM exposures during the first and second trimesters. An association between BTHM exposures during the third trimester and maternal MN frequency in BN was not evident. There was also no evidence of BTHM exposures being associated with either maternal MN frequency in MONO or MN frequency in newborns.

Our finding of an association between exposure to BTHMs and higher MN frequency in maternal BN lymphocytes are consistent with two other epidemiologic studies. Villanueva et al. (2006) reported an increase in the frequency of MN in exfoliated urine cells with higher BTHM exposures among adults. Kogevinas et al. (2010) also reported an association between BTHM in exhaled breath and an increased frequency of MN in BN lymphocytes in adults following swimming in an indoor pool. However, a third study conducted in Australia did not find an association between THM in drinking water and MN frequency in urothelial cells from adults (Ranmuthugala et al., 2003).

There is some support for the biologic plausibility of our findings of an association from experimental studies. BTHM have been found to be genotoxic in experimental systems (Le Curieux et al. 1995). Brominated DBPs were reported to be more mutagenic and cytotoxic than chlorinated DBPs based on *in vitro* assays of Chinese hamster ovary cells (Plewa et al. 2010). Experimental studies based on animal models or *in vitro* assays have provided inconsistent findings regarding the effects of brominated compounds on MN frequency. MN in cells exposed *in vitro* increased linearly with the concentration of bromide ions (Nobukawa and Sanukida 2001). MN frequency in the mouse bone marrow was not found to increase following a single intraperitoneal injection of bromodichloromethane and dibromochloromethane (Hayashi et al. 1988). Intraperitoneal injection of bromoform induced MN in one study (Melnick 1989), but not by gavage in another (Stocker et al. 1997). MN induction was observed in p53 ($\pm$) transgenic mice exposed by inhalation, but only at high concentrations (15 ppm) relative to environmental levels (Torti et al. 2002). The tissue, route, and short duration of exposure in these studies make them of questionable value for evaluating the risk of MN formation in humans following chronic exposures to mixtures of BTHM by multiple routes.

Of course it is possible that our positive findings might be the result of unrecognized confounding. There are no obvious industrial sources of pollution in the residential areas that were included in this study. Age has been strongly associated with higher MN frequency in adults, particularly among women, which was also true in our models. Tobacco smoke and air pollution have also been associated with higher MN frequency (Pedersen et al. 2009; Rossnerova et al. 2011; Zalacain et al. 2006). Our findings are adjusted for both active smoking and SHS, and for living in an urban or rural area. It is possible that residual confounding may exist by these factors, because we did not have the level of smoking, and residing in an urban area is a crude proxy for air pollution. In Heraklion, phthalates have been detected in water storage tanks that are used during periods of water shortages. However, insufficient information is available to quantify the potential for exposure to phthalates from these tanks.

We are not aware of a biologic mechanism that would explain stronger associations with exposures during the first trimester than exposures during other trimesters. There was no *a priori* time period during which we expected a maximum effect, and we estimated effects by trimester primarily for the newborns. A possible explanation is that the exposure estimates were based on the residence

around the third month of pregnancy; thus, the potential for exposure misclassification was the smallest during the first trimester. However, residential mobility among pregnant women was very low in this population (9%) (Patelrou et al. 2011).

The association of BTHM with MN in maternal BN was modified by smoking and maternal education. Significant positive associations were estimated only among women who smoked during their pregnancy, and among women with less education. The interaction with education may be related to factors not assessed in this study, such as exposure to ambient air pollution, a maternal diet high in genotoxic compounds, and/or low in antioxidants, but might also simply be a chance finding related to the multiple comparisons performed in this study. There is limited biologic support in the literature for an interaction with smoking. Smoking has been shown to increase expression of glutathione *S*-transferase (GST) (Ithum et al. 2006), which is a key metabolic pathway for the biotransformation and genotoxicity of BTHM (DeMarini et al. 1997; Pegram et al. 1997).

There was no evidence in our study that exposure to BTHM had any effect on the MN frequency in lymphocytes from cord blood. It has been shown that small THM molecules, such as chloroform, can pass from the maternal circulation to the fetal circulation through the placenta (Dowty et al. 1976). The lack of associations between exposures and MN in newborns might be explained by the fact that the maternal-placental-fetal circulation becomes established only around the 10th week of pregnancy, whereas the majority of lymphocytes collected at birth in cord blood are produced during the third trimester (Blackburn 2007). If the critical window of exposure was during the first trimester, then the cord blood lymphocytes collected at birth may not have been exposed. Another possible biologic explanation is that certain BTHM are metabolized by GST to reactive mutagens (DeMarini et al. 1997; Pegram et al. 1997), and it is likely that *in utero* metabolism of BTHM is immature, resulting in a lower exposure of the reactive toxic metabolites of THM to the fetus (Wild and Kleinjans 2003).

Exposure to BTHM was not associated with higher MN frequencies in MONO in either mothers or newborns. This might be explained by the fact that MN in MONO is less common than MN in BN, resulting in lower statistical power. Another explanation is that MN frequencies in MONO are thought to provide an estimate of genomic instability accumulated over many years in stem cells and circulating T lymphocytes, whereas MN in BN provide a measure of the lesions that have accumulated in the DNA or in key proteins

since the lymphocytes last replicated *in vivo* (Kirsch-Volders and Fenech 2001; Kirsch-Volders et al. 2011). Thus, the estimates of BTHM exposures over the course of the pregnancy may not be relevant for studying MN frequencies in MONO for the mothers, which may have been influenced by earlier exposures.

Taking baths was strongly associated with MN frequency in maternal BN and MONO lymphocytes based on a small number of women who did not use showers ($n = 5$). Bathing has been reported to result in a higher uptake of THM through both skin absorption and inhalation than showering (Gordon et al. 1998). Furthermore, in the present study population, the duration of bathing was on average longer than the time showering (32 vs. 14 min), increasing the potential for exposure to BTHM. Compared with the 43 women who consumed public water, the 11 women who consumed only spring water had a reduced frequency of MN in MONO lymphocytes. Spring water is generally not chlorinated, so women consuming spring water would have low exposures to THM in their drinking water.

This study had a number of strengths and some weaknesses as well. The strengths include the fact that MN frequency was available from a relatively large and well-characterized sample of maternal and cord blood, and that BTHM concentrations were estimated at both residential and personal levels. Potential variation related to the use of multiple scores of the lymphocytes and the MN was reduced as a semi-automatic imaged based scoring system was developed and applied in the current study (Decordier et al. 2009; Vande Look et al. 2011).

There were multiple potential sources of exposure classification error in our study. The models developed were based on a limited number of water analyses. The models assume that all of the homes within the same water system have the same level of exposures, and thus ignores potential spatial variation within the water systems. The addresses were generally from early pregnancy, and it was assumed that the mothers did not move later in their pregnancies. Self-reported estimates of water habits are likely to be prone to error. These errors are all expected to be non-differential with respect to MN formation. Under these conditions these errors generally, but not always, bias the exposure response toward the null (Armstrong 1998).

The estimated BTHM concentrations in residential water supplies for our study population were lower than concentrations reported for other populations. For example, the average residential THM concentration for a Spanish population was 33 $\mu\text{g/L}$ (Villanueva et al. 2006), compared with a mean BTHM concentration of only 2 $\mu\text{g/L}$ in

our study. The residential drinking-water concentrations in our population were also much lower than the current permissible regulatory limits, which are 100 $\mu\text{g/L}$ in the European Union and 80 $\mu\text{g/L}$ in the United States.

In conclusion, we observed significant increases in the frequency of MN in maternal BN in association with exposure to BTHM in residential water during the first and second trimesters of pregnancy. We also observed an association between increased MN frequency in women who took baths, and a decreased frequency of MN among women who consumed primarily spring water, based on small numbers of observations. If these findings truly reflect a causal association, they may have important health and policy implications, particularly because the BTHM exposures in this study were considerably lower than the current standards limits for BTHM in drinking water.

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Erratum: "Exposure to Brominated Trihalomethanes in Water During Pregnancy and Micronuclei Frequency in Maternal and Cord Blood Lymphocytes"

In the article "Exposure to Brominated Trihalomethanes in Water During Pregnancy and Micronuclei Frequency in Maternal and Cord Blood Lymphocytes" by Stayner et al. [*Environ Health Perspect* 122:100–106 (2014)], there was an error in Table 1. The number of women in exposure quartile 4 who had missing data for maternal smoking was given as zero instead of 3. The corrected table appears below and has also been corrected online.

EHP regrets the error.

Table 1. Study population characteristics [*n* (%)]^a for all and by quartiles of the residential exposure to brominated trihalomethanes during the full pregnancy.^b

Characteristic	All (<i>n</i> = 240)	Quartile 1	Quartile 2	Quartile 3	Quartile 4	<i>p</i> -Value ^c
Ethnicity						0.82
Greek	205 (86.3)	60 (88.2)	43 (84.3)	50 (83.3)	30 (88.1)	
Other	33 (13.9)	8 (11.8)	8 (15.7)	10 (16.7)	7 (11.9)	
Missing	2	1	0	0	1	
Maternal age (years)						0.24
≤ 35	210 (87.8)	65 (94.2)	44 (88.0)	50 (83.3)	51 (85.0)	
> 35	29 (12.1)	4 (5.8)	6 (12.0)	10 (16.7)	9 (15.0)	
Missing	1	0	1	0	0	
Maternal smoking						0.06
Nonsmokers	145 (61.2)	45 (65.2)	33 (68.9)	28 (46.7)	39 (65.0)	
Ex-smokers	44 (18.6)	16 (23.2)	5 (10.4)	14 (23.3)	9 (15.0)	
Active smokers	48 (20.2)	8 (11.6)	10 (20.8)	18 (30.0)	12 (20.0)	
Missing	3	0	3	0	3	
SHS ^d						0.42
Not exposed	26 (10.9)	5 (7.3)	5 (10.0)	6 (10.0)	10 (16.7)	
Exposed	213 (89.1)	64 (92.8)	45 (90.0)	54 (90.0)	50 (83.3)	
Missing	1	0	1	0	0	
Maternal education						0.68
Low	55 (23.0)	19 (27.5)	11 (22.0)	13 (21.7)	12 (20.0)	
Moderate	126 (52.7)	36 (52.2)	30 (60.0)	30 (50.0)	30 (50.0)	
High	58 (24.3)	14 (20.3)	9 (18.0)	17 (28.3)	18 (30.0)	
Missing	1	0	0	0	0	
Residence						< 0.001
Urban	171 (72.1)	38 (55.9)	26 (52.0)	55 (91.7)	52 (88.1)	
Rural	66 (27.9)	30 (44.1)	24 (48.0)	5 (8.3)	7 (11.9)	
Missing	3	1	1	0	0	
Gestational age (weeks)						0.98
≥ 37	225 (93.8)	64 (92.8)	48 (94.1)	57 (95.0)	56 (93.3)	
< 37	15 (6.3)	5 (7.3)	3 (5.9)	3 (5.0)	4 (6.7)	
Missing	0	0	0	0	0	
Drinking water						< 0.001
Bottled	174 (72.8)	40 (58.0)	31 (62.0)	53 (88.3)	50 (83.3)	
Public	49 (20.5)	23 (33.3)	15 (30.0)	6 (10.0)	5 (8.3)	
Spring	16 (6.7)	6 (8.7)	4 (8.0)	1 (1.7)	5 (8.3)	
Missing	1	0	1	0	0	
Type of bathing						0.91
Shower only	221 (94.5)	63 (94.0)	48 (98.0)	55 (84.8)	55 (91.7)	
Bath only	5 (2.1)	2 (3.0)	0 (0.0)	1 (1.7)	2 (3.3)	
Both	8 (3.4)	2 (3.0)	1 (2.0)	2 (3.5)	3 (5.0)	
Missing	6	2	2	2	0	
Swimming pool use						0.24
Ever	229 (98.7)	67 (100.0)	47 (97.9)	57 (100.0)	58 (96.7)	
Never	3 (1.3)	0 (0.0)	1 (2.1)	0 (0.0)	2 (3.3)	
Missing	8	2	3	3	0	
Hand dishwashing						0.21
No	82 (35.2)	25 (37.3)	13 (27.1)	26 (44.8)	18 (30.0)	
Yes	151 (64.8)	42 (62.7)	35 (72.9)	32 (55.2)	42 (70.0)	
Missing	7	2	3	2	0	

All variables correspond to maternal characteristics during pregnancy.

^aNumber of subjects with micronuclei analyses (either mother or newborn). ^bBrominated trihalomethanes in residential water quartiles: 0.06–0.15; > 0.15–0.74; > 0.74–4.44; > 4.44–7.09 µg/L. ^c*p*-Value based on Fisher exact test for table frequencies (excluding the missing values). ^dExposed to secondhand smoke either at work or at home.

RESEARCH ARTICLE

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Colon and rectal cancer incidence and water trihalomethane concentrations in New South Wales, Australia

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Abstract

Background: There is evidence, although inconsistent, that long term exposure to disinfection by products (DBPs) increases the risk of bowel cancer. No study has been conducted in Australia to examine this association and due to difference in the methods of disinfection the risk can vary across geographical regions and. This study was conducted to analyse the association of trihalomethanes (THMs) in water with colon and rectal cancer in NSW Australia.

Methods: Average yearly concentrations of total and individual species of THMs were obtained for 50 local government areas (LGAs). Indirectly-standardized incidence rates of colon and rectal cancers in LGAs for the period 1995 to 2001 were regressed against mean THM concentrations lagged five years, adjusting for socioeconomic status, high risk drinking, smoking status, usual source of water and year of diagnosis, including local and global random effects within a Bayesian framework. The incidence rate ratios (IRRs) for an interquartile range (IQR) increase in THMs were estimated.

Results: Using five year lag of exposure there was a positive association between bromoform concentration and CRC in men (IRR = 1.025, 95% CI 1.010, 1.040) but not in women (IRR = 1.003, 95% CI 0.987, 1.018). The association in men was mainly found in colon cancer with bromoform (IRR = 1.035, 95% CI 1.017, 1.053). There was no appreciable association of colorectal cancer with other species of THMs. Sensitivity analyses did not materially change the associations observed.

Conclusion: A positive association was observed between colon cancer and water bromoform concentrations in men. Given the potential population impact of such an association, further research into the relationship between THMs, particularly brominated species, and colorectal cancer is warranted.

Keywords: Cancer, Colon, Rectal, Disinfection by-products, Chlorination, Ecological studies

Background

Epidemiological studies have reported increased risks of bladder, colorectal and renal cancer, and adverse reproductive and developmental outcomes in people exposed to chlorinated drinking water or chemical by-products of chlorination (disinfection by-products or DBPs), although not consistently [1-7]. These studies have usually

used measurements of trihalomethanes (THMs, e.g., total THM, chloroform, bromoform etc.), a major sub-group of DBPs, as a measure of exposure.

A recent meta-analysis of case-control and cohort studies of the association of DBPs with colorectal cancer (CRC) found summary odds ratios (ORs) of 1.30 (95% CI 1.06, 1.59) for rectal cancer and 1.27 (95% CI: 1.08, 1.50) for colon cancer, comparing the highest exposure category with the lowest [8]. Many of the studies in the meta-analysis did not report the actual concentration of THM in the water. Weaknesses in exposure measurement and in the control of potential confounders in many of the

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studies make these findings uncertain. In addition, all the studies included in the meta-analysis were conducted in Europe or in North America. It has been revealed in a recent meta-analysis and pooled analysis that the method of disinfection varies importantly between North America and Europe which may contribute to the differences in the risk of cancer [2]. Therefore, the findings from studies conducted in other countries may not be applicable to Australia.

Due to limited generalizability of the previous studies, we have conducted an ecological study as a starting point to explore the association in Australia. In this study, we investigated whether the incidence of CRC is associated with THM concentrations in two water supply regions in New South Wales, Australia. All public water supply systems in these regions are served by chlorinated or chloraminated water.

Methods

We undertook a spatial ecological study with local government area (LGA) by calendar year as the unit of analysis. The study covered two separate geographical areas: the Sydney Water Corporation (SWC) region, which supplies water to 47 LGAs and the Hunter Water Corporation (HWC) region which supplies water to 5 LGAs. For each of the LGAs we sought data on the incidence of colorectal cancer from 2001 to 2006 and estimates of THMs in water supplies from 1995 to 2001, to allow a five-year lag. Among the DBP species, only THMs were routinely measured in these supplies; they had been consistently measured since 1995 in the SWC region and since 1997 in the HWC region.

In the HWC water supply system, water is piped into reservoirs in six water supply zones and then distributed to homes located in nine water distribution zones that contain the sampling sites. The SWC water supply system has 14 delivery systems encompassing 33 distribution systems, which, in turn, encompass 180 reservoir zones that contain the sampling sites. A detailed description of the study areas, the water supply system, disinfection practices etc. is given elsewhere [9].

Estimation of THM concentrations at LGA level

We obtained data on THM concentrations for all the monitored sampling sites by date of sample collection from the SWC and the HWC and used them to estimate yearly average THM concentrations for the LGAs from 1995 (1997 in HWC) to 2001. For HWC, we used data at the distribution zone level. Complete monthly THM data for HWC were available at this level. For SWC, we averaged monthly concentrations of total THMs and THM species for each year across all sampling sites at the distribution system level. At this level, 10% to 20% of

monthly average values were missing for the years 1995 to 1999 and fewer than 10% for the years after 1999. We used THM data at the distribution system level as our ecological exposure measure because distribution systems are of similar size to LGAs and most of the disinfection and re-chlorination happens at this level (Additional file 1).

We adopted a cluster mean approach to impute missing THM data from SWC. If a distribution system value was missing for any month we estimated it by taking the value for that month from the delivery system in which the distribution system lay. This approach provided complete data from 2000 onwards and nearly complete data (1% missing) for 1998 and 1999. For the preceding years approximately 80% of values were still missing. For 1996 and 1997 we obtained complete coverage by taking the annual average of THM concentration at the distribution system level. For 1995, THM values were still missing for six (18%) distribution systems. This approach was used in a previously published paper on maternal exposure to trihalomethanes and the risk of small for gestational age births in the Sydney and Hunter regions [10].

There is no spatial alignment of LGA and distribution zone or system boundaries in either HWC or SWC. Some distribution systems supply water to two or more LGAs. Four distribution systems in SWC supplied water to one LGA only, other systems, on average, supplied to four LGAs (min 2, max 16). In the SWC region, 14 of the LGAs were served by only one distribution system. On average, LGAs are supplied by three distribution systems (min 2 max 8). To cope with these spatial anomalies we calculated area weighted average THM concentrations for LGAs from the distribution zones or systems they covered, where the weights were the proportions of the LGA area that they covered. We used ArcGIS (version 9.3) [11] to determine the area coverage of LGAs by the distribution systems and also estimated the standard deviations (SDs) of the weighted mean THMs. This process left missing means for only two LGAs (out of 47) in the SWC region, which we excluded from the analysis. This imputation method has been validated in another study where it did not affect the effect estimates of small for gestational age [10].

In the SWC region, 18.7% of bromoform concentration values fell below the detection limit (DL) of 1 µg/L (1995 to 1998), and 63.3% of values fell below the DL of 3 µg/L (1999 onwards). In the HWC region, the DL for bromoform was 1 µg/L for the whole study period and 51% of all observations were below this DL. For all other species of THMs approximately 1% of values were below the specified DL. We replaced values below the DL with a value that was two thirds of the DL [12]. We conducted a sensitivity analysis by using a different method to replace the values below the DL (Additional file 2).

Cancer incidence data

We obtained de-identified unit record data for CRC incidence by sex, five-year age group, year of diagnosis and LGA of residence from the NSW Central Cancer Registry for the period 2000 to 2006. Since the CRC rate is very low for age groups below 35 years, the analysis was restricted to people aged 35 years and above. Several studies have examined the agreement between the Central Cancer Registry data and medical records for colorectal cancer. One study examined the agreement between stage of colorectal cancer at diagnosis and found a 70% agreement between the registry data and data recorded in a survey of treating doctors [13]. Another study reported high agreement between self-reported cancers in older women in the Longitudinal Study in Women's Health and records in the Central Cancer Registry with sensitivity of 90% (95% CI: 78.6-95.6) and specificity 99.3% (95% CI: 98.9-99.5) for colorectal cancer [14].

Area-level covariates

We included five covariates on socio-economic status, high risk drinking, smoking status, drinking water treatment at home and usual source of drinking water (tap, bottle, rainwater, well, other) at the LGA level. In 2003, 88% of metropolitan areas used the public water supply, 9% bottled water, 1.4% rainwater and 0.2% private bore or well water [15]. We obtained area level information on socio-economic status. Socio-Economic Indexes for Areas (SEIFA) is a set of indexes produced by the Australian Bureau of Statistics (ABS) after every Census [16]. The SEIFA utilizes relevant Census data on education, income, employment and housing to produce index scores that rank areas based on their relative socioeconomic advantage and disadvantage [17]. We used the index of relative socio-economic disadvantage (IRSD) as our indicator of socio-economic status [18,19]. We used the IRSD from the 2001 census for 2001 to 2003 and from the 2006 census for 2004 to 2006. The LGA level IRSD scores were estimated by taking the population-weighted average scores of the census collector districts (typically having populations of around 300 people) in each LGA. A low index value indicates high proportions of low-income families and people with low skilled occupations or without training [19]. The other four area level indicators were obtained from the 2002 Adult Health Survey conducted by the NSW Health Department and applied to the LGAs [15]. The proportion of high risk drinking was defined as one or more of the following: consuming alcohol every day, consuming an average of four if male or two if female standard drinks a day or consuming six if male or four if female standard drinks on any one occasion or day [15]. The proportion of current smokers, and the proportion of people who use public tap water as the usual source of drinking

water, were also included in the final model. The proportion of people who treat their drinking water before consumption was not significant and not included in the model.

Statistical analysis

To model the risk of CRC with exposure we used observed and expected numbers of cases of CRC by year and LGA. Expected numbers were calculated using age and sex specific rates of CRC in NSW. To include socio-economic status in the analytical model we measured inequality in terms of the relative index of inequality [20]. It was estimated by the exponential of the negative of the parameter for the IRSD quintile in the regression model.

We used the observed number of cases as the outcome variable and the log of the expected number as the offset in a Poisson regression model. We adopted a full Bayesian hierarchical framework to fit the model including the other covariates (year of diagnosis of CRC, SES, smoking status, usual source of drinking water, high risk drinking and region of residence (SWC or HWC)) and estimated the area-specific and overall incidence rate ratio (IRR) of CRC for THM exposure. We adjusted for region because of different levels of urbanicity as well as the difference in water source (HWC water sources are river based and ground water from coastal aquifers, while SWC water is supplied by a number of large dams/reservoirs). We used a conditional auto-regressive model to adjust for spatial autocorrelation and possibly some unknown factors [21], which entailed the addition of global and spatial random effects to our model [22]. The Markov Chain Monte Carlo (MCMC) method was used to sample from the posterior probability distribution. To determine how the spatial random effects term affected the overall model fit and the estimates, the Bayesian hierarchical models were fitted with and without the spatial random effect.

Pure specification bias (within-area variability bias) due to aggregating a nonlinear individual-level model over the within-area distribution of covariates can severely bias risk estimates in ecological studies [23-25]. To control for this bias we also fitted a non-linear model including the variance term (whose regression parameter is the square of the regression parameter for the mean term divided by two). Since some of the area means did not have a variance (when they came from only one observation), we examined the effect of missing variances by fitting another model restricted to data sets that had non-missing variances.

We made the a priori assumption of a five year lag between exposure and outcome. To assess the sensitivity of the results to this assumption, we reanalysed the data by averaging the exposure data (but not the outcome data) across the calendar years (1995 to 2001). Since the

HWC region has only five LGAs and its inclusion required that we restrict the analysis to three exposure and outcome years, we also compared models including and excluding the HWC region.

All model comparisons were made using the deviance information criterion (DIC) [26]. For each Bayesian hierarchical model two MCMC chains from different starting points were estimated to assure convergence. Depending on the complexity of the models, the first half (20,000) of the total iterations in each chain were removed (as "burn-ins"). Convergence of the models was monitored by visual examination of MCMC chains, autocorrelation plots and Gelman–Rubin statistic plots. Full Bayes hierarchical models were estimated using WinBUGS version 1.4.3 software using the GeoBUGS package, with scripting in R version 2.9.1 using R2WinBUGS.

We obtained the exposure data on disinfection by-products from the SWC and HWC upon obtaining their official approval. We obtained the cancer incidence data from the NSW central cancer registry upon their approval. The area level data on other demographic factors are publicly available and do not require permission from any authorities to use them.

To conduct this study Ethics approval was obtained from the NSW Population & Health services Research Ethics Committee (Ref: 2006/03/002).

Results

The indirectly age-standardized incidence rate of CRC for the period 2000 to 2006 for ages 35 years and over in the SWC region was 69.8 (95% CI 67.6, 72.0) per 100,000

in men and 55.9 (95% CI 54.1, 57.7) per 100,000 in women. The corresponding rates in the HWC region were 81.3 (95% CI 75.6, 87.0) in men and 60.4 (95% CI 55.3, 65.6) in women.

The means of the estimated concentrations of THMs at LGA level in the SWC and HWC regions for 1995 to 2001 are shown in Table 1. They were generally similar in the two regions. The ranges for all THM species were greater in the SWC region than in the HWC region. Detailed information on area specific and yearly concentrations of THM species in the two regions is available elsewhere [9].

The results of our statistical modeling of CRC incidence with THM concentrations at the LGA level are summarized in Table 2. We expressed the results as the incidence rate ratio (IRR) of CRC for an IQR increase in THM species. Using five year lag of exposure, for individual THM species, there was a positive association between bromoform concentration and incidence of CRC in men with IRR = 1.025 (95% CI 1.01, 1.040), but not in women. Analysis by cancer site showed that the positive association of CRC incidence in men with bromoform concentration was evident only for colon cancer. The IRRs for rectal cancer were not significantly increased for men or women for total THM or any of the THM species. All other site-specific associations were close to the null.

The adjusted IRR for year of diagnosis of CRC was below one for both sexes and for all species of THMs, indicating that CRC incidence rates were falling over the period of the study (not shown in the analysis). The

Table 1 Descriptive statistics for THM concentration (µg/L) in SWC and HWC water supplies, 1995 to 2001¹

Region	Statistics	Chloroform	Bromoform ²	BDCM	DBCM	TTHM
Sydney water corporation (n = 45)	Mean	37.3	2.86	16.9	6.93	64.0
	SD	24.0	2.87	5.32	3.34	29.8
	Median	33.2	2	17.3	5.5	66.1
	IQR	22.9	1.2	5.6	3.1	30.1
	Range	8.5 to 201	0.67 to 17.8	6.66 to 45.0	0.67 to 27.7	20.5 to 234
Hunter water corporation (n = 5) ³	Mean	42.7	1.76	14.7	7.25	66.4
	SD	13.1	1.11	5.26	6.15	11.4
	Median	39.8	2.0	17.3	5.5	66.4
	IQR	22.2	1.3	5.6	3.2	29.0
	Range	23.3 to 65.0	0.67 to 3.95	5.64 to 24.8	1.06 to 21.9	36.7 to 81.3
Both areas combined (n = 50)	Mean	37.7	2.8	16.7	7.0	66.4
	SD	23.4	2.8	5.3	3.6	28.9
	Median	34.4	2.0	17.3	5.5	66.4
	IQR	22.2	1.3	5.6	3.2	29.0
	Range	8.5 to 201.2	0.67 to 17.8	5.6 to 45.0	0.67 to 27.7	20.5 to 234.3

¹Means, standard deviations and range of THM concentrations across LGAs for SWC and HWC.

²SWC: 18.7% of values were below the detection limit in 1995–1998 and 63.6% from 1999 onwards. HWC: 51% of values were below the detection limit.

³HWC data available from 1997 to 2001.

Table 2 Incidence rate ratio of colorectal, colon and rectal cancer in men and women, lagged by 5 years, per IQR¹ increase in total THMs and THM species, adjusted for socio-economic status, area of residence, year of incidence, water source², smoking³, risky alcohol consumption⁴ and spatial random effect

THM species	Sex	Colorectal cancer	Colon cancer	Rectal cancer
Total THM	Male	1.018 (0.995, 1.040)	1.020 (0.990, 1.049)	1.013 (0.977, 1.049)
Chloroform	Male	1.010 (0.988, 1.032)	1.010 (0.983, 1.037)	1.011 (0.980, 1.045)
Bromoform	Male	1.025 (1.009, 1.040)	1.035 (1.017, 1.053)	1.011 (0.989, 1.036)
BDCM	Male	1.018 (0.994, 1.044)	1.024 (0.994, 1.055)	1.012 (0.972, 1.051)
DBCM	Male	1.010 (0.984, 1.035)	1.017 (0.987, 1.050)	0.996 (0.959, 1.037)
Total THM	Female	0.977 (0.953, 1.001)	0.976 (0.946, 1.006)	0.984 (0.940, 1.027)
Chloroform	Female	0.978 (0.954, 0.999)	0.974 (0.946, 1.003)	0.989 (0.946, 1.038)
Bromoform	Female	1.003 (0.987, 1.018)	0.999 (0.979, 1.019)	1.012 (0.982, 1.042)
BDCM	Female	0.979 (0.956, 1.000)	0.983 (0.952, 1.014)	0.973 (0.926, 1.024)
DBCM	Female	0.995 (0.970, 1.021)	0.997 (0.966, 1.028)	0.994 (0.945, 1.045)

¹IQR: Total THM = 29 µg/L, Chloroform = 22 µg/L, Bromoform = 2 µg/L, BDCM = 6 µg/L and DBCM = 4 µg/L.

Note that the IQR values have been rounded to estimate IRR for ease of interpretation.

²Proportion of people using tap water in each LGA.³Proportion smokers in each LGA.⁴Proportion of risky alcohol drinker.

adjusted IRR for the relative index of inequality were below unity for all exposure categories, more so in women than men. Overall, men in the lowest socioeconomic quintile had 7% less risk of CRC than men in the highest quintile; women in the lowest socioeconomic quintile had 12% less risk than women in the highest quintile (not shown in the analysis). Men whose drinking water came from sources other than tap water had 24% less risk and for men who engaged in high risk drinking there was a 29% higher risk of CRC but none of these associations was statistically significant.

Removing socio-economic status from the model, exclusion of HWC area data or removal of the spatial random effect did not have an influential effect on the IRRs for total THMs or individual THM species (Table 3). In

particular, the significant association of CRC incidence in men with bromoform concentration persisted regardless of these changes. Testing for pure specification bias by adding the variances of the LGA mean THM concentrations to the models reduced the IRRs in men somewhat but had little effect on women (Table 3). When we repeated this analysis including only LGAs where the variance was available (87%), the results were not different from those including the missing variances (not shown in the analysis). Exclusion of the spatial random effect term from the model in Table 2 had no material effect on the IRRs for any THM species for either sex (Table 3). When we averaged the THM concentration across the calendar years 1995–2001, in place of the five-year lag, and re-fitted the Bayesian model, the

Table 3 Sensitivity analyses for the model of incidence rate ratios for colorectal cancer per IQR¹ increase in concentration of total THMs and selected specific THM species after adjusting for the covariates mentioned in Table 2

THM species	Sex	Average exposure ²	IRSD excluded	Restricted to SWC area	Spatial random effect excluded	Variance of THMs added
Total THM	Male	1.033 (0.954, 1.119)	1.018 (0.993, 1.041)	1.018 (0.993, 1.041)	1.019 (0.997, 1.042)	1.007 (0.979, 1.032)
Chloroform	Male	1.022 (0.946, 1.110)	1.008 (0.985, 1.031)	1.008 (0.985, 1.031)	1.011 (0.990, 1.034)	1.005 (0.982, 1.029)
Bromoform	Male	1.064 (1.021, 1.113)	1.025 (1.011, 1.040)	1.025 (1.011, 1.040)	1.026 (1.011, 1.041)	1.020 (1.005, 1.036)
BDCM	Male	1.031 (0.973, 1.102)	1.022 (0.995, 1.050)	1.022 (0.995, 1.050)	1.021 (0.996, 1.046)	1.008 (0.980, 1.039)
DBCM	Male	0.998 (0.956, 1.042)	1.028 (0.999, 1.058)	1.028 (0.999, 1.058)	1.012 (0.988, 1.038)	1.000 (0.975, 1.029)
Total THM	Female	0.986 (0.919, 1.056)	0.973 (0.948, 0.999)	0.973 (0.948, 0.999)	0.980 (0.957, 1.004)	0.970 (0.945, 0.994)
Chloroform	Female	1.004 (0.930, 1.087)	0.974 (0.950, 0.997)	0.974 (0.950, 0.997)	0.980 (0.957, 1.004)	0.979 (0.951, 1.006)
Bromoform	Female	1.008 (0.965, 1.050)	1.005 (0.989, 1.023)	1.005 (0.989, 1.023)	1.004 (0.987, 1.020)	1.005 (0.985, 1.023)
BDCM	Female	0.992 (0.937, 1.045)	0.976 (0.948, 1.005)	0.976 (0.948, 1.005)	0.981 (0.957, 1.006)	0.973 (0.938, 1.007)
DBCM	Female	0.982 (0.942, 1.020)	0.997 (0.964, 1.028)	0.997 (0.964, 1.028)	0.995 (0.971, 1.021)	0.995 (0.966, 1.023)

¹IQR: Total THM = 29 µg/L, Chloroform = 22 µg/L, Bromoform = 2 µg/L, BDCM = 6 µg/L and DBCM = 4 µg/L.

Note that the IQR values have been rounded to estimate IRR for ease of interpretation.

²Exposure averaged for all relevant years of the study.

positive associations became slightly stronger and the negative associations shifted towards the null with reduced precision. In particular, the association for CRC in men and bromoform concentration became much stronger (IRR = 1.064, 95% CI 1.021, 1.113).

Discussion

We found a positive association between CRC incidence in men lagged five years, with bromoform concentrations in water. This association was largely confined to colon cancer. There was no appreciable association of colorectal cancer with any other species of THMs or with total THMs for either sex. The results showed little sensitivity to removal of SES (IRSD), the spatial random effect term, or addition of the within-area THM variance to the model. When the exposure was averaged across the calendar years, in place of the five-year lag, the positive associations became slightly stronger with reduced precision, possibly because of less attenuation due to non-differential measurement error.

The ecological study design is a primary limitation of our study because we could not adjust adequately for individual level covariates such as consumption of meat and vegetables, which might confound the association of CRC with THM concentrations. The ecological study design also did not allow us to incorporate estimated exposures relevant to the etiologic period that might be gleaned from long-term residential and drinking water histories. That we used only five years of lag between exposure and outcome is another limitation; other investigators have argued that even a 34 year period between the beginning of exposure and the end of follow-up might be too short to detect an effect of environmental exposure on mortality from cancer [27]. However, available evidence on THMs suggests that they may cause cancer by gene mutation or by cell proliferation followed by cytotoxicity, with the former more prominent for the brominated species [28-30]. Thus it is possible that effects could be seen after both short and long periods. In our study the THM exposure data required for a long lag period were not available (available only from 1995). Another major limitation to our study was that we made no assumption about contribution of THMs from different exposure routes (inhalation and dermal absorption through showering, bathing or swimming or other water use activities) which may be significant contributors to the overall exposure to THMs [31]. The associations observed may not be directly related to THMs but with unmeasured DBPs correlated with their formation [32].

A further weakness of the ecological design is that people often change their residence and hence their exposure status, if DBP concentration varies spatially (which was true in our case and necessary to the ecological design). Australian Census data for 2007 show

that 80% of people in NSW did not change their residential address in the previous year, 6% moved to another address in the same Statistical Local Area (SLA) (SLAs are the same as or, for a small number of cases, subsets of LGAs), and 14% moved a greater distance [33]. For the previous five years, 55% of people did not change their residential address, 13% moved to another address within the same SLA and 32% moved a greater distance [34]. We did not take into account the exposure misclassification which might have resulted from this population mobility.

The main strengths of our study are the use of estimated annual mean concentrations of THM species for small areas, albeit often with missing data; a lag period between exposure and outcome; and more advanced statistical methods. No previous study of this type has used exposure data at this level of detail or specificity (monthly measurement of THMs), or used a lag period in the analysis [35-40]. Annual exposure estimates and disease rates, and a lag period may be quite important because THM concentrations in water vary over time due to factors such as changes in disinfection practice (e.g., change from chlorination to chloramination and change in the chlorine to ammonia ratio), installation of filters in water treatment plants, rechlorination practices throughout the distribution systems and change in environmental conditions (drought breaking rains triggered the increase in brominated trihalomethanes and chloroform concentration around 1998) [9].

Another strength are the analytical methods used which included Poisson variability, spatial random effects and within-area variability of exposure that permitted control for pure specification bias. Previous ecological analyses of associations of DBPs with cancer risk have used only correlation coefficients or simple linear regression. Correlation coefficients mix the strength (size) and precision of an association, whereas the regression coefficient reports them separately. Simple linear regression using rate as the outcome is prone to several problems. First, the assumption of homoscedasticity (that is, the error term of the regression model has a constant standard deviation that does not depend on the value of the outcome) is a particular issue for studies that have used unweighted linear regression. Generally, small areas have unstable rates and including them in a regression model without taking account of this factor can cause unpredictable bias. Second, simple linear regression assumes independence of spatial units, such that there would be no clustering of adjacent areas with similar rates, which is unlikely. Third, least squares estimators assume that the rates or log of the rates are normally distributed, whereas we would generally expect rates in small areas to have a Poisson distribution. The analytical methods we have used address all of these issues; thus our results are more likely to faithfully reflect

the reality than results based on linear regression. In addition, our methods have allowed us to largely rule out within area variability and spatial autocorrelation as explanations for the positive associations we observed between bromoform concentrations and colon cancer.

To our knowledge, this is the first study in which the associations between colon and rectal cancers and THM species concentrations in drinking water have been examined. The finding of a relationship between bromoform and colorectal cancer might be dismissed as being a chance finding, given the multiple testing. However, some recent results suggest otherwise. In a case-control study of rectal cancer in men, Bove and co-workers [1] found a positive association of rectal cancer with bromoform (OR 1.20, 95% CI 1.05, 1.35). Like us, Bove and co-workers [1] found no association of rectal cancer with chloroform or total THMs. While it is possible that the lack of an association between rectal cancer incidence and bromoform in our study could be due to the short lag period, since 'low-level' environmental exposures may require several decades to cause a detectable effect on cancer risk [27,41], it might also be due to lack of statistical power, since we did find an association with colon cancer. The only other study of the association of colon or rectal cancers with a specific THM found a positive association of chloroform with colon cancer (RR 1.68, 95% CI 1.11, 2.53), but not rectal cancer (RR 1.07, 95% CI 0.60, 1.93), in postmenopausal women; other species of THMs were not examined [42]. We found no evidence of such an association in either men or women.

Our recent meta-analysis of cohort and case-control studies of total THM exposure and colon and rectal cancers [8] found that risks of both were increased in the highest category of exposure relative to the lowest: colon cancer OR 1.33 (95% CI 1.12, 1.57) and rectal cancer OR 1.30 (95% CI 1.06, 1.59). These results suggest that THMs may increase the risk of both colon and rectal cancer and that if the effect is specific to a particular species of THM that species is a large component of the total or it has a strong effect. The former, at least, is not true for bromoform [28,43]. There were too few sex-specific results to see if there were risk differences by sex of colon or rectal cancers with THM exposure in the meta-analysis.

Expert evaluation of the evidence has concluded there is limited evidence for the carcinogenicity of bromoform in experimental animals. This evaluation, however, was made in 1999 and was based on only one relevant experimental study [29]. With respect to the other THM species, there was considered to be sufficient evidence for the carcinogenicity of chloroform [44] and bromodichloromethane [45] in experimental animals, when evaluated in 2005, but only limited evidence for

dibromochloromethane [46] (evaluated in 1999). Some individual studies, however, have found that brominated trihalomethanes (bromoform, bromodichloromethane and dibromochloromethane) are more carcinogenic than chloroform [47,48]. In our study, both bromodichloromethane and dibromochloromethane were more strongly positively associated with colorectal cancer, or just colon cancer in men, than were chloroform or total THMs. The IRRs for all brominated trihalomethanes in men were 1.072 (95% CI 1.033, 1.113) for colon cancer and 1.080 (95% CI 1.031, 1.131) for rectal cancer (not shown in the analysis). Considered together the experimental and epidemiological results suggest that further investigation of the associations of brominated trihalomethanes with colon and rectal cancers is warranted.

While causality between THM exposure and colorectal cancer has not been established, most people in developed countries, drink water containing THMs. Therefore, a small association projected across the globe could translate into a large number of cases. Thus the reason the associations between THMs, and particularly bromoform, and colon and rectal cancers should be investigated further in higher quality epidemiological studies.

Since the existing epidemiological studies provide some, although weak evidence, that the effects of different THM species could differ by sex and cancer site, future studies should measure individual species of THMs and study the effects on men and women with regard to colon and rectal cancers separately. The studies should be sufficiently powered to detect small associations, as that small association could translate into an important number of cases.

Conclusion

We found weak evidence of a positive association between incidence of colorectal cancer in men and total THM concentration in water supplies and a somewhat stronger association for bromoform concentration. This was primarily because of an association of colon cancer incidence in men and bromoform concentration. Although an association of rectal cancer in men with bromoform concentration has been observed previously, the association we observed with colon cancer has not been previously reported. The inconsistency of these observations by cancer type and the ecological study design prevent inference of causation. However, the potential population impact of such an association justifies further research into the effects of THMs in drinking water, particularly the brominated species, and colorectal cancer.

Additional files

Additional file 1: SWC Distribution Systems and LGA coverage.

Additional file 2: Sensitivity analysis of values below the detection limit.

Abbreviations

ABS: Australian Bureau of Statistics; CRC: Colorectal cancer; DBP: Disinfection by-products; DIC: Deviance information criterion; DL: Detection limit; HWC: Hunter Water Corporation; IQR: Inter-quartile range; IRR: Incidence rate ratio; IRSD: Index of relative socio-economic disadvantage; LGA: Local government area; MCMC: Markov Chain Monte Carlo; NSW: New South Wales; SEIFA: Socio-Economic Indexes for Areas; SES: Socio-Economic Status; SLA: Statistical Local Area; SWC: Sydney Water Corporation; THM: Trihalomethane.

Competing interests

T Driscoll, C Cowie and B Armstrong were recipients of a contract from the Sydney Water Corporation to study the health of sewer workers and MB Rahman worked on the contract. Sydney Water Corporation has assisted their research by giving them access to results of routine measurements of water quality, including concentrations of disinfection by-products.

Authors' contributions

BR conceived the study, conducted the analyses and drafted the manuscript. CC conceived the study and contributed drafting the manuscript. TD conceived the study and proof read the manuscript. RS collected and collated some of the information for the study and contributed drafting some parts of the manuscript. BA conceived, designed and planned the study, help conducting the study and revised the manuscript. MC supervised all the analyses and conducted some of the analyses and proof read the manuscript. All authors read and approved the final manuscript.

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Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Monday, March 09, 2015 2:10 PM
To: donna. cole; gdn2@aol.com; James Henry; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Laura Sullivan; Mike Lane; Prysby, Mike (DEQ); Norb Birchmeier; Pete Levine; Russell Hudson; JoAnne Herman; Michael Glasgow; Daugherty Johnson; Brent Wright; Warren Green; Samir Matta; Robert Nicholas
Subject: Literature
Attachments: Bottled Water NRDC.pdf; CA study on THMs and pregnancy.pdf; Egorov-ExpDBPsRussia-Proofs.pdf; Guidance for People with Severely Weakened Immune Systems.pdf; KrasnerWright-DBPBoil-WatRes2005.pdf; TTHM fact sheet (1).pdf; vulnerable to drinking water.pdf; ycn-infection-safedrinkingwaterguidelines-sept2004.pdf

All,

I am sending out the literature that I received from Dr. Rose and from Mr. Wright of the EPA. There is a lot of information to go through here and we will attempt to put together a new fact sheet from these documents.

We are working on a cover letter that will be mailed out with the DEQ notice and I still intend to send a draft copy to this group prior to the mailer going out. We are targeting this Wednesday to have the letter ready for preview (along with a fact sheet) and we will potentially mail it out by this weekend or next Monday if the notice has been received.

Thank you,

--

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Bottled Water : Pure Drink or Pure Hype?. By Erik D. Olson. April 1999

Bottled Water Pure Drink or Pure Hype?

[Report page](#)

Chapter 3

Bottled Water Contamination: An Overview of NRDC's and Others' Surveys

Setting aside the question of whether bottled water is as pure as advertised, is the public's view that bottled water is safer than tap water correct? Certainly the aggressive marketing by the bottled water industry would lead us to believe so.

NRDC undertook a four-year, detailed investigation to evaluate the quality of bottled water. We reviewed published and unpublished literature and data sources, wrote to and interviewed by phone all 50 states asking for any surveys of bottled water quality they have conducted or were aware of, and interviewed experts from FDA. In addition, through three leading independent laboratories, we conducted "snapshot" testing of more than 1,000 bottles of water sold under 103 brand names.

What NRDC has found is in some cases reassuring and in others genuinely troubling. The results of all testing NRDC conducted is presented in Appendix A; [Figure 4](#) summarizes the results.

The bottled water industry generally has publicly maintained that there are no chemical contaminants in bottled water. For example, as noted in Chapter 2, a widely disseminated fact sheet on bottled water distributed by the International Bottled Water Association (IBWA) -- the industry's trade association -- states flatly that bottled water contains no chlorine or harmful chemicals. ⁽²⁵⁾

However, our investigation has found that potentially harmful chemical contaminants are indeed sometimes found in some brands of bottled water. (*The [box](#) at the end of this chapter highlights a particularly troubling example.*) NRDC's testing of more than 1,000 bottles of water (for about half of FDA-regulated contaminants; see the *Technical Report* [print report only]), found that at least one sample of 26 of the 103 bottled water brands tested (25 percent) contained chemical contaminants at levels above the strict, health-protective limits of California, the bottled water industry code, or other states⁽²⁶⁾ (23 waters, or 22 percent, had at least one sample that violated enforceable state limits). We found only two waters that violated the weaker federal bottled water standards for chemicals (in two repeat samples), and two waters that violated the federal standards for coliform bacteria in one test (though another batch of both of those waters tested clean for bacteria). The *Technical Report* (print report only) also discusses evidence provided by other investigators who in the past found that chemical contaminants were found in bottled water at levels violating the federal bottled water standards. ⁽²⁶⁾

Thus, in our limited bottled water testing, while strict health-protective *state* limits for chemicals sometimes were not met by about one fourth of the waters, the weaker *federal* bottled water standards generally were not violated. As noted in Table 2, among the chemical contaminants

of greatest potential concern in bottled water are volatile organic chemicals, arsenic, certain other inorganic chemicals, and plastic or plasticizing compounds. Although most bottled water contained no detectable levels of these contaminants, or contained levels of the contaminants lower than those found in many major cities' tap water, we determined that one cannot assume on faith, simply because one is buying water in a bottle, that the water is of any higher chemical quality than tap water.

Table 2: Selected Contaminants of Potential Concern for Bottled Water

Contaminant	Health Concern with Excess Levels
Coliform Bacteria	Broad class of bacteria used as potential indicator of fecal contamination; may be harmless of themselves. Harmful types of coliform bacteria (such as certain fecal coliform bacteria or <i>E. coli</i>) can cause infections with vomiting, diarrhea, or serious illness in children, the elderly, and immunocompromised or other vulnerable people.
Heterotrophic Plate Count (HPC) Bacteria	Potential indicator of overall sanitation in bottling and source water; may be harmless of themselves. In some cases may indicate presence of infectious bacteria; data show sometimes linked to illnesses. Can interfere with detection of coliform bacteria or infectious bacteria. Unregulated by FDA.
<i>Pseudomonas aeruginosa</i> bacteria	Possible indicator of fecal contamination or unsanitary source water or bottling. Can cause opportunistic infections. Unregulated by FDA.
Arsenic	Known human carcinogen. Also can cause skin, nervous, and reproductive or developmental problems.
Nitrate	Causes "blue baby" syndrome in infants, due to interference with blood's ability to take up oxygen. Potential cancer risk.
Trihalomethanes (i.e., chloroform, bromodichloromethane, dibromochloromethane, and bromoform)	Cancer of the bladder, colorectal cancer, possibly pancreatic cancer. Also concerns about possible birth defects and spontaneous abortions.
Phthalate (DEHP)	Cancer; possible endocrine system disrupter. Unregulated by FDA.

Source: NRDC

NRDC Testing Methodology

NRDC began during the summer of 1997 to test bottled water quality and continued testing or retesting some brands through early 1999. Our testing methodology is summarized in [Table 3](#), and described in greater detail in the accompanying *Technical Report* (print report only). We conducted a four-pronged testing program, using three of the nation's most respected laboratories: two major independent commercial labs and one academic laboratory. In this four-

pronged testing program, we tested water sold in the five states with the highest bottled water consumption in 1994 (California, Florida, Illinois, New York, and Texas), plus bottled water sold in the District of Columbia. ^[77] We tried to test major brands that held a significant percentage of the national or regional market share (for those brands for which market-share information was available), and we strove to purchase a variety of other brands and types of water, including the major bottled water products offered by some of the leading supermarket chains in the areas where the water was purchased.

The first prong of our survey was a preliminary screening of 37 California bottled waters in the summer and fall of 1997. The second involved detailed testing of 73 California waters in late 1997 and early 1998. The third was a survey of five bottled waters from each of five states other than California (a total of 25 waters) in late 1997 and early 1998. The final prong involved retesting more than 20 in which contamination had been found in earlier tests, which took place in mid- to late-1998 and early 1999.

We sampled the most waters from California, whose residents are by far the greatest consumers of bottled water in the nation. More bottled water is purchased in California than in the next five largest consuming states combined (see [Figure 3](#)). California generally has the most stringent standards and warning levels applicable to bottled water in the nation.

All of the labs we contracted with used standard EPA analytical methods for testing water. We conducted "snapshot" testing -- that is, we purchased several bottles of a single type of water, at a single location, and had those bottles tested. If we found a problem, we generally repurchased and then retested the water to confirm the earlier results. ^[78] Our testing methodology is summarized in Table 3, and described in greater detail in the accompanying *Technical Report* (print report only).

We asked the labs to use their standard contaminant test packages in order to control the total testing costs. In general, this meant that the labs tested for many of the most commonly found regulated contaminants, plus certain other contaminants that they could readily detect and quantify using the standard EPA methods and the analytical equipment they routinely use. Thus, some labs were able to detect more contaminants than others, though all tested for a core set of more than 30 regulated contaminants.

Table 3: Summary of Lab Testing Protocols

Lab	# of Brands of Water Tested	Number of Contaminants Tested	General Testing Protocol	Comments
Environmental Quality Institute (Univ. N.C.)	37	41 regulated, over 40 unregulated	EPA analytical methods, single bottle sampled per contaminant type	Initial screening of California waters to determine whether more in-depth testing needed.

Table 3: Summary of Lab Testing Protocols

Lab	# of Brands of Water Tested	Number of Contaminants Tested	General Testing Protocol	Comments
Sequoia Analytical	73	32 regulated, over 40 unregulated	EPA analytical methods, FDA protocol for sampling (test 1 composite sample of 10 bottles for chemical and microbial contaminants; 10 individual bottles tested for microbial follow-up if excess bacteria found in first round)	More extensive testing of California waters only.
National testing	25	57 regulated, over 200 unregulated	EPA analytical methods, FDA protocol for sampling (test 1 composite sample of 10 bottles; 10 individual bottles of all tested for bacteria)	Testing of waters from 5 states outside of California (NY, FL, TX, IL, and DC).

Summary of Results of NRDC Testing

NRDC testing: the good news

First, the good news: Most brands of bottled water we tested were, according to our "snapshot" analyses of a subset of regulated contaminants, of relatively good quality (i.e., they were comparable to good tap water). Most waters contained no detectable bacteria, and the levels of synthetic organic chemicals and inorganic chemicals of concern for which we tested were either below detection limits or well below all applicable standards.

Caveats. This is not to say that all of these brands are without risk. One of the key limitations of the testing is that most tests were done just once or twice, so we could have missed a significant but intermittent problem. Numerous studies of source-water quality -- particularly surface-water sources and shallow groundwater sources -- demonstrate that source-water quality may substantially vary over time. ^[29] Operation, maintenance, or other mishaps at a bottling plant may cause periodic water-contamination problems that would not be detected by such "snapshot" tests. Thus, depending upon the bottler's source water, treatment technology (if any), and manufacturing, operation, and maintenance practices, some bottled waters' quality may vary substantially with time and with different production runs.

In addition, while we did test for dozens of contaminants at a cost of from about \$400 to about \$1,000 per type of water per round of testing (depending on the intensity of the testing), we were unable to test for many contaminants that may be of health concern. Thus, as is discussed in the accompanying *Technical Report* (print report only), we were unable to test for many kinds of bacteria, parasites, radioactivity, and toxic chemicals regulated by EPA and FDA in tap water or bottled water because such testing would have been even more expensive or difficult. Still,

with those caveats, many bottled waters do appear to be of good quality, based on our limited testing.

NRDC testing: the bad news

For some other bottled waters, the story is quite different. The independent labs that conducted testing for NRDC found high levels of heterotrophic-plate-count bacteria in some samples, and in a few cases coliform bacteria (no coliforms were found in retests of different lots of the same water). The labs also found that some samples contained arsenic (a carcinogen) and synthetic organic chemicals (SOCs, i.e., man-made chemicals containing hydrogen and carbon), such as those contained in gasoline or used in industry. SOCs found included the probable human carcinogen phthalate (likely from the plastic water bottles), and trihalomethanes (cancer-causing by-products of water chlorination, which have been associated with birth defects and spontaneous abortions when found in tap water at high levels).^[32]

A detailed review of all our testing results and those of other investigators is presented in the accompanying *Technical Report* (print report only), and the actual results for each brand of bottled water we tested are presented in Appendix A. In summary, our testing of 103 types of water found:

- **Violations of state standards.** At least one sample of about one fourth of the bottled waters bought in California (23 waters, or 22 percent) violated enforceable state limits (either bottled water standards or mandatory warning levels).
- **Violations of federal bottled water quality standards (coliform bacteria and fluoride).** Based on limited testing, four waters violated the weak federal bottled water standards (two for coliform bacteria that on retest contained no coliforms, and two for fluoride that were confirmed on retest to contain excessive fluoride). Coliform bacteria in water may not be dangerous themselves, but they are widely used as an indicator that may signal the presence of other bacteria or pathogens that could cause illness. Fluoride at excessive levels can cause mottling or dental fluorosis (pitting of teeth), skeletal fluorosis (adverse effects on bones), and cardiovascular and certain other health effects.^[33]
- **Arsenic contamination.** Arsenic is a "known human carcinogen" when in drinking water; it also can cause many other illnesses, including skin lesions, nervous-system problems, and adverse reproductive and cardiovascular effects (the precise levels in drinking water necessary to cause these effects are the subject of heated debate).^[34] Our testing found that one or more samples of eight waters (8 percent) purchased in California exceeded the 5 ppb warning level for arsenic set under California's Proposition 65, a law requiring public warnings if a company exposes people to excessive levels of toxic chemicals.^[35] (See [Figure 5.](#))
- **Trihalomethane violations.** Trihalomethanes (THMs) are a family of chemicals created when chlorine is used to disinfect water (chlorine reacts with organic matter in the water to form THMs and other byproducts). Studies of people and animals exposed to THMs in their tap water have found elevated risks of cancer^[36] and potentially a higher risk of spontaneous abortions and birth defects.^[37] California has adopted a 10 ppb total THM

limit, a standard recommended by the International Bottled Water Association (IBWA), the bottled water industry trade association. Twelve waters (12 percent) purchased in California had at least one sample that violated the state and IBWA bottled water standard for THMs in the same fashion. (See [Figure 6](#).) Two waters sold in Florida exceeded the IBWA standard (Florida repealed its 10 ppb TTHM standard in 1997), and one sold in Texas violated the IBWA standard (Texas has not made the stricter 10 ppb standard enforceable). Chlorinated tap water also typically contains THMs (generally at levels above 10 ppb if the water is chlorinated), though many people who buy bottled water to avoid chlorine and its taste, odor, and by-products may be surprised to learn THMs are sometimes found in bottled water as well.

- **Excessive chloroform** Chloroform is the most common THM found in tap and bottled water; it is of particular concern because it is listed by EPA as a probable human carcinogen. Twelve waters purchased in California had at least one sample that exceeded the warning level for chloroform (a trihalomethane) set by California under Proposition 65, but they were sold without the required health warning (see Appendix A).
- **Excessive bromodichloromethane (BDCM).** BDCM is another THM that EPA has listed as a probable human carcinogen. Ten waters we bought in California that contained unlawful TTHM levels also had at least one sample that exceeded the Proposition 65 warning level for bromodichloromethane. These waters all were sold with no health warning that they contained BDCM at a level above the Proposition 65 level.
- **Excessive heterotrophic-plate-count (HPC) bacteria.** HPC bacteria are a measure of the level of general bacterial contamination in water. HPC bacteria are not necessarily harmful themselves, but they can indicate the presence of dangerous bacteria or other pathogens and are used as a general indication of whether sanitary practices were used by the bottler. Nearly one in five waters tested (18 waters, or 17 percent) had at least one sample that exceeded the unenforceable microbiological-purity "guidelines" adopted by some states for HPC bacteria (500 colony-forming units, or cfu, per milliliter). (See [Figure 7](#).) These states use unenforceable HPC-bacteria "guidelines" to measure bacterial contamination and sanitation. These state guidelines actually are weaker than voluntary HPC guidelines used by the industry trade association to check plant sanitation. (200 cfu/ml in 90 percent of samples taken five days after bottling), and are weaker than the European Union (EU) standard (100 cfu/ml, at bottling at 22 degrees Celsius).
- **Elevated nitrates, but at levels below standards.** Nitrates can be present in water as a result of runoff from fertilized fields or lawns, or from sewage; nitrates also may occur naturally, generally at lower levels. At elevated levels, nitrates can cause blue-baby syndrome -- a condition in infants in which the blood has diminished ability to take up oxygen, potentially causing brain damage or death; according to some, nitrates may be linked to cancer in adults. ^[64] The EPA and FDA standard for nitrates is 10 parts per million (ppm). There is spirited debate about whether these standards are sufficient to protect all infants in light of some studies suggesting ill effects at lower levels, ^[65] but both EPA and the National Research Council maintain that the current standard is adequate to protect health. ^[66] We found six bottled waters that had at least one sample containing more than 2 ppm nitrates; four of these had at least one sample containing more than 3 ppm nitrates (two contained up to 5.6 ppm nitrates in at least one test). (See Table 4.) Four of the six waters containing higher nitrate levels were mineral waters. The U.S. Geological Survey says that nitrate levels in excess of 3 ppm may indicate human-caused nitrate

contamination of the water, ⁽⁸²⁾ although it may be that some mineral waters naturally contain higher nitrate levels. To be safe, babies probably should not be fed with mineral water containing elevated nitrate levels.

Table 4: Selected Nitrate Levels Found in Bottled Waters

Bottled Water Brand	Nitrate Level (as Nitrogen, in ppm)	(First Test)	Nitrate Level (as Nitrogen, in ppm)	(Subsequent Tests, If Any)
Fiuggi Natural Mineral Water	2.5			
Hildon Carbonated Mineral Water	5.6	5.4		
Hildon Still Mineral Water	5.6			
Perrier Sparkling Mineral Water	2.8, 2.6	4.3, 4.1		
Sahara Mountain Spring Water	2.5			
Sparkling Springs	3.1			
Source: NRDC, 1997-1999				

- **No fecal coliform bacteria or *Pseudomonas aeruginosa*.** Although, as noted previously, we did find total coliform bacteria in a few samples, no fecal coliform bacteria or *E. coli* bacteria were found. Earlier studies have found multiple species of the bacteria *Pseudomonas* in bottled water. ⁽⁸³⁾ However, in an effort to control costs, we looked only for the species *Pseudomonas aeruginosa* and found none.
- **Synthetic organic chemicals at levels below enforceable standards.** About 16 percent of the waters (16 of 103) had at least one sample that contained human-made synthetic organic chemicals (SOCs) at levels below state and federal standards. The most frequently found SOC were industrial chemicals (e.g., toluene, xylene, and isopropyltoluene), and chemicals used in manufacturing plastic (e.g., phthalate, adipate, and styrene). As discussed in the accompanying *Technical Report* (print report only), some of the chemicals found (such as phthalate) may pose health risks such as potential cancer-causing effects, even if present at relatively low levels. Generally, long-term consumption (over many years) is required to pose such chronic risks. The levels of these contaminants found in our testing are indicated in Table 5.
- **Overall contamination findings** Overall, at least one sample of about one third of the tested waters (34 waters, or 33 percent) contained significant contamination (i.e., contaminants were found at levels in excess of standards or guidelines). This is not simply the sum of the waters that violate enforceable standards plus those that exceeded guidelines, as some waters violated both.

- The detailed results of our testing for each type of water are presented in the *Technical Report* (print report only). As is discussed there, testing by states and by academic researchers have also sometimes found the contaminants we studied or other potentially toxic and infectious agents in some brands of bottled water.

TABLE 5 Selected Synthetic Organic Compounds (Other Than THMs) in Bottled Water				
Bottled Water (& State of Purchase)	Xylene Level (ppb)	Toluene Level (ppb)	Other VOCs Found (in ppb)	Comments
Alhambra Crystal Fresh Drinking Water (CA)	2.7 (test 1) 0 (test 2)	12.5 (test 1) Not Detected (test 2)	Not Detected (tests 1 & 2)	Xylene and toluene below FDA & CA standards, but presence could indicate treatment standard violation.
Black Mountain Spring Water (CA)	Not Detected (tests 1-3)	8.9 (test 1) Not Detected (tests 2 & 3)	Not Detected (tests 1 & 2)	Toluene below FDA and CA standards, but presence could indicate treatment standard violation.
Lady Lee Drinking Water (Lucky, CA)	2.9 (test 1) Not Detected (test 2)	11.0 (test 1) 0.5 (test 2)	Not Detected (tests 1 & 2)	Xylene and toluene below FDA & CA standards, but presence could indicate treatment standard violation.
Lady Lee Natural Spring Water (Lucky, CA)	3.0 (test 1) Not Detected (test 2) 0 (test 3)	13.9 (test 1) Not Detected (test 2) 0.5 (test 3)	Not Detected (tests 1 & 2)	Xylene and toluene below FDA & CA standards, but could indicate CA treatment standard violation.
Lady Lee Purified Water (Lucky, CA)	9.4 (test 1) Not Detected (test 2)	9.5 (test 1) Not Detected (test 2)	Ethylbenzene 2.0 ppb (test 1) Ethylbenzene not detected (test 2) Ethylbenzene not detected (test 3) Methylene Chloride 4.1 ppb (test 3)	Xylene, toluene, methylene chloride, and ethylbenzene below FDA & CA standards, but could indicate CA treatment standard violation. Methylene chloride standard is 5 ppb.
Lucky Sparkling Water (w/raspberry)(CA)	Not Detected	Not Detected	p-isopropyltoluene 5.4 ppb	Single test; no standard for p-isopropyltoluene.
Lucky Seltzer Water (CA)	Not Detected (tests 1 & 2)	Not Detected (test 1) 1.8 (test 2)	n-isopropyltoluene at 230 ppb (test 2) n-butylbenzene at 21 ppb (test 2) Neither detected in test 1	Source of elevated level of n- isopropyltoluene and of n- butylbenzene contamination unknown; no standards apply.

Dannon Natural Spring Water (NY)	Not Detected (tests 1-3)	Not Detected (tests 1-3)	Methylene chloride at 1.5 ppb (test 3) Methylene chloride not detected in tests 1 & 2	FDA's Methylene chloride (dichloromethane) standard is 5 ppb.
Nursery Water (CA)	3.2 (test 1) Not Detected (test 2)	12.4 (test 1) 0.6 (test 2)	Styrene 3.0 (test 1) Not Detected (test 2)	Xylene, toluene, and styrene below FDA & CA standards, but could indicate CA treatment standards violation.
Perrier Mineral Water (CA)	Not Detected (tests 1-3)	Not Detected (tests 1-3)	2-Chlorotoluene 4.6 ppb (test 1) 2-Chlorotoluene 3.7 ppb (test 2) 2-Chlorotoluene Not Detected (test 3)	No standard for 2-chlorotoluene; contamination from unknown source.
Polar Spring Water (DC)	Not Detected	2.5	Not Detected	Toluene detected at level below FDA standard (single test).
Publix Drinking Water (FL)	Not Detected (tests 1-3)	Not Detected (tests 1-3)	Acetone 11 ppb (test 1) Acetone 14 ppb (test 2) Acetone 16 ppb (test 3) Styrene 0.6 ppb (test 1) (No styrene found tests 2-3)	Styrene found at level well below EPA Health Advisory level; no standard or Health Advisory for acetone.
Publix Purified Water (FL)	Not Detected	Not Detected	Styrene 0.2 ppb	Styrene found at level well below EPA Health Advisory level (single test).
Safeway Purified Water (CA)	Not Detected (tests 1 & 2)	8.4 (test 1) Not Detected (test 2)		Toluene detected at level below FDA and state standard, but could indicate CA treatment standard violation.
Safeway Spring Water (CA)	3.1 (test 1) Not Detected (test 2)	14.2 (test 1) Not Detected (test 2)		Xylene and toluene below FDA & CA standards, but could indicate CA treatment standard violation.
Safeway Spring Water (DC)	Not Detected	4.7		Single test, toluene below FDA standard.

Source: NRDC 1997-1999

Other Surveys of U.S. Bottled Water Quality

Relatively little information about bottled water quality is readily available to consumers. Few surveys of bottled water quality have been conducted in the United States during the past four years, and fewer still are widely available.

A handful of state governments have done surveys in recent years. Kansas has done a small survey of certain waters sold in the state, ^[90] Massachusetts prepares an annual summary of industry testing of waters sold in that state, ^[91] and New Jersey issues an annual summary, primarily of industry testing of water sold there. ^[92] In addition, Pennsylvania periodically issues a small state survey of waters sold locally, ^[93] and Wisconsin issues a small annual testing of about a dozen state waters. ^[94] In general, these states have reached conclusions similar to those we have reached: that most bottled water is of good quality but that a minority of the bottled water tested contains contaminants such as nitrates or synthetic organic chemicals, in a few cases at levels of potential health concern. These surveys are summarized in detail in the *Technical Report* (print report only).

A few academicians have published papers focusing on bottled water contamination from specific types of contaminants. For example, academic studies have focused on *Pseudomonas* bacteria in various brands of bottled water, ^[95] the leaching of chemicals from plastic manufacturing (such as phthalates) ^[96] from plastic bottles into the water, or contamination of bottled water with certain volatile synthetic organic compounds. ^[97] The researchers often tested only a relatively small number of brands of water, or failed even to name which bottled water was tested, making the information of limited value to consumers seeking to select a brand of water that is uncontaminated. Comprehensive studies of Canadian bottled waters also have been published -- without naming the brands with problems. The results of many of these studies are in the *Technical Report* (print report only), which presents in greater detail the evidence of microbiological and chemical contamination of bottled water.

Potential for Disease from Bottled Water

As is discussed in the accompanying *Technical Report* (print report only), there is no active surveillance for waterborne disease from tap water in the United States, nor is there active surveillance of potential disease from bottled water. There are certain "reportable" diseases, such as measles, which are reportable to CDC and state health departments, and for which there is active surveillance. Most diseases caused by organisms that have been found in bottled water, however, are not reportable, and in any event may come from a variety of sources, so the amount of disease from microbiologically contaminated bottled water (or tap water) is unknown. Thus, since no one is conducting active surveillance to determine if waterborne illnesses are occurring, even if waterborne illness from bottled water were relatively common, it would be unlikely that it would be noticed by health officials unless it reached the point of a major outbreak or epidemic.

There are cases of known and scientifically well-documented waterborne infectious disease from bottled water, but most have occurred outside of the United States (see *Technical Report* [print report only] and Appendix B). However, there clearly is a widespread potential, according to independent experts, for waterborne disease to be spread via bottled water. ^[98]

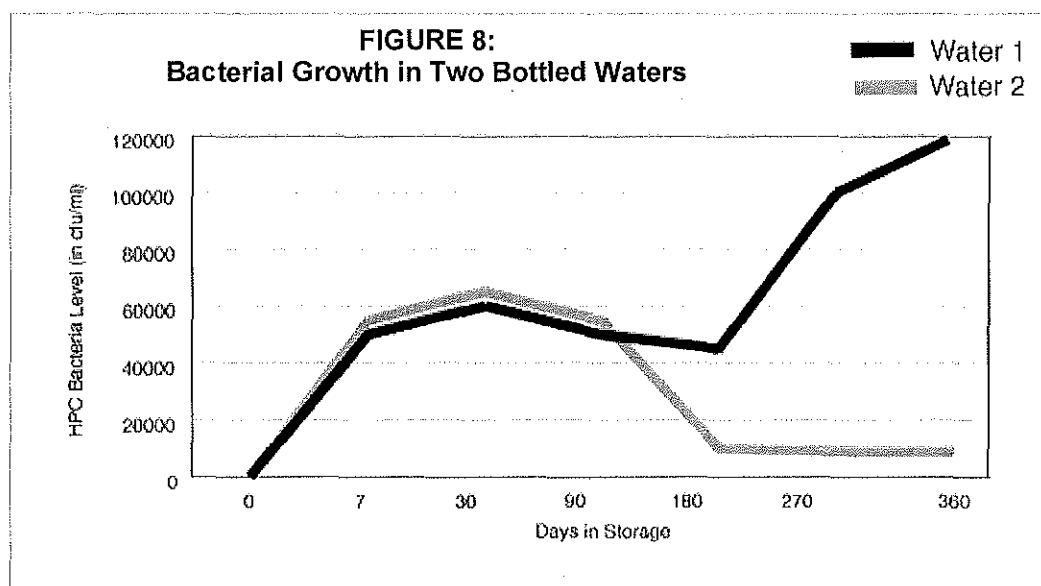
Bottled Water and Vulnerable Populations

Many people who are especially vulnerable to infection (such as the infirm elderly, young infants, people living with HIV/AIDS, people on immunosuppressive chemotherapy, transplant patients, etc.) use bottled water as an alternative to tap water out of concern for their safety. Some leading public-health experts, therefore, argue that bottled water should be of higher microbiological quality than most foods. ^[99] In fact, health-care providers and other professionals often recommend that people who are immunocompromised or who suffer from chronic health problems drink bottled water. Indeed, FDA's guidance for immunocompromised people (posted on the FDA Web site) recommends that people with lowered immunity should "drink only boiled or bottled water. . . ." ^[99]

Immunocompromised people often are not aware of the need to ensure that they are drinking microbiologically safe water or are vaguely aware of this issue but simply switch to bottled water on the assumption that it is safer than tap water. As discussed previously and in detail in the accompanying *Technical Report* (print report only), this may not be a safe assumption.

Bottled Water Storage and Growth of Microorganisms

Bottled water often is stored at relatively warm (room) temperatures for extended periods of time, generally with no residual disinfectant contained in it. As noted in the *Technical Report* (print report only) and shown in Figure 8, several studies have documented that there can be substantial growth of certain bacteria in bottled mineral water during storage, with substantial increases in some cases in the levels of types such as heterotrophic-plate-count-bacteria and *Pseudomonas*. ^[100] Studies also have shown that even when there are relatively low levels of bacteria in water when it is bottled, after one week of storage, total bacteria counts can jump by 1,000-fold or more in mineral water. ^[101]



Source: Adapted from P.V. Morais and M.S. Da Costa, "Alterations in the Major Heterotrophic Bacterial Populations Isolated from a Still Bottled Mineral Water," *J. Applied Bacteriol.*, v. 69 pp. 750-757, Figure 1 (1990).

Conclusions Regarding Bottled Water Contaminants

Our limited "snapshot" testing, and that published in a few other recent surveys of bottled water, indicate that most bottled water is of good quality. However, our testing also found that about one fourth of the tested bottled water brands contained microbiological or chemical contaminants in at least some samples at levels sufficiently high to violate enforceable state standards or warning levels. About one fifth of the brands tested exceeded state bottled water microbial guidelines in at least some samples. Overall, while most bottled water appears to be of good quality, it is not necessarily any better than tap water, and vulnerable people or their care providers should not assume that all bottled water is sterile. They must be sure it has been sufficiently protected and treated to ensure safety for those populations.

An Example of Industrial-Solvent Contamination of Bottled Water ^[102]

One particularly troubling case of industrial-chemical contamination of bottled water arose in Massachusetts. Massachusetts Department of Public Health files reveal that the Ann & Hope commercial well in Millis, Massachusetts, for years supplied several bottlers, including Cumberland Farms, West Lynn Creamery, Garelick Farms, and Spring Hill Dairy with "spring water" sold under many brand names.

According to state officials and records, this well is located literally in a parking lot at an industrial warehouse facility and is sited near a state-designated hazardous-waste site. Several chemical contaminants were found in the water, including trichloroethylene (an EPA-designated probable human carcinogen). On at least four occasions these chemicals were found at levels above EPA and FDA standards in the well water. Dichloroethane, methylene chloride, and other synthetic organic chemicals (industrial chemicals) were also found, though the source of these contaminants reportedly was not identified.

Contamination was found in the water in 1993, 1994, 1995, and 1996, but according to a state memo written in 1996, "at no time did Ann & Hope [the well operating company] do anything to determine the source of the contamination nor treat the source. Rather, they continued to sell water laced with volatile organic compounds, some of which were reported in finished

product." The contamination levels depended on pumping rates from the wells. After a state employee blew the whistle on the problem and demanded better protection of bottled water in the state, she was ordered not to speak to the media or bottlers and was reassigned by Massachusetts Department of Public Health supervisors to other duties, in what she alleges was a retaliatory action. State officials deny that her reassignment was due to retaliation. The well reportedly is no longer being used for bottled water after the controversy became public.

Chapter Notes

3a. For cost reasons, we did not test for any radiological contaminants.

3b. Throughout this report and the attached Technical Report (print report only) we refer to two categories of chemicals for which we tested, semivolatile synthetic organic chemicals and volatile organic chemicals (VOCs). Technically, synthetic organic chemicals (SOCs) include any man-made chemicals—including nonvolatile, semivolatile, and volatile—that contain hydrogen and carbon. We, EPA, and FDA refer to VOCs as a shorthand for volatile synthetic organic chemicals, and to semivolatile SOCs as separate types of chemicals, even though many VOCs are also a type of SOC. The reason for differentiating between these two categories of contaminants is that EPA standard methods for testing for them are different, and because both EPA and FDA rules tend to artificially distinguish between VOCs and SOCs—the later being shorthand for semivolatile SOCs.

3c. None of the waters we tested exceeded the FDA and EPA standard for arsenic in water of 50 ppb. That standard originally was set in 1942 and is 2,000 times higher than the level EPA recommends for ambient surface water for public-health reasons; it also is 5 times higher than the World Health Organization and European Union arsenic-in-drinking-water limit. Congress has required that the EPA standard be updated by the year 2001. For reasons discussed in the accompanying Technical Report (print report only), many public health, medical, and other experts believe that the current EPA/FDA standard is far too high.

Report Notes

75. IBWA, "FAQs [Frequently Asked Questions] About Bottled Water," (1998); available at www.bottledwater.org/faq.html#3.

76. See, e.g., "The Selling of H₂O," *Consumer Reports*, p. 531 (September 1980), (finding excessive arsenic in several waters); "Water, Water Everywhere," *Consumer Reports*, pp. 42-48 (January 1987), (also finding excessive arsenic in several waters); see also, "Bottled Water Regulation," Hearing of the Subcommittee on Oversight and Investigations of the House Committee on Energy and Commerce, Serial No. 102-36, 102nd Cong., 1st Sess. 5, (April 10, 1991), (noting excessive benzene and other contaminants in bottled water).

77. According to figures for 1994 collected by the Beverage Marketing Corporation, the leading states were, in order, California (about 30% of the market), Florida (about 6%), New York (about

6%), Texas (about 6%) and Illinois (about 4%). Beverage Marketing Corporation, *Bottled Water in the U.S.*, 1996 Edition (1996), as cited in New Jersey Department of Health & Senior Services, *Report to the New Jersey Legislature, Summarizing Laboratory Test Results on the Quality of Bottled Drinking Water for the Period January 1, 1995 through December 31, 1996*, p. 6 (July 1997). A more recent survey found "California remains the top market for bottled water, with four times the number of gallons sold as the second-largest market. In fact, Californians drank 893,700 gallons of bottled water in 1997, more than the next four states combined: Florida (221,700 gallons), Texas (218,700), New York (204,400), and Arizona (124,900)." C. Roush, "Bottled Water Sales Booming," *The Daily News of Los Angeles*, p. B1 (April 16, 1998).

78. In a handful of cases, water was found in a test to contain contamination at levels of potential concern, but not retested -- generally because the water could not be found for retesting or it was logistically impractical to repurchase and reship the water for retesting. (See Appendix A.)

79. For example, the U.S. Geological Survey's (USGS) National Water Summaries (see, e.g. USGS, *National Water Summary*, 1988-1996), and National Water Quality Assessment Program (see, e.g., USGS *National Water Quality Assessment Program--Pesticides in Ground Water* (1996), USGS *National Water Quality Assessment Program -- Pesticides in Surface Water* (1997); see also www.usgs.gov (amply document that water quality measured using pesticides or other indicator contaminants can vary by orders of magnitude in a stream or shallow groundwater in some areas, depending upon the time of year, chemical use, hydrologic events such as precipitation, etc.)

80. See, U.S. Public Health Service, Department of Health and Human Services, *Review of Fluoride: Benefits and Risks* (February 1991); B. Hileman, "Fluoridation of Water: Questions About Health Risks and Benefits Remain After More than 40 Years," *Chemical & Engineering News*, pp. 26-42 (August 1, 1988); Robert J. Carton, Ph.D., and J. William Hirzy, Ph.D., EPA, and National Treasury Employees Union, "Applying the NAEP Code of Ethics to the Environmental Protection Agency and the Fluoride in Drinking Water Standard," *Proceedings of the 23rd Annual Conference of the National Association of Environmental Professionals*; 24 June 1998, San Diego, California, Sponsored by the California Association of Environmental Professionals, available at <http://home.cdsnet.net/~fluoride/naep.htm>.

81. Smith et al., "Cancer Risks from Arsenic in Drinking Water," *Environmental Health Perspectives*, vol. 97, pp. 259-67 (1992); Agency for Toxic Substances and Disease Registry, *Toxicological Profile for Arsenic*, (1993); NRDC, USPIRG, and Clean Water Action, *Trouble on Tap: Arsenic, Radioactive Radon, and Trihalomethanes in Our Drinking Water* (1995); United States Environmental Protection Agency, *Health Assessment Document for Inorganic Arsenic - Final Report* (March 1984); M. S. Golub, M.S. Macintosh, and N. Baumrind, "Developmental and Reproductive Toxicity of Inorganic Arsenic: Animal Studies and Human Concerns," *J. Toxicol. Environ. Health B. Crit. Rev.*, vol. 1, no. 3, pp. 199-241 (July 1998).

82. R.D. Morris, "Chlorination, Chlorination By-Products, and Cancer: A Meta Analysis," *American Journal of Public Health*, vol. 82, no. 7, at 955-963 (1992); EPA, "Proposed National Primary Drinking Water Regulations for Disinfectants and Disinfection By-Products," 59 Fed. Reg. 38668 (July 29, 1994); NRDC, U.S. PIRG, and Clean Water Action, *Trouble on Tap: Arsenic, Radioactive Radon, and Trihalomethanes in Our Drinking Water* (1995).

83. See, S.H. Swan, et al., "A Prospective Study of Spontaneous Abortion: Relation to Amount and Source of Drinking Water Consumed in Early Pregnancy," *Epidemiology*, vol. 9, no. 2, pp.

126-133 (March 1998); K. Waller, S. H. Swan, et al. (1998). "Trihalomethanes in Drinking Water and Spontaneous Abortion," *Epidemiology*, vol. 9, no. 2, pp. 134-40 (1998); F. J. Bove, et al. "Public Drinking Water Contamination and Birth Outcomes," *Amer. J. Epidemiol.*, vol. 141, no. 9, pp. 850-862 (1995); see also, NRDC, U.S. PIRG, and Clean Water Action, *Trouble on Tap: Arsenic, Radioactive Radon, and Trihalomethanes in Our Drinking Water* (1995).

84. EPA, "National Primary Drinking Water Regulations, Final Rule," 56 Fed. Reg. 3526, at 3537-38 (January 30, 1991); Environmental Working Group, *Pouring it On: Nitrate Contamination of Drinking Water* (1996); National Research Council, *Nitrate and Nitrite in Drinking Water* (1995).

85. Environmental Working Group, *Pouring it On: Nitrate Contamination of Drinking Water*, p. 11 (1996), (citing P.G. Sattelmacher, "Methemoglobinemia from Nitrates in Drinking Water," *Schriftenreihe des Verins fur Wasser Boden und Luthygiene*, no. 21 (1962), and Simon, et al., "Uber Vorkommen, Pathogenese, und Moglichkeiten sur Prophylaxe der Durch Nitrit Verursachten Methamogloniamie," *Zeitschrift fur Kinderheilkunde*, vol. 91, pp. 124-138 (1964)).

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87. R. J. Madison and J.O. Brunett, U.S. Geological Survey, "Overview of Nitrate in Ground Water of the United States," *National Water Summary, 1984: USGS Water Supply Paper 2275*, p. 93 (1985).

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91. New Jersey Department of Health and Senior Services, Division of Environmental and Occupational Health Services, *Report to the New Jersey legislature, Senate Environment & Assembly Environment, Science, and Technology Committees, Summarizing Laboratory Test Results on the Quality of Bottled Drinking Water for the Period January 1, 1995 through December 31, 1996* (July 1997).

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Bottled Water : Pure Drink or Pure Hype?. By Erik D. Olson. April 1999

Exposures to drinking water chlorination by-products in a Russian city

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Abstract

Exposures to water disinfection by-products (DBPs) via ingestion of drinking water, and dermal absorption and inhalation during showering/bathing were assessed in the city of Cherepovets, Russia, which uses heavy chlorination to disinfect organic-rich surface water. Concentrations of DBPs (mean $\pm$ standard deviation) in tap water were the following: total trihalomethanes (THMs) 205 ± 70 $\mu\text{g/l}$, five haloacetic acids (HAAs) 150 ± 30 $\mu\text{g/l}$, and 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (mutagen X or MX) 160 ± 50 ng/l . Concentrations of THMs and HAAs exceeded the corresponding US standards by a factor of 2.5, while MX concentrations were the highest ever reported. The mutagenic activity of tap water extracts in the *Salmonella* TA-100 assay was 14,900 net revertants/l. Concentrations of chloroform in breathing zone air in bathrooms during showering were 330 ± 260 $\mu\text{g/m}^3$, shower room air at an industrial plant $2,600 \pm 1,100$ $\mu\text{g/m}^3$, and bedrooms of local residents 2 ± 2 $\mu\text{g/m}^3$. The mean concentration of chloroform was 3.2 $\mu\text{g/m}^3$ in exhaled air samples collected before showering and 110 $\mu\text{g/m}^3$ after showering. Data on water ingestion and water use practices in the general population and for pregnant women were collected using questionnaires and diaries. Due to concerns over microbiological safety of water, average daily consumption of non-boiled tap water in pregnant women was only 0.01 l/day, while consumption of boiled tap water was 0.81 l/day. This resulted in low ingestion exposures to volatile THMs. Inhalation and dermal absorption determined total exposures to these compounds. HAAs and MX persist in boiled water and drinks resulting in high ingestion exposures. Several brands of inexpensive home water filters were tested for removal of these compounds. To demonstrate a method of exposure reduction in a sensitive subpopulation, the most efficient filters were given to a group of pregnant women. These women and a control group of pregnant women without filters maintained water ingestion diaries for two weeks. The use of home filters resulted in reduction of exposures to HAAs by a factor of three and a greater reduction in exposures to MX.

Key words: DBPs – trihalomethanes – haloacetic acids – MX – water – ingestion – inhalation – dermal absorption – pregnant women

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Introduction

Chlorination of water results in formation of an array of DBPs (disinfection by-products). THMs (trihalomethanes) are the most common volatile DBPs and HAAs (haloacetic acids) are the major non-volatile DBPs (Cunning and Jolley, 1993; U.S. Environmental Protection Agency (EPA), 1997b; Boorman et al., 1999). Other DBPs, such as haloacetonitriles (HANs), chloropicrine and chlorinated furanones are usually present at lower concentrations. Concentrations of 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX) are usually in the ng/l range (Smeds et al. 1997). However, this compound is the strongest determinant of mutagenic activity of chlorinated drinking water in *Salmonella* assays (Kronberg and Vartiainen, 1988; Tuomisto and Vartiainen, 1990; Vartiainen et al., 1990; Wright et al., 2002).

Health effects of exposures to DBPs are thought to include various cancers and reproductive health effects, including spontaneous abortions, stillbirths, congenital malformations and retarded fetal development (Smallwood et al., 1993; Chiu et al., 1996; Swan and Waller, 1998; Nieuwenhuijsen et al., 2000a; Bove et al., 2002).

Concentrations of DBPs usually vary by season reflecting variability in source water composition and disinfection practices (Arora et al., 1997). DBP concentrations may also vary within the distribution system due to continuous formation and decomposition (LeBel et al., 1997; Chen and Weisel, 1998; Rossman et al., 2001).

Water boiling results in volatilization of chloroform and other THMs. These compounds are present at low concentrations in drinks prepared with boiled water and are not detectable in most foods. Thus, individual ingestion exposures are determined by consumption of non-boiled tap water. Inhalation is an important pathway of exposures to THMs as these compounds can accumulate in in-door air during showering, bathing and other activities associated with water use (Backer et al., 2000; Kerger et al., 2000; Lynberg et al., 2001). Dermal absorption during showering/bathing is another major route of exposure to THMs (Weisel, 1993; Weisel and Jo, 1996; Weisel et al., 1999; Nieuwenhuijsen et al., 2000b). Within the exposed population, individual dermal and inhalation exposures depend on showering/bathing frequency and duration, and other parameters, such as water temperature (which strongly affects dermal absorption of THMs), water flow, type of showerhead, and air exchange rate in the bathroom.

Polar molecules of HAAs, HANs, and MX (mutagen X) do not readily penetrate the skin (Xu et al., 2002). Inhalation exposures to these non-volatile and semi-volatile DBPs have also been demonstrated to be insignificant (Kim and Weisel, 1998). On the other hand, these compounds, especially dichloroacetic acid (DCAA), persist in boiled water and foods (Raymer et al., 2000; Wu et al., 2001). Thus, individual exposures to these compounds are determined by total ingestion of tap water (non-boiled and boiled), hot drinks and tap water-containing foods.

Point-of-use treatment of drinking water using activated carbon filters may reduce ingestion exposures to DBPs. However, the efficiency of home filters may vary depending on filter brand, age and characteristics of tap water.

The DBP exposure assessment study presented in this paper was conducted in the city of Cherepovets, Russia, by the Harvard School of Public Health and the Cherepovets Center for Sanitary and Epidemiological Control (Sanepid) in cooperation with the National Public Health Institute (Finland), and Research and Production Corporation Typhoon (Russia). Cherepovets (population of 320,000) is located 400 km to the North of Moscow in the sparsely populated area of coniferous forests. The city uses a major water artery in the area, the Sheksna River, as its sole water source. The single water treatment plant uses chlorination with high doses of liquid chlorine, which vary from 5 mg/l to 13 mg/l depending on the immediate chlorine demand of source water. No DBP precursor removal is practiced. Chlorination is followed by coagulation with aluminum sulfate and rapid upward filtration through sand filters (direct clarification). Most of the time, total residual chlorine concentration in effluent water varies from 1 mg/l to 2 mg/l (these limits are set by local water quality standards) with free chlorine accounting for two thirds and chloramines accounting for the remainder. In the spring of 1999, the mean free chlorine concentration in effluent water was 1.09 mg/l, the mean concentration of chloramines was 0.47 mg/l, while the mean pH was 6.85. Secondary chlorination in the distribution system is not practiced. According to the utility company, mean residence time of water in the distribution system is several hours, while exact water residence times for specific locations are unknown. The mean concentrations of free chlorine at point of use sites (a sample of residences in different parts of the city) were 0.06 mg/l in fall 1998 and 0.03 mg/l in spring 1999, while the mean concentrations of chloramines were correspondingly 0.43 mg/l and 0.26 mg/l (Egorov et al., 2002a).

According to the water utility's data, concentrations of chloroform in treatment plant effluent frequently exceed the Russian standard of 200 µg/l. Monitoring of chloroform at point-of-use sites is not practiced and other DBPs are not routinely monitored in Cherepovets.

Materials and methods

Water sampling and analysis

Water and air samples for DBP analysis were collected during several short visits of Harvard specialists to Cherepovets from the fall of 1999 through the spring of 2001. Samples were then transported to the chemistry laboratories at Harvard University or Typhoon Corp. Tests of mutagenicity were conducted at the National Public Health Institute (Kuopio, Finland), which also provided methodology for MX monitoring and analyzed replicate control samples.

Cold tap water samples were collected from local households for determination of HAAs, HANs, MX and mutagenicity, while warm water samples (at a temperature normally used for showering) were collected for determination of THMs. Several samples of boiled tap water and tea have also been analyzed.

Water samples for determination of THMs were collected into 40 ml bottles, acidified and preserved with sodium thiosulfate and transported in insulated containers with ice packs. Analysis was conducted using a gas chromatography/mass spectrometry (GC/MS) capillary column technique with head space sample introduction in accordance with the method developed by the Pacific Northwest National Laboratory (PNNL Method VOA-4, 1998). Water samples for determination of HAAs were collected, preserved, transported and analyzed in accordance with the US EPA Method 552.2 (US EPA, 1995a). Analysis of HANs was conducted using GC/MS in accordance with the US EPA method 551.1 (US EPA, 1995b).

For determination of MX, tap water samples of 2 l volume were collected into precleaned glass bottles, acidified and filtered through sorption columns with XAD-8 resin. MX was eluted from the sorbent with ethyl acetate. MX solution in ethyl acetate was evaporated to a non-volatile residue. MX was methylated with 2% H₂SO₄ in methanol and then extracted with hexane. MX concentrations were determined using GC/MS in accordance with the method described by Vartiainen et al. (1991) and Smeds et al. (1997).

Water samples for determination of mutagenic activity in the standard *Salmonella typhimurium* assay (Maron and Ames, 1983) were collected, processed and extracted following the procedure for determination of MX as described above. Tests were conducted using the tester strain TA100 without metabolic activation in accordance with the method used in previously conducted studies of tap water mutagenicity (Vartiainen and Liimatainen 1988; Wright et al. 2002).

Selection of home water filters to reduce ingestion exposures

To assess removal efficiency of THMs, HAAs, HANs and MX, we concurrently tested three commercially available inexpensive home filters: Brita™ and Aquaphor™ tabletop pitcher filters and a detachable faucet-tip Rodnik filter. Cartridges in all of these filters contained activated carbon. Brita filters also contained ion-exchange resins for removal of heavy metals, and, thus, a smaller amount of activated carbon. Filtered water samples were collected after filtration of a predefined quantity of tap water through these new filters (for example, from 1st, 50th, 100th, and 150th liters). Non-filtered tap water samples were collected concurrently to determine baseline concentrations. In addition, two previously used faucet-tip filters of different brands were tested by collecting filtered and non-filtered samples from apartments of Sanepid employees. Testing of water filters was conducted in April 2001.

Air sampling and analysis

Indoor air sampling for determination of THMs was conducted using an active sampling method. The sampling equipment included a portable pump, electronic flowmeter/totalizer, Tygon™ tubing, and sorption tubes packed with Carboxpack-B™ sorbent (Supelco Inc., Bellefonte, Pennsylvania, USA). Samples from shower rooms at industrial facilities were collected when workers were taking showers after work shifts. Bathroom, kitchen and bedroom air samples were collected from apartments of Sanepid employees. Bathroom samples were collected during showering activities at a distance of 20 cm from the water flow for 15 to 20 minutes (duration of normal showering in Cherepovets) at an average flow rate of approximately 10 ml/min. Bedroom samples were collected for 20 minutes at an average flow rate of approximately 100 ml/min and kitchen samples were collected at an average flow rate of 20 ml/min for 20 min. Sample volumes were measured using an electronic totalizer. In addition, to assess temporal variability of chloroform concentrations in air during long bathing activities, two Sanepid volunteers collected air samples during consecutive 10-minute intervals while taking 50 minute-long baths. To determine how ventilation affects accumulation of chloroform in breathing zone air, several samples were collected from bathrooms with all ventilation openings temporarily sealed. For determination of THMs in indoor air samples, analytes were thermally desorbed from Carboxpack-B™ sorption tubes in accordance with the US EPA Method TO-17 (US EPA, 1997a) and analyzed in accordance with the US EPA Method TO-15 (US EPA, 1999) using an automatic thermal desorption unit connected to GC/MS.

Air exchange rates (AER) were measured in several selected bathrooms of Sanepid employees with different ventilation types. AER were determined using air concentrations of a volatile tracer compound, perfluorinated methylcyclohexane (PMCH), under steady-state conditions. PMCH was allowed to permeate into bathrooms for several (six to eight) hours. Concentrations of PMCH

Table 1. Sampling schedule and number of samples analyzed.

Type of analyses	Number of samples				
	October-December 1999	February 2000	August 2000	April 2001	Total
THMs in tap water	—	—	4	10	14
HAAs in tap water	3	2	—	11	16
HANs and chloropicrin in tap water	—	—	—	3	3
MX in tap water	—	—	—	11	11
Mutagenicity of tap water	—	—	—	2	2
THMs in indoor air	17	—	13	5	35
THMs in exhaled air	—	—	—	9	9
Air exchange rates	—	—	—	4	4

were then measured using a passive sampling technique (open sorption tubes). Analysis was conducted using a gas chromatograph with electron capture detector (GC/ECD) by Mr. Robert Weker (Harvard School of Public Health).

Exhaled air concentrations of THMs were measured in samples collected from Sanepid employees before and within 1 minute after their routine showering and bathing activities. Samples were collected into five-liter Tedlar™ air sampling bags with mouthpieces and valves. All samples were collected in bedrooms, where inhaled air had low concentrations of THMs. Within 12 hours from sampling, analytes were transferred into Carboxen-B™ sorption tubes by pumping air from sampling bags at a flow rate of 50 ml/min. Sorption tubes were transported to the laboratory where sample processing and analysis were conducted as described above for indoor air samples.

Questionnaire and diary surveys in the general population

A cross-sectional questionnaire survey of the use of water filters and showering and bathing activities was conducted in randomly selected households in the fall of 1998 (500 families) and the spring of 1999 (750 families). These surveys were nested within a cross-sectional epidemiological study of health effects of microbiological water pollution in the distribution system (Egorov et al., 2002a). A daily diary survey of tap water consumption in 100 randomly selected households was conducted from June through November 1999. This survey was nested within a prospective epidemiological study of health effects of microbiological water pollution (Egorov et al., 2003).

Questionnaire and diary surveys in pregnant women

A cross-sectional questionnaire survey of 51 pregnant women in spring 2001 was designed specifically for assessment of exposures to DBPs. Participants of this survey were recruited by local health care specialists at one of the city's pregnancy consultation centers.

A two weeks-long diary survey of tap water consumption and water exposures was conducted in 27 women recruited from the cross-sectional survey population. Only pregnant women who did not have home water filters purchased through their own initiative were recruited for this survey. At baseline, 10 participants received free-of-charge pitcher-type home water filters and replacement cartridges. The remaining 17 participants contin-

ued to use non-filtered tap water for drinking. All survey participants recorded detailed information on water use and water consumption at home and outside the home. Daily DBP ingestion exposures for each woman were then estimated using the data on DBP concentrations in filtered and non-filtered tap water.

Results

Sampling schedule and numbers of air and water samples collected are presented in Table 1.

Concentrations of DBPs in water

The results of DBP measurements in Cherepovets tap water are presented in Table 2. Chloroform was the major THM species forming 96% of total THMs in water, while bromoform was below the detection limit in all samples collected. The concentration of total THMs in August 2000 was 50% higher than in April 2001 (270 µg/l vs. 180 µg/l). The mean total THM concentration in two samples of boiled tap water collected from teakettles in local residences was 7 µg/l (these samples are not included in Tables 1 and 2).

Total concentrations of five HAAs in Cherepovets tap water were rather stable over time: 157 µg/l in December 1999, 158 µg/l in February 2000 and 148 µg/l in April 2001.

Concentrations of MX at point-of-use sites (180 ± 51 ng/l; $N = 8$) were higher than concentrations in the treatment plant effluent (113 ± 12 ng/l; $N = 3$). Although MX is unstable in water at the neutral pH, the rate of MX decomposition is low with a half-life of more than seven days (Vartiainen et al., 1991). Thus, in this distribution system with a short water residence time, continuing formation of MX through reactions of residual chlorine with organic compounds appears to be more important than its decomposition. The concentration of MX in

Table 2. Concentrations of DBPs in tap water in Cherepovets ($\mu\text{g/l}$).

Parameter	Mean	SD	Method detection limit
Chloroform	198	70	0.1
Bromodichloromethane (BDCM)	6.7	2.0	0.1
Dibromochloromethane (DBCM)	0.5	0.5	0.1
Bromoform	ND	—	0.3
Total THMs	205	70	
Monochloroacetic acid (MCAA)	3.6	2.9	0.4
Dichloroacetic acid (DCAA)	62	19	0.01
Trichloroacetic acid (TCAA)	83	26	0.01
Bromochloroacetic acid (BCAA)	1.9	1.5	0.01
Bromodichloroacetic acid (BDCAA)	0.4	0.4	0.01
Total HAAs	150	31	
Dichloroacetonitrile (DCAN)	5.6	0.3	0.01
Bromochloroacetonitrile (BCAN)	0.3	0.2	0.02
Trichloroacetonitrile (TCAN)	0.1	0.01	0.01
Dibromoacetonitrile (DBAN)	0.2	0.1	0.02
Total HANs	6.2	0.2	
Chloropicrin	0.35	0.04	0.02
MX	0.16	0.05	0.004

Table 3. Removal of DBPs by various home water filters (manufacturer recommended capacity of cartridges is 150 liters of water for Brita™ and Aquaphor™ and 1,000 liters for Rodnik).

Filter	Made in	Compound	Percent removal of DBPs						
			1 st liter	50 th liter	100 th liter	150 th liter	300 th liter	600 th liter	1000 th liter
Brita	Germany	DCAA	95	48	49	2			
		TCAA	87	57	39	— 19			
		MX	NA	> 99	NA	> 99			
		Chloroform	94	96	92	90			
Aquaphor	Russia	DCAA	97	96	67	59			
		TCAA	95	88	67	63			
		MX	> 99	> 99	NA	> 99			
		Chloroform	94	95	95	95			
Rodnik	Russia	DCAA	80	NA	51	NA	47	45	31
		TCAA	81	NA	37	NA	45	40	18
		MX	95	NA	NA	NA	NA	73	60
		Chloroform	91	NA	88	NA	88	90	77

one sample of tea prepared by boiling tap water for approximately 1 minute was 84 ng/l.

In April 2001, the mutagenic activity of water extracts in the *Salmonella* TA-100 assay was $14,900 \pm 800$ net revertants/L ($N = 2$).

Removal of DBPs by point-of-use activated carbon filters

The results of testing home water filters for removal of major DBP species are presented in Table 3. Removal of MX and THMs was consistently higher than removal of HAAs. The latter limited the useful life of carbon cartridges. As suggested by negative TCAA removal by a Brita filter from the 150th liter,

longer use of a cartridge may result in elution of previously accumulated HAAs (probably due to HAA replacement by compounds with higher affinity to binding sites). At the same time, the metal removing capacity of Brita was underutilized as concentrations of heavy metals including lead were very low in Cherepovets (data not shown). The Russian-made Aquaphor™ filter, which employs a mixture of fibrous and granular absorbents (U.S. patents 5904854 and 5521008), demonstrated the highest removal rates of all DBP species.

Our tests of two faucet-mounted filters, which had been used for various amounts of time by Sanepid employees in their apartments, demonstrated practically zero removal of DBPs (data not shown).

Table 4. Results of indoor air chloroform monitoring in Cherepovets ($\mu\text{g}/\text{m}^3$).

Type of sampling site	N	Mean	SD	Min	Max
Bathrooms	15	330	310	75	900
Kitchens	4	86	91	ND	170
Bedrooms	5	2.1	2.3	ND	5.0
Hotel shower with enclosure	1	5,400	NA	5,400	5,400
Factory shower	5	2,600	1,100	1,900	4,900
Change room at a factory shower	1	18	NA	18	18
Bathrooms with all ventilation openings closed	4	7,800	6,300	2,400	15,600

Air concentrations of volatile DBPs

A summary of chloroform concentrations in indoor air by the type of sampling site is presented in Table 4. The method detection limits (MDL) for chloroform were $1.2 \mu\text{g}/\text{m}^3$ for samples of 2 l volume and $0.3 \mu\text{g}/\text{m}^3$ for 200 ml samples. Chloroform was the major species present in bathroom air forming almost 98% of total THMs. Chloroform concentrations in kitchens varied widely from non-detectable to a maximum of $170 \mu\text{g}/\text{m}^3$ depending on ventilation rate, cooking and washing activities. Its concentrations in bedrooms were invariably low. The concentration of bromodichloromethane (BDCM) in bathrooms during showering was $8.4 \pm 4.1 \mu\text{g}/\text{m}^3$. The MDLs for BDCM were $1.0 \mu\text{g}/\text{m}^3$ and $0.2 \mu\text{g}/\text{m}^3$ for 2 l and 200 ml samples respectively. Dibromochloromethane and bromoform were non-detectable in most samples.

Concentrations of chloroform in female shower rooms at the city's largest industrial factory, when workers were taking showers after their work shift, were almost an order of magnitude higher than in residential bathrooms ($2,600 \mu\text{g}/\text{m}^3$ vs. $330 \mu\text{g}/\text{m}^3$). The chloroform concentration in one sample collected in an adjacent changing room was only $18 \mu\text{g}/\text{m}^3$, suggesting that water used for showering was the main source of chloroform in indoor air. A hotel shower enclosure was another site with a very high chloroform concentration in breathing zone air.

The analysis of predictors of chloroform concentrations in bathroom air indicated that variability in bathroom volumes in typical apartment buildings of standard design is very low (from 5.2 m^3 to 7.0 m^3). This low variability in bathroom volumes could not substantially affect the rate of chloroform accumulation. However, air exchange rates in four bathrooms with different ventilation settings varied from 1.4 to 4.2 air exchanges per hour with an average of 2.9.

The results of multiple chloroform measurements in bathroom air during 50-minute bathing (not

included in Table 4) in two different bathrooms are presented in Figure 1. Figure 1 (left panel) shows that chloroform concentrations in air continued to increase throughout bathing in a bathroom with a low air exchange rate. Figure 1 (right panel) shows a decrease in chloroform concentration during bathing activity in a bathroom with a higher air exchange rate. This decrease followed an initial rise due to the use of the shower to fill the bathtub. Maximum BDCM concentrations in 10-minute samples from these two experiments were $14.5 \mu\text{g}/\text{m}^3$ and $5.4 \mu\text{g}/\text{m}^3$ respectively.

The mean chloroform concentration in breathing zone air in four bathrooms with all ventilation openings temporarily sealed was $7,800 \mu\text{g}/\text{m}^3$ (SD = $6,300 \mu\text{g}/\text{m}^3$; range from $2,400 \mu\text{g}/\text{m}^3$ to $15,600 \mu\text{g}/\text{m}^3$). Air exchange rates in these bathrooms were not measured. However, these rates were likely to be very low. The equilibrium concentration of chloroform in air for a $200 \mu\text{g}/\text{l}$ concentration in water at 40°C is $30,000 \mu\text{g}/\text{m}^3$. Thus, concentration of chloroform in air at the end of a 20 minute-long shower was likely to be close to the equilibrium point (the $15,600 \mu\text{g}/\text{m}^3$ average reflects accumulation of chloroform from near zero to the equilibrium concentration $30,000 \mu\text{g}/\text{m}^3$).

The mean chloroform concentration in exhaled air of local residents before showering was $3.2 \mu\text{g}/\text{m}^3$ (N = 3, SD $0.7 \mu\text{g}/\text{m}^3$, MDL $0.3 \mu\text{g}/\text{m}^3$) while after showering/bathing it increased to $110 \mu\text{g}/\text{m}^3$ (N = 6, range from 11 to $410 \mu\text{g}/\text{m}^3$, standard deviation $160 \mu\text{g}/\text{m}^3$). BDCM was non-detectable in all samples before showering (N = 3), while average concentration after showering was $0.8 \mu\text{g}/\text{m}^3$ (N = 6, range from non-detectable to $3.7 \mu\text{g}/\text{m}^3$, MDL $0.2 \mu\text{g}/\text{m}^3$). Bromoform and DBCM were non-detectable in all samples collected before and after bathing. Concentrations of benzene, toluene, o-xylene, m, p-xylenes, tetrachloroethene, ethylbenzene and tetrachloromethane in exhaled air before and after showering did not differ significantly (data not shown).

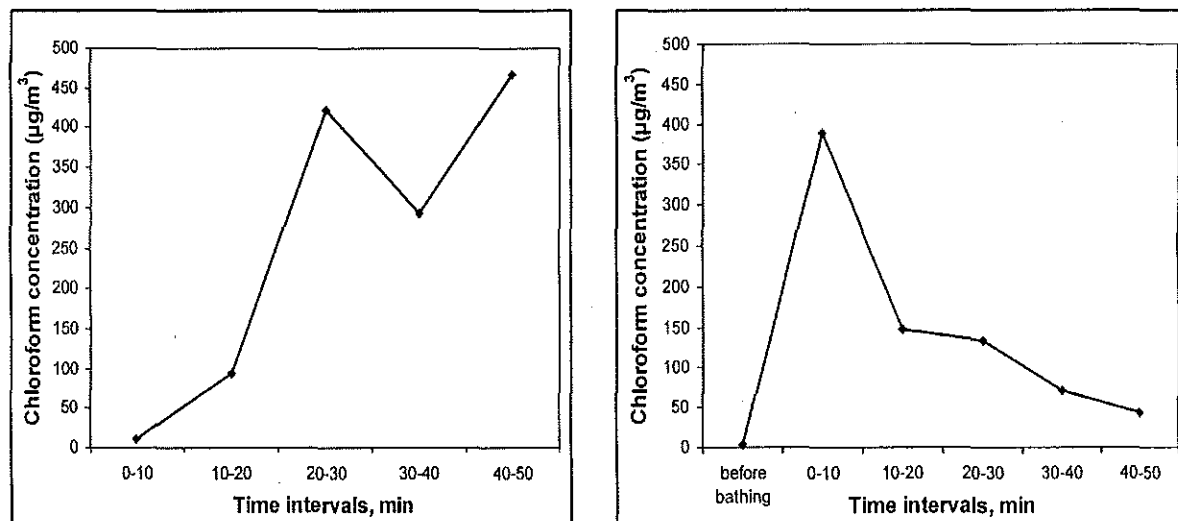


Fig. 1. Air concentrations of chloroform in two Cherepovets bathrooms during bathing. Left panel: Air exchange rate 1.4/hour; volunteer fills the bathtub using the faucet; then sits in the bathtub for 50 minutes. Right panel: Air exchange rate 3.4/hour; volunteer fills the bath using the shower head; then turns shower off and sits in the bath tub for 50 minutes.

Surveys of water exposures in the general population

The results of questionnaire surveys in the general population show that 15% of study participants used home water filters. These were predominantly (83%) faucet-mounted filters designed mainly for removal of suspended particles. Table-top pitcher-type filters were less popular, while the use of more expensive stationary in-line filters was very uncommon (only 3% of all filters used). The average frequency of showering and bathing in study participants was 0.7 times per day with a range from once per week to three times per day.

The results of the 5.5 month-long diary survey of 100 families (367 individuals; mean age 29.6 years) indicated that the majority of Cherepovets residents never drinks non-boiled tap water or drinks it rarely. Only 39% of study participants reported some episodes of non-boiled tap water consumption. Each day, from 3% to 13% of study participants (7% on average) reported consumption of non-boiled tap water, with higher rates corresponding to higher ambient air temperatures. This high rate of boiling is due to concerns about microbiological safety of tap water (the Cherepovets health officials advise local residents to boil their drinking water).

Questionnaire survey of water exposures in pregnant women

The age of 51 pregnant women who participated in the questionnaire survey (mean $\pm$ standard deviation) was 24.0 ± 4.6 years; their weight was 66.4 ± 12.4 kg; and the pregnancy term was 27.1 ± 8.1 weeks. Study participants had, on average, 1.20 previous pregnancies, including 0.31 live births, 0.12 miscarriages and 0.77 medical abortions. Only 10% were smokers. Prevalence of home water filter use in this group was 18%. Only one individual regularly attended a swimming pool with chlorinated water and two individuals reported attendance at public saunas. The average reported frequency of showering and bathing was 1.2 times per day, substantially higher than in the general population. The mean reported daily duration of showering and bathing in this group was 21.8 ± 11.1 min. There was no association between daily duration of showering/bathing and pregnancy term.

Diary survey of water exposures in pregnant women

The results of the two weeks-long diary survey involving 27 of these pregnant women are presented in Table 5. At the inception of the survey, 10 women received free-of-charge home filters and replacement cartridges while the remaining 17 women continued to use non-filtered tap water. The mean daily consumption of non-boiled tap water in both groups

Table 5. Daily consumption of water and drinks by a group of pregnant women in Cherepovets during a 14 days-long diary survey. Mean (standard deviation), liters.

Types of water	Did not use home water filters (17 women)	Used home water filters (10 women)
Non-boiled non-filtered tap water and drinks prepared of it	0.01 (0.03)	0.02 (0.04)
Non-boiled filtered tap water and drinks prepared of it	0 (0)	0.07 (0.13)
Boiled non-filtered tap water and drinks prepared of it	0.78 (0.16)	0.18 (0.23)
Boiled filtered tap water and drinks prepared of it	0 (0)	0.62 (0.21)
Non-chlorinated non-bottled water (wells at summer houses)	0.05 (0.08)	0.01 (0.01)
Bottled water (boiled and non-boiled) and drinks prepared of it	0.21 (0.16)	0.18 (0.13)
Total self-reported water intake	1.04 (0.23)	1.07 (0.13)

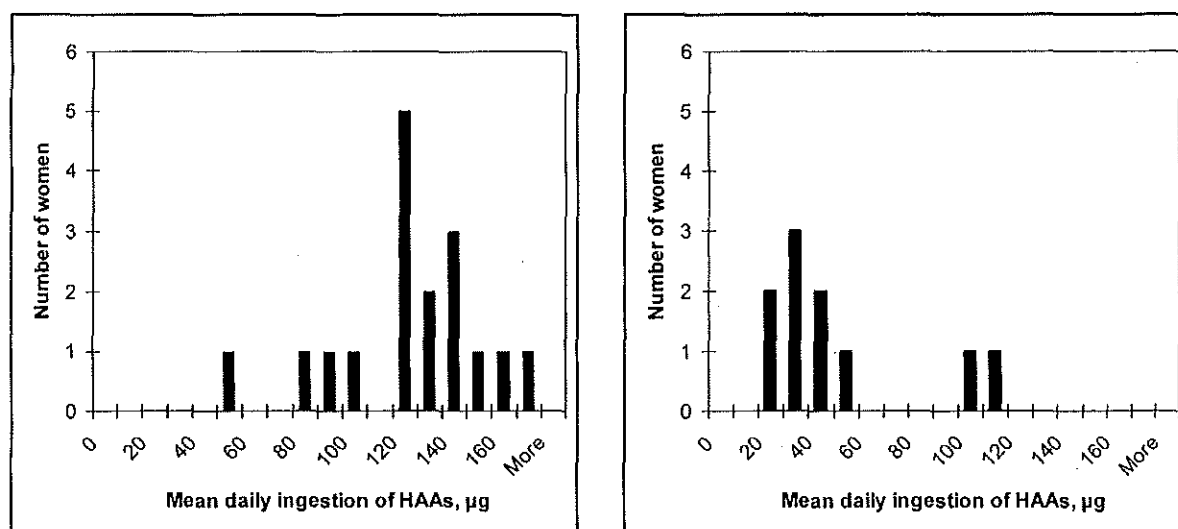


Fig. 2. Estimated daily ingestion of HAAs with water and drinks by pregnant women in Cherepovets. Left panel: Pregnant women without home water filters. Right panel: pregnant women with home water filters.

of pregnant women was very low, while consumption of boiled water and drinks that were prepared from boiled water (hot tea, coffee, etc.) was substantial. Average daily total intake of tap water (boiled and non-boiled) was 0.82 l/day. Women with filters continued to boil most of their water for drinking. They also consumed some non-filtered tap water outside their homes (mostly at work places). Survey participants in both groups also reported substantial consumption of milk (0.8 l/day) and natural juices (0.3 l/day), while consumption of bottled soft drinks was low (0.07 l/day).

Figure 2 shows approximate estimates of daily ingestion of HAAs with water and drinks by pregnant women with home water filters and without filters. The estimates assume a mean concentration of total HAAs in non-filtered tap water of 150 µg/l, 90% mean removal efficiency of filters

during the first two weeks of use (~ 75 liters of filtered water), no change in HAA concentration after boiling and preparation of hot drinks, and zero concentration of HAAs in bottled water, juices and soft drinks. These crude estimates, which do not account for ingestion of HAAs with foods that are prepared with tap water, indicate a substantial (approximately by a factor of three) reduction in exposures to HAAs in women using filtered water (42 µg/day vs. 117 µg/day).

In the group of pregnant women, the total daily duration of full-body water contact (mean $\pm$ standard deviation) was 15.5 ± 12.6 min. The daily duration of showering at home was 12.0 ± 7.8 min. The mean daily duration of showering at work places was 0.5 min (standard deviation 2.2 min) and bathing at home 3.0 min (standard deviation 3.9 min). The total daily duration of water

contact estimated from the diary data was lower than the duration reported by the same individuals in their questionnaires, suggesting a reporting bias (rounding up) in the questionnaire study.

Discussion

In the city of Cherepovets, Russia, high doses of chlorine are applied to poor quality source water with high concentrations of dissolved organic compounds. Concentrations of chlorination by-products, including THMs, HAAs, HANs and MX, as well as mutagenic activity of treated water are, therefore, very high.

The mean concentration of five HAAs in Cherepovets (150 µg/l) exceeds by far the 95th percentile of the distribution of HAAs concentrations in US municipalities of 86 µg/l (US EPA, 1997c). The mean concentration of five HAAs in Cherepovets exceeded the current US EPA standard, the annual running average of 60 µg/l (US EPA, 2001), by a factor of 2.5. The concentrations of DHAA in 11 out of 16 samples analyzed exceeded the provisional WHO guideline for this compound of 50 µg/l (WHO, 1993). The concentrations of TCAA exceeded the provisional WHO guideline of 100 µg/l in four out of 16 samples.

The mean concentration of total THMs in Cherepovets (205 µg/l) also exceeds the current US EPA standard (US EPA, 2001), the annual running average of 80 µg/l, and the 95th percentile of concentrations in the US water supply systems (104 µg/l; US EPA, 1997c), to a similar degree. The concentrations of total THMs were above the EU standard of 100 µg/l (Council of the European Union, 1998) in all but one sample. Chloroform concentrations in six out of 14 samples were above the WHO guideline of 200 µg/l, while concentrations of bromoform, DBCM and BDCM were well below the corresponding WHO guidelines of 100 µg/l, 100 µg/l and 60 µg/l in all samples.

MX concentrations in chlorinated waters in Massachusetts in 1997–1998 ranged from 4 ng/l to 80 ng/l (N = 88), with a mean value of 28 ng/l (Wright et al., 2002). Reported concentrations of MX in Finland, Japan and the UK are even lower (Kronberg and Vartiainen 1988; Smeds et al., 1997; Suzuki and Nakanishi, 1990; Fawell and Horth, 1990). Thus, the average concentration of MX in Cherepovets (160 ng/l) exceeded the highest previously reported concentration by two-fold.

Water extracts from Cherepovets also had very strong mutagenic activity in the *Salmonella* TA100

assay (14,900 net revertants/liter), which by far exceeds mutagenic activity of tap waters in Finland (from 230 to 3,250 rev/l, Smeds et al., 1997) and in Massachusetts (from 300 to 5,700 rev/l, with a mean of 1,450 rev/l, Wright et al., 2002). Determination of mutagenicity in these three studies was conducted by the same laboratory in Kuopio, Finland.

A characteristic feature of the Cherepovets population and especially of pregnant women in this city is low consumption of non-boiled tap water due to concerns over its microbiological safety. These concerns seem to be justified: surveys conducted by regional health authorities demonstrated the presence of hepatitis A and rotaviruses (A. Tereschenko and N. Drizhd, personal communication), while a survey conducted by the Harvard School of Public Health in cooperation with the local Sanepid demonstrated the presence of disinfection-resistant protozoan parasites in treated water (Egorov et al., 2002b). Epidemiological studies demonstrated associations between episodes of elevated effluent water turbidity and daily episodes of self-reported diarrheal illness (Egorov et al., 2003), and between deterioration of microbiological water quality in the distribution system and elevated rates of diarrheal illness in some areas of the city (Egorov et al., 2002a). Pregnant women in Cherepovets consumed 0.01 l/day of non-boiled tap water vs. 0.56 l/day reported by Shimokura et al. (1998) for pregnant women in the USA. This low consumption of non-boiled tap water in Cherepovets results in low ingestion exposures to THMs, as concentrations of these compounds are low in boiled water. Total tap water consumption (0.82 l/day) by pregnant women in Cherepovets was comparable to daily consumption by pregnant women in the USA (Shimokura et al. (1998), 0.78 l/day; Ershow et al. (1991), 1.19 l/day) and Italy (Barbone et al. (2002), 0.6 l/day). Most home water filters that were used by Cherepovets residents were likely to be inefficient for DBP removal. As concentrations of non-volatile DBPs, which persist in boiled water, are very high in Cherepovets, ingestion exposures to these compounds in pregnant women may result in non-trivial adverse health effects. Using simple exposure-reduction measures, such as more efficient home filters, can reduce these adverse effects.

This study demonstrated a high efficiency of activated carbon filters (Aquaphor™) for removal of DBPs. Application of these inexpensive filters to the sensitive subpopulation of pregnant women is a cost-effective method to reduce exposures to potentially fetotoxic DBPs. When this study was conducted, the total cost of an Aquaphor pitcher and 20 replacement cartridges was the Ruble equivalent of

approximately \$ 90, an affordable expense for most families in this city with a very low birth rate. In this pilot study, with filtered water used only at homes, ingestion exposures to HAAs were reduced by almost 3-fold. The use of filtered water both at home and outside the home could result in up to a 10-fold reduction in exposures to HAAs and even greater reduction in exposures to MX.

Exposures to volatile THMs occur predominantly through dermal absorption and inhalation during showering, bathing and other activities associated with water contact. In general, daily duration of bathing and showering in Cherepovets' pregnant women (15.5 min) was slightly higher than that reported by Shimokura et al. (1998) for US pregnant women (13.1 min). The Cherepovets distribution was substantially skewed to the right, probably due to fixed hot water fees and the centralized hot water supply, which is conducive to excessive use of hot water by some individuals.

As concentrations of THMs in indoor air depend on many factors, a precise assessment of inhalation exposures may require extensive THM measurements in bathrooms (where concentrations are the highest) and in kitchens (where individuals spend more time). Our results of chloroform measurements suggest that ventilation rate is an important determinant of chloroform concentrations in bathroom air during showering and bathing. The ratio of chloroform concentrations in bathroom breathing zone air and water in this study was approximately $1.6 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$, which is somewhat lower than $3.3 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$ reported by Kerger et al. (2000). The difference might be due to different construction of bathrooms (for example, the fact that many bathrooms in Cherepovets do not have shower enclosures and curtains).

This ratio was higher in the shower room of an industrial factory (approximately $13 \mu\text{g}/\text{m}^3$ per $1 \mu\text{g}/\text{l}$) probably due to the continuous use of multiple showers resulting in a high rate of chloroform volatilization. Very high concentrations of chloroform in shower room air at the largest industrial factory in Cherepovets suggest substantial exposures in factory workers. In this industrial city, more than 50% of active age males and a substantial proportion of females are industrial workers who take regular showers in factories' shower rooms.

The results also suggest that inhalation exposures in kitchens may be another important determinant of total exposure. However, a larger exposure assessment study would be needed to assess the contribution of the various microenvironments.

Measurements of concentrations of THMs in exhaled air have been demonstrated to be informa-

tive bioindicators of dermal and inhalation exposures (Weisel et al., 1992; Pleil and Lindstrom, 1997; Gordon et al., 1998; Aggazzotti et al., 1998). Exhaled air sampling, which is much more acceptable to study participants than blood sampling, is a method of choice for population surveys. The average concentration of chloroform in exhaled air in Cherepovets volunteers after showering ($110 \mu\text{g}/\text{m}^3$ average) was higher than levels previously reported (Gordon et al., 1998: $45 \mu\text{g}/\text{m}^3$; Weisel et al., 1999: from 4 to $54 \mu\text{g}/\text{m}^3$) reflecting higher concentrations of chloroform in Cherepovets tap water. Similar exhaled air concentrations have been reported after swimming in indoor swimming pools (Aggazzotti et al., 1995: $94 \mu\text{g}/\text{m}^3$; Levesque et al., 1994: $89 \mu\text{g}/\text{m}^3$). A study of competitive swimmers (Lindstrom et al., 1997) reported an increase in chloroform concentrations in exhaled air of a male swimmer from about $3 \mu\text{g}/\text{m}^3$ before swimming to $148 \mu\text{g}/\text{m}^3$ at the eighth minute, to $371 \mu\text{g}/\text{m}^3$ at the 90th minute. The present study did not include assessment of chloroform exposures in swimming pools. However, the contribution of this pathway to developmental health risks in Cherepovets is likely to be very small as very few pregnant women attend swimming pools there.

THMs are fully metabolized by the liver after ingestion. Thus, biologically effective doses of these compounds depend on route of exposure and target organs. For the same amount of internalized chloroform, ingestion results in a higher dose to the liver, while inhalation and dermal absorption result in higher fetal exposure (Weisel and Jo, 1996). As inhalation and dermal absorption exposures to THMs in Cherepovets are high in pregnant women, these exposures may result in measurable fetotoxic and teratogenic effects.

HAAs, HANs and MX are not volatilized during boiling, which results in high ingestion exposures in Cherepovets pregnant women. Most epidemiological studies of pregnancy outcomes conducted to date relied on THMs measurements to characterize exposures. Thus, epidemiological data on developmental toxicity and teratogenicity of other classes of DBPs are extremely limited or non-existent (Neuwenhuijsen et al., 2000a and 2000b). However, toxicological studies have demonstrated fetotoxic and teratogenic effects of HAAs (Smith et al., 1989a and 1992; Hunter et al., 1996; Ward et al., 2002) and HANs (Smith et al., 1988 and 1989b). It would also be prudent to minimize exposures to MX and other unknown mutagenic DBPs that determine high mutagenic activity of Cherepovets tap water in the standard *Salmonella* assay.

Construction of a new more sophisticated water treatment plant that will minimize formation of

DBPs in treated water was under way in Cherepovets at the beginning of 2003. Meanwhile, application of home filters may be recommended to a sensitive subpopulation such as pregnant women as a temporary measure to reduce ingestion exposures to semi-volatile and non-volatile DBPs in Cherepovets and elsewhere.

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Guidance for People with Severely Weakened Immune Systems

(co-released with the Centers for Disease Control and Prevention, 1995)

INTRODUCTION

Cryptosporidium is a parasite commonly found in lakes and rivers, especially when the water is contaminated with sewage and animal wastes. *Cryptosporidium* is very resistant to disinfection, and even a well-operated water treatment system cannot ensure that drinking water will be completely free of this parasite. Current EPA drinking water standards were not explicitly designed to assure the removal or killing of *Cryptosporidium*. Many large water systems already voluntarily take actions for greater control of *Cryptosporidium* and other microbial contaminants. By 2001, the water systems serving the majority of the United States population (those relying on a surface water source, such as a river, and serving more than 10,000 people) must meet a new EPA standard that strengthens control over microbial contaminants, including *Cryptosporidium*. EPA continues to conduct research on microbial contaminants which will be used for determining priorities for the drinking water program, including setting future standards and reevaluating existing standards.

Cryptosporidium has caused several large waterborne disease outbreaks of gastrointestinal illness, with symptoms that include diarrhea, nausea, and/or stomach cramps. People with severely weakened immune systems (that is, severely immunocompromised) are likely to have more severe and more persistent symptoms than healthy individuals. Moreover, *Cryptosporidium* has been a contributing cause of death in some immunocompromised people. Individuals who are severely immunocompromised may include those who are infected with HIV/AIDS, cancer and transplant patients taking immunosuppressive drugs, and people born with a weakened immune system.

BACKGROUND

Data are not adequate to determine how most people become infected. For example, we do not know the importance of drinking water compared to other possible sources of *Cryptosporidium*, such as exposure to the feces of infected persons or animals, sex involving contact with feces, eating contaminated food, or accidentally swallowing contaminated recreational water.

Thus, in the absence of an outbreak, there are insufficient data to determine whether a severely immunocompromised individual is at a noticeably greater risk than the general public from waterborne *Cryptosporidiosis*. Even a low level of *Cryptosporidium* in water, however, may be of concern for the severely immunocompromised, because the illness can be life-threatening. The risk of a severely immunocompromised individual acquiring *Cryptosporidiosis* from drinking water in the absence of an outbreak is likely to vary from city to city, depending on the quality of the city's water source and the quality of water treatment. Current risk data are not adequate to support a recommendation that severely immunocompromised persons in all U.S. cities boil or avoid drinking tap water.

In the absence of a recognized outbreak, this guidance has been developed for severely immunocompromised people who may wish to take extra precautions to minimize their risk of infection from waterborne *Cryptosporidiosis*. To be effective, the guidance must be followed consistently for all water used for drinking or for mixing beverages. During outbreaks of waterborne *Cryptosporidiosis*, studies have found that people who used precautions only part of the time were just as likely to become ill as people who did not use them at all.

GUIDANCE

EPA and CDC have developed the following guidance for severely immunocompromised people who may wish to take extra precautions. Such individuals should consult with their health care provider about what measures would be most appropriate and effective for reducing their overall risk of *Cryptosporidium* and other types of infection.

Although data are not sufficient for EPA/CDC to recommend that all severely immunocompromised persons take extra caution with regards to their drinking water, individuals who wish to take extra measures to avoid waterborne Cryptosporidiosis can bring their drinking water to a full boil for one minute. **Boiling water is the most effective way of killing *Cryptosporidium*.** As an alternative to boiling water, people may use the following measures:

- **A point-of-use (personal use, end-of-tap, under-sink) filter.** Only point-of-use filters that remove particles one micrometer or less in diameter should be considered. Filters in this category that provide the greatest assurance of *Cryptosporidium* removal include those that use reverse osmosis, those labeled as "Absolute" one micrometer filters, or those labeled as certified by NSF International under standard 53 for "Cyst Removal." The "Nominal" one micrometer rating is not standardized and many filters in this category may not reliably remove *Cryptosporidium*. As with all filters, people should follow the manufacturer's instructions for filter use and replacement. Water treated with a point-of-use filter that meets the above criteria may not necessarily be free of organisms smaller than *Cryptosporidium* that could pose a health hazard for severely immunocompromised individuals.
- **Bottled water.** Many, but not all, brands of bottled water may provide a reasonable alternative to boiling tap water. The origin of the source water, the types of microorganisms in that water, and the treatment of that water before it is bottled vary considerably among bottled water companies and even among brands of water produced by the same company. Therefore, individuals should not presume that all bottled waters are absolutely free of *Cryptosporidium*. Bottled waters derived from protected well and protected spring water sources are less likely to be contaminated by *Cryptosporidium* than bottled waters containing municipal drinking water derived from less protected sources such as rivers and lakes. Any bottled water treated by distillation or reverse osmosis before bottling assures *Cryptosporidium* removal. Water passed through a commercial filter that meets the above criteria for a point-of-use device before bottling will provide nearly the same level of *Cryptosporidium* removal as distillation or reverse osmosis. Bottled waters meeting the above criteria may not necessarily be free of organisms other than *Cryptosporidium* that could pose a health hazard for severely immunocompromised individuals.

Neither EPA nor CDC maintains a list of point-of-use filters or bottled water brands that meet the above criteria. NSF International can provide a list of filters that meet the NSF criteria. The NSF address is 789 N. Dixboro Road, PO Box 130140, Ann Arbor, Michigan 48113-0140; phone number (877) 8-NSF-HELP (<http://www.nsf.org/>). Individuals who contact bottlers or filter manufacturers for information should request data supporting claims that a brand of bottled water or filter can meet the above criteria.

FURTHER INFORMATION

When an outbreak of waterborne Cryptosporidiosis is recognized and is determined to be on-going, officials of the public-health department and/or the water utility will normally issue a "boil water" notice to protect both the general public and the immunocompromised.

Current testing methods cannot determine with certainty whether *Cryptosporidium* detected in drinking water is alive or whether it can infect humans. In addition, the current method often requires several days to get results, by which time the tested water has already been used by the public and is no longer in the community's water pipes.

Severely immunocompromised people may face a variety of health risks. Depending on their illness and circumstances, a response by such individuals that focuses too specifically on one health risk may decrease the amount of attention that should be given to other risks. Health care providers can assist severely immunocompromised persons in weighing these risks and in applying this guidance.



The effect of boiling water on disinfection by-product exposure

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Abstract

Chloraminated and chlorinated waters containing bromide were used to determine the impact of boiling on disinfection by-product (DBP) concentrations. No significant changes were detected in the concentrations of the dihalogenated haloacetic acids (DXAAs) (i.e., dichloro-, bromochloro-, dibromoacetic acid) upon boiling of chloraminated water, whereas the levels of the trihalogenated haloacetic acids (TXAAs) (i.e., trichloro- (TCAA), bromodichloro- (BDCAA), dibromochloroacetic acid (DBCAA)) decreased over time (e.g., 9–37% for TCAA). Increased DXAA concentrations (58–68%) were detected in the boiled chlorinated sample, which likely resulted from residual chlorine reacting with DXAA precursors. TCAA concentration was unchanged after boiling chlorinated water for 1 min, but a 30% reduction was observed after 5 min of boiling. BDCAA concentrations decreased 57% upon boiling for 1 min and were completely removed after 2 min of boiling, whereas DBCAA was removed after boiling chlorinated water for 1 min. Trihalomethane concentrations were reduced in both chloraminated (74–98%) and chlorinated (64–98%) water upon boiling. Boiling chloraminated water for 1 min reduced chloroform concentration by 75%. Chloroform was reduced by only 34% in chlorinated water after a 1 min boil, which indicates that simultaneous formation and volatilization of chloroform was occurring. Most of the remaining DBPs (e.g. halo ketones, chloral hydrate, haloacetonitriles) were removed by at least 90% after 1 min of boiling in both samples. These data suggest that other mechanisms (e.g., hydrolysis) may have been responsible for removal of the non-volatile DBPs and further highlight the importance of examining individual species when estimating thermal effects on DBP concentrations.

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Keywords: Disinfection by-products; Trihalomethanes; Haloacetic acids; Halo ketones; Haloacetonitriles; Boiling water

1. Introduction

Disinfection by-products (DBPs) are ubiquitous in chemically disinfected water containing natural organic matter and/or bromide. Carcinogenic and reproductive effects of DBPs have been reported in toxicological and epidemiological studies (Nieuwenhuijsen et al., 2000;

Villanueva et al., 2003). Epidemiologic studies of DBPs have often relied on ecologic measures, including type of treatment, type of source water, and trihalomethane (THM) compliance monitoring data (e.g., utility average concentrations) to estimate individual-level exposures. These indirect measures of exposure lead to measurement error, which can result in bias and reduced statistical power to detect associations. Key DBP research needs have been identified to address these exposure assessment limitations, including collection of detailed individual water use data, examination of

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non-volatile DBPs, use of sensitivity and uncertainty analysis, and development of exposure prediction models (Arbuckle et al., 2002; Nieuwenhuijsen et al., 2000). Recent DBP research has begun to address some of these DBP exposure assessment issues (Whitaker et al., 2003; Waller et al., 2001; Wright and Bateson, 2004; Wright et al., 2004; Dodds et al., 2004; Fenster et al., 2003; Windham et al., 2003), but it remains unclear which of these needs are most critical.

Information on exposure modifying factors, such as point-of-use filtration and boiling water prior to consumption (e.g., hot water-based beverages) needs to be considered in epidemiologic studies, because these activities can influence estimates of DBP ingestion exposure (Egorov et al., 2003; Eslinger and Weinberg, 2003). Experimental data have shown that boiling water prior to consumption can greatly impact DBP concentrations (Table 1). Batterman and colleagues (2000) examined thermal effects on THM concentrations by heating chlorine-free distilled water in an electric kettle. Average volatilization rates of 81% for chloroform (trichloromethane (TCM)) and 73% for bromodichloromethane (BDCM) were reported at 100 °C, with a 69% reduction in the four regulated THMs (THM4). Wu and colleagues (2001) conducted boiling experiments of Seattle tap water typically containing 0.9 mg/L chlorine residual and 0.9–1.5 mg/L of dissolved organic carbon (DOC). As boil time increased from 1 to 5 min, reductions of 68% and 83% for chloroform and 75% and 94% for BDCM were observed. Lahl and colleagues (1982) reported THM4 volatilization losses of 73% for a 1-min boil and 88% following a 5-min boil. Chloroform had the highest loss, and the amount removed during boiling decreased with increasing bromine substitution. Kuo and colleagues (1997) found similar removals of chloroform and BDCM upon boiling chlorinated water from Taiwan.

Different effects of boiling on haloacetic acid (HAA) concentrations have been reported in previous experimental studies (Table 1). Trichloroacetic acid (TCAA), a trihalogenated acid (TXAA), has been shown to be more readily removed (30–70%) upon boiling compared to the other subclasses of HAAs (i.e., dihaloacetic acids (DXAAs) and monohaloacetic acids (MXAAs)). Wu and colleagues (2001) reported more than a doubling of dichloroacetic acid (DCAA) levels in chlorinated water upon boiling for 1 or 5 min, whereas Kim (1997) observed no change in DCAA levels in distilled water following a 5-min boil. These results suggest that DCAA originally present was not impacted by boiling and that, in the presence of chlorine, additional DCAA could form during the boiling process. Changes in MXAA concentrations from previous studies varied from –28% to 46%. The MXAAs are typically present (if detected) at concentrations near their minimum reporting levels (MRLs) in most chlorinated waters, which limits the ability to quantify changes upon heating.

Table 1
Previous experimental studies of boiling effects on disinfection by-product concentrations^a

Study (boiling time)	TCM (%)	BDCM (%)	DBCM (%)	THM4 (%)	MCAA (%)	MBAA (%)	DCAA (%)	BCAA (%)	DBAA (%)	TCAA (%)
Kim (1997) (5 min) ^b							0			–40
Dojido et al. (1999) (10 min) ^c					–6	–28	–18		–11	–70
Wu et al. (2001) (1 min) ^d	–68	–75			25	40	122	–13		–30
Wu et al. (2001) (5 min) ^d	–83	–94			32	46	130	–7		–46
Batterman et al. (2000) (12.5 min) ^b	–81	–73		–69						
Kuo et al. (1997) ^{d,e}	–79	–79	–93							
Lahl et al. (1982) (1 min) ^f	–80	–76	–71	–73						
Lahl et al. (1982) (5 min) ^f	–91	–90	–87	–88						

Abbreviations: TCM = chloroform (trichloromethane), BDCM = bromodichloromethane, DBCM = dibromochloromethane, TBM = bromoform (tribromomethane), THM4 = sum of the four regulated trihalomethanes, MCAA = monochloroacetic acid, MBAA = monobromoacetic acid, DCAA = dichloroacetic acid, BCAA = bromochloroacetic acid, DBAA = dibromoacetic acid, TCAA = trichloroacetic acid.

^aNegative value corresponds to decrease in concentration of DBP, whereas positive value corresponds to increase in concentration of DBP.

^bDistilled water with known DBP concentration.

^cOzonated and chlorinated water.

^dChlorinated water.

^eBoil time not reported.

^fHypochlorite treated water.

Hot and cold water use is an increasingly important consideration for DBP exposure assessment, because hot water-based beverages can contribute substantially to overall water consumption levels (Kaur et al., 2004; Egorov et al., 2003) and may have higher levels of certain DBPs compared to cold water. Balko and colleagues (2001) reported TCAA and DCAA concentrations up to three times as high in tea, coffee, and juice samples compared to chloraminated tap water, suggesting that the residual chlorine reacted with HAA precursors in the beverages. In the present study, boiling experiments were conducted on chloraminated and chlorinated water containing bromide. The effects of boiling on a wide range of regulated and emerging DBPs of health concern (Woo et al., 2002) were examined in relation to degree of DBP volatility and bromine substitution.

2. Methods

The boiling experiments were conducted on water samples from the Weymouth water treatment plant (La Verne, CA) in winter 2000. Although not measured, the DOC and bromide levels of this water were typically ~ 3.0 and ~ 0.1 – 0.2 mg/L, respectively. Conventional water treatment does not remove bromide, so bromide would have been present in the finished water. The typical pH of this water was ~ 8.2 . Separate aliquots of chlorinated filter effluent and chloraminated plant effluent were collected in 1-L glass bottles. Although not measured, the chlorine and chloramine residuals at these locations were each typically ~ 2.5 mg/L as Cl_2 . Residual chlorine and chloramines were not measured in each sample, but were at comparable levels based on treatment plant specifications. The disinfectant residuals of these samples were not quenched. Shortly after sampling, the water samples were boiled using a 2.5-quart tea kettle on a stovetop in the Metropolitan Water District of Southern California (MWDSC) laboratory kitchen. The experiments consisted of 1-, 2-, and 5-min boil times. The samples were allowed to cool down prior to extraction. Control samples consisted of water that was not boiled (i.e., boil time = 0). Note, the comparisons between the two water treatments are the results from a single set of samples. The samples underwent liquid/liquid extraction (LLE) and were analyzed for DBPs by gas chromatography/electron capture detection (GC/ECD) (Krasner et al., 2001). Additional samples underwent LLE, were derivatized with an acidic methanol solution, and were analyzed by GC/ECD for HAAs (Munch et al., 1995). Sample analysis included standard measures of quality assurance for precision, accuracy, and bias.

Values for Henry's Law constant—a measure of the volatility of a compound—were obtained from the literature or were estimated using a quantitative structure activity relationship model (HENRYWIN version 3.10, part of the Estimation Program Interface for Windows from the US Environmental Protection Agency) (Westerhoff, 2003). HENRYWIN provided experimental values where available and predicted the Henry's Law Constants at 25 °C by the bond contribution method for those DBPs without experimental values. Henry's Law Constants were not determined for boiling water at 100 °C. The Henry's Law Constants served as a tool to ascertain if a DBP was considered volatile (10^{-1} – 10^{-3} atm-m³/mol), moderately volatile (10^{-3} – 10^{-5} atm-m³/mol), slightly volatile (10^{-5} – 10^{-7} atm-m³/mol) or non-volatile ($<10^{-7}$ atm-m³/mol). DBPs that are not volatile would still be considered relatively non-volatile in boiling water.

3. Results

3.1. Overview

The HAAs were the most prevalent DBP in the chlorinated and chloraminated samples, followed by the THMs (Tables 2 and 3). Significant amounts of haloaldehydes, haloacetonitriles (HANs), and halo ketones (HKs) were also detected. Because of the presence of bromide in the treated source waters, there was a mix of bromine- and chlorine-containing DBP species detected for those DBP classes (i.e., THMs, HANs, haloaldehydes, HAAs) in which brominated species were analyzed. An iodinated THM (dichloriodomethane) was detected in the chlorinated water, while low levels of chloropicrin (trichloronitromethane (TCNM)) were found in both the chlorinated and chloraminated samples. As shown in Tables 2 and 3, with the exception of the HAAs as a class sum, the sum of the THMs and that of the other DBPs were significantly reduced following a 1-min boil. More modest reductions in these DBP concentrations occurred upon boiling for 2 and 5 min. Within some DBP classes, however, there were significant differences in the impact of boiling on the concentrations of individual DBPs (Fig. 1).

3.2. THMs

Reduction (presumably due to volatilization) in the sum of the THMs (i.e., THM4 and dichloriodomethane) was (in general) comparable for chlorinated and chloraminated waters, especially after 2 and 5 min of boiling (Tables 2 and 3). THM4 removals ranged from 64% to 98% across the different boiling times.

Table 2

Cumulative percent change (from time 0) in DBP concentrations ($\mu\text{g/L}$) from boiled chloraminated water^a

DBP class	Analyte	Time (min)			
		0	1	2	5
Regulated trihalomethanes (THMs)	Chloroform (trichloromethane) (TCM)	18	4.6 (–75%)	3.0 (–84%)	0.6 (–97%)
	Bromodichloromethane (BDCM)	26	6.3 (–75%)	4.2 (–84%)	0.6 (–98%)
	Dibromochloromethane (DBCM)	13	4.1 (–70%)	2.1 (–84%)	ND (–100%)
	Bromoform (tribromomethane) (TBM)	0.9	0.4 (–60%)	ND (–100%)	ND (–100%)
	Sum of 4 regulated THMs (THM4)	58	15 (–74%)	9.3 (–84%)	1.2 (–98%)
Haloacetonitriles (HANs)	Dichloroacetonitrile (DCAN)	4.3	0.2 (–96%)	0.1 (–98%)	ND (–100%)
	Bromochloroacetonitrile (BCAN)	1.1	0.05 (–96%)	0.07 (–94%)	ND (–100%)
Haloaldehydes (HAs)	Dichloroacetaldehyde (DCA)	1.5	0.5 (–70%)	0.4 (–75%)	0.2 (–85%)
	Chloral hydrate (CH) (trichloroacetaldehyde)	5.1	0.1 (–98%)	0.1 (–98%)	ND (–100%)
Haloketones (HKs)	1,1-Dichloropropanone (1,1-DCP)	0.5	ND (–100%)	ND (–100%)	ND (–100%)
	1,3-Dichloropropanone (1,3-DCP)	0.1	0.07 (–42%)	ND (–100%)	ND (–100%)
	1,1,1-Trichloropropanone (1,1,1-TCP)	2.2	ND (–100%)	ND (–100%)	ND (–100%)
	1,1,3-Trichloropropanone (1,1,3-TCP)	0.1	ND (–100%)	ND (–100%)	ND (–100%)
Halonitromethane (HNM)	Chloropicrin (trichloronitromethane) (TCNM)	1.4	0.7 (–50%)	0.5 (–67%)	ND (–100%)
Sum of other DBPs (i.e., HANs, HAs, HKs, HNM)		16	1.6 (–90%)	1.1 (–93%)	0.2 (–99%)
Haloacetic acids	Dichloroacetic acid (DCAA)	38	34 (–9%)	37 (–3%)	40 (7%)
	Bromochloroacetic acid (BCAA)	14	14 (4%)	15 (9%)	15 (12%)
	Dibromoacetic acid (DBAA)	4.5	4.2 (–7%)	4.1 (–9%)	4.3 (–4%)
	Sum of dihalogenated HAAs (DXAAs)	56	53 (–6%)	56 (–1%)	60 (7%)
	Trichloroacetic acid (TCAA)	26	23 (–9%)	20 (–21%)	16 (–37%)
	Bromodichloroacetic acid (BDCAA)	15	7.1 (–53%)	3.2 (–79%)	1.1 (–93%)
	Dibromochloroacetic acid (DBCAA)	3.9	ND (–100%)	ND (–100%)	ND (–100%)
	Sum of trihalogenated HAAs (TXAAs)	45	30 (–32%)	23 (–48%)	17 (–61%)
Sum of HAAs		100	83 (–17%)	79 (–22%)	77 (–23%)

Abbreviations: DBP = disinfection by-product, ND = not detected.

^aPercent changes were calculated from the values of the concentrations before those values were rounded to the number of significant figures given in this table.

Table 3
Cumulative percent change (from time 0) in DBP concentrations ($\mu\text{g/L}$) from boiled chlorinated water^a

DBP class	Analyte	Time (min)			
		0	1	2	5
Regulated trihalomethanes (THMs)	Chloroform (trichloromethane) (TCM)	30	20 (−34%)	2.8 (−91%)	1.0 (−97%)
	Bromodichloromethane (BDCM)	33	6.4 (−81%)	2.2 (−93%)	0.7 (−98%)
	Dibromochloromethane (DBCM)	16	2.9 (−82%)	0.4 (−97%)	ND (−100%)
	Bromoform (tribromomethane) (TBM)	1.0	0.2 (−76%)	ND (−100%)	ND (−100%)
	Sum of 4 regulated THMs (THM4)	80	29 (−64%)	5.4 (−93%)	1.6 (−98%)
Iodinated THM	Dichloriodomethane (DCIM)	0.8	ND (−100%)	ND (−100%)	ND (−100%)
Sum of THMs		81	29 (−64%)	5.4 (−93%)	1.6 (−98%)
Haloacetonitriles (HANs)	Dichloroacetonitrile (DCAN)	6.2	0.1 (−98%)	ND (−100%)	ND (−100%)
	Bromochloroacetonitrile (BCAN)	1.6	0.1 (−94%)	ND (−100%)	ND (−100%)
Haloaldehydes (HAs)	Dichloroacetaldehyde (DCA)	1.2	0.9 (−27%)	0.2 (−85%)	0.06 (−95%)
	Chloral hydrate (CH) (trichloroacetaldehyde)	12	0.4 (−97%)	ND (−100%)	ND (−100%)
	Tribromoacetaldehyde (TBA)	0.4	0.4 (0%)	ND (−100%)	ND (−100%)
Haloketones (HKs)	Chloropropanone (CP)	1.1	0.08 (−93%)	ND (−100%)	ND (−100%)
	1,1-Dichloropropanone (1,1-DCP)	0.3	ND (−100%)	ND (−100%)	ND (−100%)
	1,3-Dichloropropanone (1,3-DCP)	0.2	ND (−100%)	ND (−100%)	ND (−100%)
	1,1,1-Trichloropropanone (1,1,1-TCP)	6.2	ND (−100%)	ND (−100%)	ND (−100%)
Halonitromethane (HNM)	Chloropicrin (trichloronitromethane) (TCNM)	1.5	0.7 (−57%)	ND (−100%)	ND (−100%)
Sum of other DBPs (i.e., HANs, HAs, HKs, HNM)		31	2.6 (−92%)	0.2 (−99%)	0.06 (−100%)
Haloacetic acids (HAAs)	Monochloroacetic acid (MCAA)	3.4	3.9 (15%)	4.2 (24%)	4.6 (35%)
	Dichloroacetic acid (DCAA)	43	68 (59%)	72 (69%)	75 (76%)
	Bromochloroacetic acid (BCAA)	17	26 (51%)	25 (48%)	25 (49%)
	Dibromoacetic acid (DBAA)	4.3	7.4 (72%)	6.9 (60%)	6.8 (58%)
	Sum of dihalogenated HAAs (DXAAs)	64	101 (58%)	104 (63%)	107 (68%)
	Trichloroacetic acid (TCAA)	31	31 (0%)	28 (−10%)	21 (−30%)
	Bromodichloroacetic acid (BDCAA)	17	7.4 (−57%)	3.1 (−82%)	ND (−100%)

Table 3 (continued)

DBP class	Analyte	Time (min)			
		0	1	2	5
	Dibromochloroacetic acid (DBCAA)	4.6	ND (–100%)	ND (–100%)	ND (–100%)
	Sum of trihalogenated HAAs (TXAAs)	52	38 (–27%)	31 (–41%)	21 (–60%)
Sum of HAAs		120	142 (19%)	139 (16%)	133 (11%)

Abbreviations: DBP = disinfection by-product, ND = not detected.

^aPercent changes were calculated from the values of the concentrations before those values were rounded to the number of significant figures given in this table.

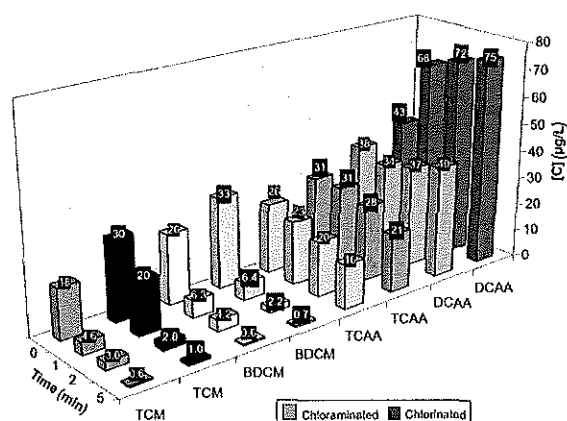


Fig. 1. The effects of boiling chlorinated and chloraminated water on the concentrations of the major THM and HAA species.

Individual THM removals in the chloraminated water ranged from 60% to 75% in chloraminated water boiled for 1 min (Table 4). The THMs are the most volatile group of the DBPs studied, based on their values of Henry's Law constant (the higher the value, the more volatile the compound). Eighty-four percent or more of each species was removed following a 2-min boil, whereas 97% or more of each THM was removed upon boiling for 5 min (Table 2). In the chlorinated water, slightly higher removal of the bromine-containing THMs was detected following a 1-min boil (76–82%), whereas there was limited removal (34%) of chloroform (Table 3). There was little difference between THM removal in chlorinated versus chloraminated water upon further boiling, with both samples having removals of 97% or greater for each THM detected after 5 min of boiling. The only iodinated THM that was detected, dichloriodomethane, was completely eliminated after boiling chlorinated water for 1 min.

Table 4

Relationship of volatility of DBPs to percent change from time 0 after 1 min of boiling in chloraminated water

DBP	Henry's Law Constant (atm·m ³ /mol)	% Change from time 0 at 1 min in chloraminated water ^a
TCM	3.67E–03 ^b	–75
BDCM	2.12E–03 ^b	–75
TCNM	2.05E–03 ^b	–50
DBCM	7.83E–04 ^b	–70
TBM	5.35E–04 ^b	–60
DCA ^c	8.42E–06	–70
DCAN	3.79E–06	–96
DCAA	3.52E–07 ^b	–9
TBA	1.04E–07	N/A
BCAA	2.22E–08	4
TCAA	1.35E–08 ^b	–9
BDCAA	7.83E–09	–53
MCAA	9.42E–09 ^b	N/A
DBAA	7.27E–09	–7
CH	5.71E–09	–98

Abbreviations: DBPs = disinfection by-products, N/A = not applicable (not detected in chloraminated water at time 0).

^aVolatility comparisons were made with the test in chloraminated water, to eliminate the confounding phenomena of simultaneous formation of some DBPs in the presence of chlorine.

^bFrom literature values provided in HENRYWIN. Other Henry's Law Constants in this table were estimated by HENRYWIN.

^cHenry's Law Constant was estimated for dichloroacetaldehyde and not for its hydrate.

3.3. HAAs

The overall impact of boiling on HAAs gave different results in the two water samples that were

analyzed. Increased HAA formation occurred in the chlorinated water after 1 min of boiling, and the concentration was still relatively high after 5 min of boiling (Table 3). A reduction in overall HAA concentration was observed in chloraminated water after 1 min of boiling, and the levels changed very little upon further boiling.

Boiling of the chloraminated sample produced no significant changes (–9% to 7%) in DCAA concentrations (Fig. 1), where the coefficient of variation of DCAA and other DBP samples is typically on the order of approximately $\pm 20\%$ (Fair et al., 2002). Similar results were observed in the chloraminated sample for the other DXAAs, with no significant change in bromochloroacetic acid (BCAA) and dibromoacetic acid (DBAA) concentrations (Table 2). DCAA concentrations in chlorinated water increased from 59 to 76% as boiling time increased from 1 to 5 min (Table 3). BCAA and DBAA concentrations increased by at least 50% in chlorinated water for a 1-min boil but remained relatively constant upon further boiling. No change in TCAA concentration was observed for a 1-min boil of chlorinated water, but 10% and 30% reductions were noted in water boiled for 2 and 5 min, respectively (Fig. 1). Among the chloraminated samples, somewhat larger reductions (9–37%) in TCAA concentrations were found as boil time increased. Similar reductions were observed over time for bromodichloroacetic acid in both the chlorinated (57–100%) and chloraminated samples (53–93%). Although found in smaller concentrations compared to the other TXAAs, dibromochloroacetic acid was not detected upon boiling for 1 min. Small increases in the monochloroacetic acid (MCAA) concentration were noted for the chlorinated sample upon boiling.

3.4. HKs

For the chloraminated water sample, substantial reductions in concentrations were noted for most of the other DBPs upon boiling (Table 2). The following HKs were not detected after 1 min: 1, 1-dichloropropanone (1,1-DCP), 1, 1, 1-trichloropropanone (1,1,1-TCP), and 1, 1, 3-trichloropropanone (1,1,3-TCP). The level of 1, 3-dichloropropanone (1,3-DCP) decreased 42% upon boiling for 1 min and was completely removed after 2 min of boiling. Similar reductions were observed in the chlorinated water with complete removal of 1,1-DCP, 1,1,1-TCP and 1,3-DCP upon boiling for 1 min (Table 3). In addition, the concentration of chloropropanone (CP) was reduced by 93% following a 1-min boil and was not detected after 2 min. CP was not detected in the chloraminated water sample, and 1,1,3-TCP was not found in the chlorinated water sample.

3.5. HANs

HAN concentrations in chloraminated water were reduced by 94–98% following a 1- and 2-min boil, and were not detected upon 5 min of boiling (Table 2). Similar removal of the HANs (94–98%) occurred upon boiling the chlorinated sample for 1 min, and no HANs were detected in the chlorinated water after 2 min (Table 3).

3.6. Haloaldehydes

The concentration of dichloroacetaldehyde (DCA) in chloraminated water was reduced from 70% to 85% for 1- to 5-min boil times (Table 2). Boiling chlorinated water for 1 min had a minimal effect on the level of DCA (–27%), but reductions from 85% to 95% were observed upon further boiling (Table 3). Chloral hydrate (CH) (i.e., trichloroacetaldehyde) concentration was reduced by at least 97% following a 1-min boil of both chlorinated and chloraminated water and was not detected after 2 min. Tribromoacetaldehyde (TBA) was not detected in the chloraminated water and a minimal amount was found in chlorinated water (0.37 $\mu\text{g/L}$). TBA was unchanged upon boiling for 1 min and was not detected after 2 min of boiling.

3.7. Halonitromethane

TCNM concentration was 50–67% lower in the chloraminated water boiled for 1–2 min and was not detected at 5 min (Table 2). A reduction similar in magnitude (57%) was observed for chlorinated water boiled for 1 min, and TCNM was not detected after 2 min of boiling (Table 3).

4. Discussion

Overall, large reductions in most DBP concentrations were observed in boiling experiments of chloraminated and chlorinated finished water samples. Removal rates among the THMs were similar to those noted in previous studies (Lahl et al., 1982; Kuo et al., 1997; Batterman et al., 2000; Wu et al., 2001), although a smaller net removal of chloroform was detected in the chlorinated water (34%) compared to the chloraminated water (75%) for 1 min of boiling (Fig. 1). Because there was a free chlorine residual in the chlorinated water at the time of boiling, it is likely that chloroform was being formed from the reaction of the chlorine with DBP precursors in the water at the same time that chloroform was being volatilized. Although the residuals were not measured after boiling in these tests, preliminary experiments at MWDSC have shown

that the chlorine residual was removed during the first minute of boiling. Thus, the critical issue is that there can be simultaneous formation and volatilization during the first minute, whereas in subsequent minutes of boiling only volatilization can occur. In the chloraminated water, volatilization appeared to be the most important phenomenon, even during the first minute of boiling. In that sample, the two more brominated THMs were removed to a lesser extent (60–70%) than the two more chlorinated THMs (75%). This is similar to the finding of Lahl and colleagues (1982) for a 1-min boil.

Different effects were observed in haloaldehyde concentrations upon boiling. The semi-volatile haloaldehydes, DCA and TBA (Table 4), were not significantly impacted by boiling chlorinated water for 1 min, suggesting that there was simultaneous formation and removal of these haloaldehydes while a free chlorine residual was present. Note, because conventional water treatment does not remove bromide, there can still be bromide in the finished water available to react with free chlorine to form TBA. Their removal at longer boiling times in the chlorinated water and the removal of DCA in the chloraminated water may be due to a combination of volatilization and degradation. Alternatively, the removal of the non-volatile CH (Table 4) was probably due to base-catalyzed hydrolysis. Although hydrolysis is more significant at pH 9 than at pH 7 for CH (Stevens et al., 1989), the combination of elevated temperature and alkaline pH may have resulted in the degradation of this DBP.

HAN concentrations were dramatically reduced upon boiling of chloraminated and chlorinated water. Dichloroacetonitrile (DCAN) is a semi-volatile DBP (Table 4), which can also undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989). DCAN's degradation product is dichloroacetamide, which can be further hydrolyzed to DCAA (Reckhow et al., 2001). Therefore, it is possible that some of the HANs degraded (e.g., due to hydrolysis), in addition to volatilizing, during the boiling process. TCNM does not undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989) and has a Henry's Law Constant similar to that of the THMs (Table 4), so reductions in TCNM concentrations were likely due to volatilization.

Henry's Law constant values were not obtained for the HKs. Some HKs (e.g., 1,1,1-TCP) are known to undergo base-catalyzed hydrolysis (Croué and Reckhow, 1989). The pH of the samples in the present study was ~8.2; therefore, it is possible that some of the HKs degraded (e.g., due to hydrolysis) during the boiling process. Chloroform is the degradation product of 1,1,1-TCP and CH hydrolysis; therefore, these degradation processes may have contributed to the limited removal of chloroform that was observed during the initial boil of chlorinated water.

In general, the DXAAs were not significantly impacted by boiling in the chloraminated water (Table 2), whereas their concentrations increased significantly in the chlorinated water (Table 3). Most of the increased formation occurred during the first minute of boiling as shown for DCAA (Fig. 1). These data suggest that free chlorine reacted with DBP precursors to form additional DXAAs (and perhaps MCAA), which were not volatilized or degraded by the boiling process. The DXAAs and other HAAs are not volatile (Table 4). A reduction in TXAA concentrations during the boiling process was observed, with the rate of loss higher with increased bromine substitution. Bromine-containing TXAAs have been shown to be less stable with increasing bromine substitution and are subject to thermal- and photo-degradation (Pourmoghaddas and Dressman, 1993). Thus, the loss of the brominated TXAAs in the present study was most likely due to the relative instability of these DBPs. The net impact on the sum of the HAAs (increased concentrations of 11–19% for chlorinated water and decreased concentrations of 17–23% in the chloraminated samples) reflect the very different impact of boiling on the two subclasses of HAAs, DXAAs and TXAAs. These findings highlight the importance of considering the varied formation and degradation processes of individual HAAs when estimating the impact of heating and boiling on exposures.

5. Conclusion

The different effects of boiling within DBP classes in chlorinated versus chloraminated water have important implications for DBP exposure assessment efforts in epidemiologic studies. Previous DBP research has rarely included individual-level water use information, and only two epidemiological studies have examined individual data on hot and cold beverage consumption. Compared to THM water concentrations alone, Klotz and Pyrch (1999) and Waller and colleagues (1998) reported smaller relative risks for reproductive outcomes with THM exposures that considered hot and cold water consumption. Neither study attempted to adjust estimates of individual exposure to account for volatilization or other exposure modifying effects. These studies were also limited in their ability to adequately consider the impact of dermal and inhalation exposures, which may be more important than ingestion for volatile DBPs (Gordon et al., 1998; Keating et al., 1997). THM concentrations can increase upon heating water at lower temperatures than boiling (Weisel and Chen, 1994; Batterman et al., 2000), so future studies should also consider potential exposure modifying activities (e.g., water temperatures during showering or in swimming pools) that may impact overall DBP exposure.

Based on the results of this study and the previous research cited, the effects of heating and boiling on DBPs are dependent on the degree of DBP volatility and compound stability, water temperature, type of residual disinfectant present, as well as the amount of DBP precursors and chlorine residual present in the water. Because chlorine residual can vary considerably within a distribution system, boiling and heating effects may differ between individuals using the same water supply. Failure to directly measure residential DBP concentrations or adequately capture spatial variability in residual chlorine and DBP formation/degradation when estimating individual level exposures can lead to measurement error in epidemiologic studies.

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TTHM (total trihalomethanes) FACT SHEET

WHY ARE THERE TTHMS IN DRINKING WATER?

TTHM are what is known as Disinfection- By- Products (DBPs) and are formed in water treatment.

The TTHMS are an indicator of how disinfection of the drinking water is managed. This includes the time the water is in the pipes.

Disinfection of water is important to prevent waterborne disease and thus is essential for the water industry as part of the *Safe Drinking Water Act*. Health agencies including the World Health Organization support disinfection to control microorganisms. Thus the goal for water treatment is to obtain microbial safe water while minimizing these DBPs.

WHAT ARE THE HEALTH ISSUES?

Of the many studies looking at long-term exposure a few have shown a small number of people were affected and thus the standard for TTHM levels was reduced in 1990s. A few People who drink water containing THMs in excess of the standard (MCL) over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer. However no links have been established when drinking water in excess of the standard for a few days.

A few studies have suggested that THMs in drinking water are associated with miscarriages and certain birth defects when consumed during the first three months of pregnancy. However, EPA has concluded that no link has been established between adverse reproductive outcomes and the TTHMs levels found in drinking water.

NOTE: Some individuals who are severely compromised immune compromised the elderly, and young infants may be at greater risk when using tap water. Even when tap water is safe for most healthy people to drink because a water utility is doing a good job of meeting or surpassing all standards set by the EPA, there are some groups of people such as those undergoing chemotherapy treatment for cancer, people with HIV/AIDS or other immune disorders, those who have undergone organ transplants, and some elderly and infants — who are more vulnerable to microbial and some other contaminants in their drinking water.

A particular concern is if other contaminants lead, nitrates or pesticides are in the tap water. These have been tested and are at safe levels in the drinking water.

WHAT TO DO

If you are concerned about TTHMs in your tap water, call (us the water utility, health dept?).

Some experts suggest that you can refrigerate tap water in an open container for several hours before drinking to allow TTHMs to leave the water and enter the air.

A carefully selected bottled water (check www.nrdc.org for bottled water test results) or water that has been filtered by a home system could be used.

SOURCES:

<http://water.epa.gov/lawsregs/rulesregs/sdwa/stage2/regulations.cfm>

National Primary Drinking Water : Stage 2 Disinfectants and Disinfectant By Products Rule Issues January 1, 2006 which modified the original regulation from 1979.

C2 DBP Health Effects

"EPA concludes that no dose response relationship or causal link has been established between exposure to chlorinated drinking water or disinfection byproducts and adverse developmental or reproductive effects. "

They go on as a way to justify adding the DBP2 requirements by saying: " EPA's evaluation of the best available studies, particularly epidemiological studies is that they do not support a conclusion at this time as to whether exposure to chlorinated drinking water or disinfection byproducts cause adverse developmental and reproductive health effects, but do provide an indication of a potential health concern that warrants incremental regulatory action beyond Stage 1 DBPR."

ARE YOU MORE VULNERABLE TO DRINKING WATER CONTAMINANTS?¹

Even when tap water is safe for most healthy people to drink because a water utility is doing a good job of meeting or surpassing all standards set by the EPA, there are some groups of people — such as those undergoing chemotherapy treatment for cancer, people with HIV/AIDS or other immune disorders, those who have undergone organ transplants, and some elderly and infants — who are more vulnerable to microbial and some other contaminants in their drinking water.

That is why the Environmental Protection Agency (EPA) requires that every annual water quality report, (sometimes called “Consumer Confidence Report”), include the following cautionary explanation:

“ Some people may be more vulnerable to contaminants in drinking water than the general population. Immunocompromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly and infants can be particularly at risk from infections. These people should seek advice about drinking water from their health care providers. EPA/CDC [Centers for Disease Control and Prevention] guidelines on appropriate means to lessen the risk of infection by *Cryptosporidium* and other microbial contaminants are available from the **Safe Drinking Water Hotline (800-426-4791)**”

This fact sheet will answer some frequently asked questions about health risks for such people and the precautions they may choose to take. For more information about drinking water including health risks associated with any contaminant found in your drinking water, contact the EPA hotline number highlighted above or their drinking water web site: www.epa.gov/safewater/mcl.html (*scroll down to Table*). Additional materials are also available from the Coordinator of the Campaign for Safe and Affordable Drinking Water, Lynn Thorp, who may be contacted at 202-895-0420, x 109 or by e-mail: csadw@cleanwater.org.

1 What is Cryptosporidium (Crypto)?

- *Crypto is a protozoan that takes the form of tiny cysts that can survive chlorination and slip through standard municipal water filters. Crypto is known to enter the water supply through sewage leakage or agricultural run off that is contaminated with feces. People with healthy*

¹This fact sheet has been prepared by Consumer Federation of America for **The Campaign for Safe and Affordable Drinking Water**. The Campaign is a coalition of more than 300 organizations including: Clean Water Action, Consumer Federation of America, League of Women Voters, National Association People with AIDS, Natural Resources Defense Council; Physicians for Social Responsibility and US PIRG. The Campaign urges consumers to protect the sources of drinking water from contamination and to work with local water utilities to assure that everyone can safely drink their tap water.

immune systems may not become ill or, if they do, will usually recover within 7-20 days from Cryptosporidiosis (Crypto). Symptoms include: diarrhea, nausea, abdominal cramps, and a low fever. There is no medical cure for Crypto and it can be fatal for people with severely compromised immune systems. In 1993, Milwaukee experienced a major outbreak of Crypto (about 400,000 people were affected) that resulted in about 100 deaths, mostly among the immune compromised. Smaller outbreaks and individual cases occur each year and can cause severe weight loss and death in the immune compromised, such as people with HIV/AIDS.

2 How do I know if there is Crypto in my tap water?

- You don't. Crypto is known to exist in 86% of lakes, rivers and streams. It also exists in some underground water supplies that are subject to surface contamination. Currently, there is neither an EPA maximum contaminant limit (MCL) for Crypto nor a required treatment to fully remove it. EPA plans to establish stricter standards and specific techniques for Crypto removal or disinfection by the year 2002. Water utilities may report that Crypto was not found in the treated water. Unfortunately, tests are not accurate enough to detect all Crypto cysts that can make you ill. If any Crypto is detected in either the source water or in water after treatment, it is prudent for the immune suppressed to take precautions such as those suggested in #5 below. (However the failure to find Crypto is no guarantee that it is not in the water.)*

3 Are all elderly and infants more vulnerable to these infections?

- Probably not. Healthy older people and older children in good health are unlikely to be especially vulnerable. However, some vulnerable people may feel well but not be aware that the kinds of medical care they receive in order to stay well put them at risk of microbial infections. For example, long term and heavy use of steroids for arthritis and other conditions, and chemotherapy for cancer treatment, suppress the immune system and therefore makes one more vulnerable to a Crypto infection. Moreover, infants have immature immune systems and young children are subject to dangerous dehydration from Crypto-caused diarrhea. It is best to consult your health care provider if you have questions about the vulnerability of a particular child or elderly person.*

4. Is it always safer to drink bottled water?

- No. Although the Food and Drug Administration(FDA) regulates all bottled water, it subjects that water to less rigorous testing and purity standards than the EPA requires for your tap water². Moreover, FDA does not regulate bottled water that is packaged and sold only within a state even*

² NRDC, Bottled Water: Pure Drink or Pure Hype, 1999: www.nrdc.org/find/hebw.html.

though such water comprises 60-70% of all bottled water sold³. About 25% of all bottled water is municipal tap water (sometimes further treated, sometimes not). If you or someone in your family must drink an alternative to tap water, carefully read bottled water labels and the answers to #5 and 7 below.

5. What water is safe to drink for someone who is more vulnerable to Crypto and other waterborne microbial diseases?

- Tap water that has been boiled for one minute (not longer⁴); or
- Bottled water that has been treated as follows:⁵
 - Distilled water (Preferred by many health care providers); or
 - Other bottled water that has been filtered using reverse osmosis or an absolute one micron filtration system. Read the fine print on the label and call the company or National Sanitation Foundation (NSF)⁶ to confirm the treatment used; or
 - Tap water that has been filtered in the home using a filter that is certified by the NSF to remove cysts (The label on the filter on the faucet or under the sink should read “NSF Standard #53 for cyst reduction.”⁷) It is important to change filters as frequently as directed because over time contaminants trapped by the filter build up and may enter and seriously contaminate your drinking water.

³ Call your state Health Department to learn if and how your state regulates bottled water.

⁴ At an altitude of 6,000 feet or higher, it is necessary to boil water longer than 1 minute.

⁵ Centers for Disease Control and Prevention (CDC) approved methods for Crypto removal. See also CDC's web page: cdc.gov/ncidod/dpd/crypto.htm.

⁶ Or go to the California's excellent listing of certified water treatment devices on the web at <http://www.dhs.ca.gov/ps/ddwem/technical/certification/device/table.htm>

⁷ Call NSF at 1-800-NSF-MARK or go to www.nsf.org to learn which brands of bottled water or models of water filters have the NSF certification for the type of treatment you require. NSF is an independent, not-for-profit organization that tests and verifies that each certified product meets all the requirements of the specified standard(s) and that the manufacturers' claims are true. Be aware however, as a non-governmental group, its testing records are not open to the public and its certifications do not have the force of law. The Natural Resource Defense Council (an independent non-profit organization) conducted a large study of bottled water in 1998. Find the results on its web page: www.nrdc.org.

6. Are vulnerable people also at risk from any other contaminants in water?

- *Yes. For example, lead, nitrates/nitrites and Total Trihalomethanes (TTHMs), are not only known to increase the risk of certain chronic diseases after long term exposure, they also can cause acute (immediate) adverse health effects in some groups of vulnerable people. There is also concern that organic chemicals in pesticides sometimes found in drinking water pose an increased health threat to children.⁸ This fact sheet only addresses the acute health effects of lead, TTHMs and nitrates. You can learn about both the chronic and acute health effects of any contaminant in your drinking water by accessing the Safe Drinking Water Hot Line 800-426-4791 or EPA's web site, www.epa.gov/safewater.*

7. If I want to protect someone not just from microbes but also from any other contaminants in the tap water, can I just use any of the same alternatives as listed in the answer to #5?

- *Boiling water will not necessarily remove contaminants other than microbes. In fact, prolonged boiling (longer than one minute) will only increase the concentration in the water of contaminants such as lead and other metals, many chemicals, and nitrate. Contact the NSF or the California Department of Health Services (footnotes 5 and 6) for those brands of bottled water or home filters that are not only certified to remove Crypto cysts but also remove other specifically named contaminants that are reported to be in your tap water and that you wish removed.*

8. What are nitrates and why are they a concern?

- *Nitrates/nitrites are nutrients in nitrogen-based fertilizer and manure that are washed off the land into surface source water or enter some ground water from dissolved natural deposits. Nitrate levels in your water may rise quickly for short periods of time due to rainfall or agricultural activity. Nitrate is a health risk for fetuses and can cause the potentially fatal blue baby syndrome in infants of less than six months of age. **DO NOT BOIL THE WATER to remove nitrates.** Instead, use a carefully selected bottled water or a filter certified by NSF for nitrate removal.*

9. Is lead in drinking water dangerous for children?

- *Exposure to lead is not good for anyone. However, the fetus, infants and young children whose brains and nervous systems are still developing are particularly vulnerable to this toxic metal which may be found in lead paint, dust and some drinking water. According to the CDC, even low levels of lead are harmful and associated with decreased intelligence, impaired development and*

⁸ The National Academy of Science's Committee on Pesticides in the Diets of Infants and Children [National Academy Press, 1993]

decreased growth. Nearly 1 million children in the US have lead levels in their blood that are high enough to cause irreversible damage to their health.⁹ Lead in drinking water is primarily a problem of home plumbing or service connections; most drinking water leaves the treatment plant containing little or no lead. Corrosion of lead plumbing fixtures in older buildings or service lines, or leaching of lead solder used in the copper pipes of newer buildings, are the most frequent cause of lead in drinking water. (Since August 1998, all components of pipes and plumbing fixtures that dispense drinking water must be "lead free.")

10. How do I know if lead is in my tap water? What can I do about it?

- Test the water from your own tap particularly if you are in an apartment or any high rise building where flushing the pipes (see below) may not be effective. Call the Safe Drinking Water Hotline (800-426-4791) for further information and a list of certified testing labs in your state. In addition to testing, and, if needed, purchasing a carefully selected filter or bottled water, there are immediate, inexpensive actions you can take to reduce potential exposure to lead in drinking water. It is especially important to take these precautions if you are pregnant or have young children:

! First thing in the morning or whenever the tap water has been sitting in the pipes for hours, "flush" the cold water pipe by running the water until it is cold (30 seconds to two minutes). The more time water has been sitting in your pipes, the more lead it may contain. Do not waste the flushed water. Catch it in a container and use it to water plants or for any other non-cooking or non-drinking purpose.

! Use only cold water for drinking and cooking. (Hot water leaches more lead out of the pipes)

11. Should I use tap water in my baby's bottle?

- An infant is more vulnerable to microbial pathogens, and to nitrite/nitrates, lead, and many chemicals that may be in your tap water. Studies have found that as much as 85% of the blood lead in infants who are bottle fed may come from drinking baby formula with lead-contaminated water. A spike in nitrates in the drinking water may cause the "blue baby syndrome" as noted in #8 above. The safest and simplest options for feeding a baby are breast feeding or ready-mixed formula. However, if you know that your tap water is free of lead and nitrate/nitrite, you can reduce possible microbial contamination if you boil tap water for one minute (not longer; see answer to #7 above) before mixing it with dry formula. Remember to cool the water before feeding the baby! If lead or nitrates are in the tap water, a carefully selected filter or bottled water (see # 5 above) can be used for water in a baby's bottle. Refrigerate any remaining bottled water after opening.

⁹ See web page www.cdc.gov/nceh/pubcatns/97fsheet/leadfcts/leadfcts.htm

12. I am pregnant or thinking about getting pregnant. Are there any drinking water contaminants in addition to nitrates and lead that can harm the fetus?

- *Yes, Several studies have found that Trihalomethanes (TTHMs) in drinking water are associated with miscarriages and certain birth defects when consumed during the first three months of pregnancy. TTHMs are a group of contaminants that form in drinking water during treatment when disinfectant reacts with decomposing organic matter. The amount of TTHMs in tap water can vary from day to day and may be higher in some parts of the distribution system than in others. This may explain why even when the tap water does not surpass EPA's maximum permitted level of 100 ug/L TTHMs as averaged over the course of a year, reproductive ill effects still may occur. A recent large scale California study assessed the risk of miscarriage for women drinking tap water containing TTHMs during the first trimester of pregnancy and found that some women who drank a lot of tap water that contained high levels of TTHMs (at least 75 ug or "micrograms" per liter of TTHMs) had a miscarriage rate significantly higher than those who drank less of that tap water or than those who drank tap water with lower concentrations of TTHMs.*

13. How can I protect myself from TTHMs?

- *Remember to drink lots of liquids during pregnancy and follow the advice of your health care provider. If you are concerned about TTHMs in your tap water, call your water utility, or look at your annual water quality report, to see if your tap water sometimes contains high levels of TTHMs. If it does, you have several options. Some experts suggest that you refrigerate tap water in an open container for several hours before drinking to allow TTHMs to leave the water and enter the air. Especially, if in addition to TTHMs, lead, nitrates or pesticides are a concern, it may be prudent to drink a carefully selected bottled water (check www.nrdc.org for bottled water test results and **footnote 7**) or water that has been filtered by a home system that has been certified to remove lead, nitrate and organic chemical contaminants. (See answer to #5)*



Yorkshire Cancer Network

INFECTION GROUP

PROVISION OF SAFE DRINKING WATER FOR CANCER PATIENTS WITH IMMUNOCOMPROMISE

September 2004

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1. Background

Immunocompromised patients, such as those rendered neutropenic following cytoreductive therapy for malignancy are at risk of acquiring a wide range of potentially pathogenic microorganisms from drinking water. These include environmental Gram-negative bacteria, such as pseudomonads, and atypical mycobacteria. Despite the risk for these patients, there are few guidelines on the provision of safe drinking water for immunocompromised individuals including those with solid organ or haematological malignancy.

In the UK, guidelines¹ have been focused almost exclusively on ensuring that water is free of *Cryptosporidium hominis* and *C. parvum*. These belong to a genus of coccidian protozoa, which, whilst causing self-limiting gastrointestinal infection in immunocompetent individuals, may result in life-threatening diarrhoeal illness in immunosuppressed patients. Other guidelines e.g.² make little reference to the safety of potable water for immunocompromised patients other than that which relates to the potential acquisition of *Cryptosporidium* spp. In contrast, scant attention is paid to opportunistic Gram-negative bacteria which can be found in both bottled and tap water³ and there are almost no references in published guidelines to the possibility that fungal pathogens, such as *Aspergillus* species, might be acquired through potable water.⁴

Given the lack of information provided by national guidelines, it is unsurprising that there is considerable inter-unit variation in the methods of provision of potable water to cancer and other immunocompromised patients. This was highlighted in a regional survey⁵

In the survey, questionnaires were sent to 15 Trusts across Yorkshire and Humberside. Ten Trusts replied, reporting on provision of potable water in 14 separate units. Of these, nine provided only tap water to all patients, irrespective of underlying condition. In two units, iced water, with ice from commercially available makers, was used. Five units distinguished between neutropenic and non-neutropenic patients, with the former group receiving cooled, boiled water (three units), sterile water and sterile water or carbonated water (one unit each). No unit provided filtered water. Water in jugs was changed daily, twice daily or only when empty in 7, 3 and 4 units, respectively. Water jugs were dishwasher-dried in 7 units, dried naturally in 4 and by paper or cloth towels (two and one units, respectively). On 10 units patients were allowed to provide their own potable water, but no unit provided written advice to patients on PW.

The marked disparity in practice as identified in the regional survey contrasts sharply with the guidance given in the report, *Cryptosporidium in Water Supplies* (DETR, 3rd report, 1998), which states that, *all water, from whatever source, that might be consumed by immunocompromised persons should be brought to the boil and allowed to cool before use*.¹ Drinking water for immunocompromised patients on some units which follow these guidelines may be boiled (either using a geyser or kettle), left to cool in jugs on kitchen work surfaces and then cooled further in refrigerators before distribution to patients in accordance with these guidelines.

Boiling of large volumes of water on a daily basis has, however, significant health and safety implications. Because of the perceived risk to health care workers, the options for providing safe drinking water for immunocompromised cancer patients were reviewed. The aim was to

identify methods which, while aiming for optimal protection of patients from *Cryptosporidium* spp., environmental bacteria and fungi, would not compromise safety. This is discussed elsewhere.⁵

2. Optimal provision of potable water for immunocompromised patients

The criteria to be met in providing drinking water for immunocompromised patients are:

- Microbiological safety
- Respect for patient confidentiality (of particular importance for patients with AIDS-related malignancy nursed on general wards, as provision of cooled, boiled water, may result in the identification of these patients as HIV-positive by staff and, indeed, other patients)
- Organoleptic acceptability
- Preparation of water using methods which minimise risk staff
- Uniformity of approach to provision
- Cost-effectiveness

Options available

A number of options are available:

- 2.1 Untreated tap water
- 2.2 Boiled tap water
- 2.3 Sterile bottled water
- 2.4 Commercially available bottled water
- 2.5 Filtered tap water

2.1 Untreated tap water

Although untreated tap water is provided to immunocompromised cancer patients on many units⁵ without any apparent problems, this practice is not consistent with UK national guidelines for the prevention of cryptosporidiosis in these individuals.¹ Moreover, tap water may contain other potentially harmful microorganisms such as environmental Gram-negatives and *Mycobacterium* spp and it would seem prudent not to expose vulnerable patients to these bacteria.

2.2 Boiled tap water

The major disadvantage of this option is that there are considerable health and safety implications for health care workers. In addition, preparation of cooled, boiled water places significant demands on staff time. Moreover, heating of the water and cooling it refrigerators have associated energy costs.

2.3 Sterile bottled water supplied by pharmacy

Two significant drawbacks are associated with this approach. Firstly, the organoleptic quality of this product is poor and this might lead to problems with patient acceptability. If some patients were to reject sterile bottled water as being unpalatable, then an alternative source of treated water would have to be made available. This would not meet the criterion of uniformity of practice. Secondly, there would be considerable logistical problems for delivery of water, storage of bottles on wards and collection of empty bottles. Many chemotherapy patients are advised to drink at least 4 litres of water daily to maintain adequate hydration. Assuming a “worst case scenario” of 20 patients on a given ward all undergoing chemotherapy, then pharmacy would supply the ward with at least 80 one-litre bottles each day. Space would have to be found to store these before distribution to patients. It is reasonable to assume that at some times, such as weekends, Bank and other holidays, that daily deliveries might not be possible, thus delivery of three day’s supply to a ward (at least 240 bottles) might be necessary compounding storage problems.

2.4.1 Commercially available non-carbonated bottled water

This option has an important drawback in that water of this nature represents a significant hazard to many immunosuppressed patients. In particular, it may contain large numbers (in excess of 10^6 ml⁻¹) of Gram-negative bacteria such as *Stenotrophomonas maltophilia*³ and environmental pseudomonads which may represent a particular risk for neutropenic individuals.

2.4.2 Commercially available carbonated bottled water

Carbonated bottled water is considerably safer than the non-carbonated variety because of the low pH of these products.³ However, the low pH can result in poor patient acceptability in patients with chemotherapy-associated mucositis. As with sterile bottled, logistical problems in delivery and storage of water before distribution to patients may arise.

2.5 Filtered water

Filter devices in a self-contained cartridge are readily available from commercial sources and, if of the appropriate specification, produce water that is essentially sterile and, for this reason alone, filters are an attractive option. However, several aspects of this approach require further consideration

- Robust protocols for their use. Filter units should be changed according to the manufacturer's recommendations. There is thus a requirement to identify members of staff responsible for changing the filters who will change the devices as per the manufacturer's recommendations. There should be a system in place for recording when filter changes have been carried out. Regular audit of the system is also necessary.
- Microbiological safety. Although water produced by the filter is sterile, could "splash back" occur leading to bacterial/fungal colonisation of the cartridge distal to the filter?
- Patient acceptability of water quality
- End-user acceptability of providing water in this way
- Cost. Not only of the devices have themselves, but also this cost incurred in modifying, where necessary, taps to accommodate them.

To address these issues a one-month trial was conducted of end-line filter units on two wards at LTH. Sinks in each ward kitchen which were to receive the filters were identified and taps were modified to accommodate the filter units (cost per tap £37.62 [2002 prices]). Designated persons who were to change the filters twice a week were identified on each ward. Education of nursing staff and ward housekeepers were conducted by a representative of the filter manufacturer and an ICN. Filters were swabbed inside and outside of exit nozzle after four days' use.

At the end of the trial, staff on wards which had previously provided cooled, boiled water for immunocompromised patients were very impressed with this method. The ward staff thought it saved time, was safer and that there was more space in a cooler working environment.

Staff on other wards where patients were previously given only tap water were, however, less impressed. There appeared to be an attitude of "why bother?" especially as it took the ward housekeeper longer to fill the jugs than before. There were concerns over the cost of the filters. Nevertheless, the acceptability of the filtered water for patients was very good.

The protocol for changing filters when time-expired was followed without difficulty.

Microbiological investigations revealed growth from only 2 of 22 specimens obtained from time-expired cartridges. In both instances, scanty coagulase-negative staphylococci were isolated. No specimen yielded Gram-negative bacteria. The former might have represented contamination from personnel handling the filters and might, in any case, be deemed of doubtful clinical significance for patients.

A comparison of selected options is given below. These assume that a given ward has twenty patients who are advised to drink 4 litres/day (2002 prices).

- Sterile bottled water supplied by pharmacy
Cost - £3.56 for 6 X 1litre bottles
Approx overall cost per ward - per day is £ 47.50
- per week is £336

- Carbonated bottled water supplied by supplies
 Cost - £1:98 for 6 X 1litre bottles
 Approx overall cost per ward per day is £ 26:40
 - per week is £184:80
- Still bottled water supplied by supplies
 Cost - £1:98 for 6 X 1litre bottles
 Approx overall cost per ward per day is £ 26:40
 per week is £184:80
- Filtration at the point of use – PALL Aquasafe Water Filters
 Cost - £19:65 per filter (2 required per week*)
 Approx overall cost per ward - per week is £39:30*

(Not included in the above is the once-only cost, where appropriate, of converting taps to accommodate cartridges)

*Pall have now introduced a filter which requires to be changed every 7 days.

3. Overall conclusions

- i) Provision of untreated tap water for immunocompromised cancer patients would be failing to comply with current UK guidelines.¹ Some form of treated water should, therefore, be made available to patients.
- ii) Cooled, boiled water has several disadvantages, most notably relating to the health and safety of health care personnel.
- iii) Bottled water has a number of drawbacks, including significant cost implications.
- iv) Filtered water also has cost implications (although these are less than bottled water). It is sterile at point of production (unlike some types of bottled water) and has no obvious health and safety implications. Filters require to be changed every seven days and protocols should ensure that this occurs. N.B. water quality may influence significantly the operation of the filters – for example water which contains high levels of particulates may impair filter performance. Under these circumstances, remedial action should be taken before the filters are introduced. In wards where HIV/AIDS patients are cared for, provision of filtered water does not permit identification of these patients as does, for example, cooled, boiled water.

4. Recommendations

Taking into account the criteria outlined in section 2, filtered water is the most appropriate option for the provision of potable water for immunocompromised cancer patients.

5. Ice provided by commercial ice-making machines

Ice from ice-making machines is frequently contaminated with potentially pathogenic bacteria⁶ and hospital-acquired infection from this source has long been recognised.⁷ Accordingly, ice provided for immunocompromised cancer patients should be made only from microbiologically safe water.

6. Water from water coolers

Standalone water coolers are likely to yield water contaminated with environmental bacteria⁸ and are not recommended for use on wards and other areas where immunocompromised cancer patients are cared for. Plumbed-in water coolers are less likely to yield water contaminated with Gram-negative bacteria, but still pose a risk of transmission of cryptosporidiosis as mains water is used. Water coolers for the use of staff should be sited away from patient care areas.

7. References

1. *Cryptosporidium and Water Supplies*. (The "Bouchier Report") Department of the Environment, Transport and the Regions & Department of Health, 1998, London (also available at <http://www.dwi.gov.uk/pubs/bouchier/index.htm>).
2. Centers for Disease Control and Prevention. Guidelines for *Preventing Opportunistic Infections Among Hematopoietic Stem Cell Transplant Recipients*. MMWR 2000 49 (RR10) 1-128. (also available at <http://www.cdc.gov/mmwr/preview/mmwrhtml/rr4910a1.htm>).
3. Wilkinson, F.H. and Kerr, K.G. Bottled water as a source of multi-resistant *Stenotrophomonas* and *Pseudomonas* species for neutropenic patients. *European Journal of Cancer Care*. 1997; 7: 12-14.
4. Anaissie, E.J., Stratton, S.L., Dignani, M.C., Summerbell, R.C., Rex, J.H., Monson, T.P., Spencer, T., Kasai, M., Francesconi, A. and Walsh, T.J. Pathogenic *Aspergillus* species recovered from a hospital water system: a 3-year prospective study. *Clinical Infectious Diseases*. 2002; 34:780-9.
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6. Wilson, I.G., Hogg, G.M. and Barr, J.G. Microbiological quality of ice in hospital and community. *Journal of Hospital Infection*. 1997; 36: 171-180.
7. Newsom, S.W.B. Hospital infection from contaminated ice. *Lancet* 1968; 2: 620-623.
8. Levesque, B., Simard, P., Gauvin, D., Gingras, S., Dewailly, E. and Letarte, R. Comparison of the microbiological quality of water coolers and that of municipal water systems. *Applied and Environmental Microbiology* 1994; 60: 1174-1178.

Rennaker, Joanne (DEQ)

From: Howes, Sarah (DEQ)
Sent: Thursday, March 05, 2015 5:12 PM
To: Busch, Stephen (DEQ); Wurfel, Brad (DEQ); Datema, Maggie (DEQ)
Cc: Prysby, Mike (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: Flint Drinking Water TTHM Standard Violation - 1st quarter 2015

I sent it to Reps Neeley and Phelps and Senator Ananich.

From: Busch, Stephen (DEQ)
Sent: Thursday, March 05, 2015 1:59 PM
To: Howes, Sarah (DEQ); Wurfel, Brad (DEQ); Datema, Maggie (DEQ)
Cc: Prysby, Mike (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Rosenthal, Adam (DEQ)
Subject: Flint Drinking Water TTHM Standard Violation - 1st quarter 2015
Importance: High

Attached is a copy of the Violation Notice and Public Notice Template being mailed to the City of Flint by the DEQ Office of Drinking Water and Municipal Assistance regarding an exceedance of the Maximum Contaminant Level (MCL) standard for Total Trihalomethanes at certain locations within the City's drinking water distribution system.

This violation notice is in response to updated monitoring completed in February 2015, which shows the locational running annual average for two of the City's eight compliance sampling locations continue to exceed MCL standard of 0.080 mg/L. It is however, important to note that all individual compliance sample results collected in February were well below the 0.080 mg/L levels.

You are being provided an electronic copy of this notice as exceedance of this drinking water standard is expected to generate inquiries from water system customers, news media, and the general public.

Sarah Howes will be informing members of the Michigan legislature.

If you have any questions or would like any additional information, you may contact Michael Prysby, District Engineer, DEQ-ODWMA at 517-290-8817, or you may contact me at the number below.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Thursday, March 05, 2015 1:59 PM
To: Howes, Sarah (DEQ); Wurfel, Brad (DEQ); Datema, Maggie (DEQ)
Cc: Prysby, Mike (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Rosenthal, Adam (DEQ)
Subject: Flint Drinking Water TTHM Standard Violation - 1st quarter 2015
Attachments: City of Flint VN - MCL TTHM 3-5-15.pdf
Importance: High

Attached is a copy of the Violation Notice and Public Notice Template being mailed to the City of Flint by the DEQ Office of Drinking Water and Municipal Assistance regarding an exceedance of the Maximum Contaminant Level (MCL) standard for Total Trihalomethanes at certain locations within the City's drinking water distribution system.

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Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314



RICK SNYDER
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING DISTRICT OFFICE



DAN WYANT
DIRECTOR

March 5, 2015

Mr. Brent Wright, Operations Supervisor
City Of Flint - DPW
Flint Water Plant
4500 North Dort Highway
Flint, Michigan 48505

WSSN: 02310

Dear Mr. Wright:

SUBJECT: Violation Notice (VN) – Maximum Contaminant Level for Total
Trihalomethanes (TTHM)
Operational Evaluation – Total Trihalomethanes
1st Quarter 2015 Monitoring Period

The Department of Environmental Quality (DEQ), Office of Drinking Water and Municipal Assistance (ODWMA), records show that the city of Flint (City) is in violation of the Safe Drinking Water Act, 1976 PA 399, as amended (Act 399); R 325.10610, *Maximum contaminant levels for disinfection byproducts (MCLs)*, of the 1979 Administrative Code.

In accordance with R 325.10610, *MCLs*, of the 1979 Administrative Code, the MCL for disinfection byproduct TTHM is 0.080 milligrams per liter (mg/L) as a Locational Running Annual Average (LRAA) at each monitoring location. As listed in the table below, our records show that the City's highest TTHM locational running annual average (LRAA), based on the last four quarters, ending February 28, 2015, is 0.105 mg/L which exceeds the standard, and that two of the eight sample site locations exceed the standard of 0.080 mg/L.

Further, in accordance with R 325.107191, *Disinfection byproducts: operational evaluation levels*, of the 1979 Administrative Code, when an operational evaluation level (OEL) at a monitoring location for TTHM exceeds 0.080 mg/L, a supply shall conduct an operational evaluation and submit a written report of the evaluation to the DEQ not later than 90 days after being notified of the analytical result that causes the supply to exceed the operational evaluation level. As listed in the table below, our records show that the TTHM OELs for the City exceed 0.080 mg/L at one of the City's eight sample site locations.

Mr. Brent Wright

2

March 5, 2015

TTHM Results (mg/L)	5/21/14	8/21/14	11/20/14	2/17/15	LRAA	OEL
DBP1 McDonalds 3719 Davison	0.162	0.145	0.059	0.0162	0.096	0.059
DBP2 Liquor Palace 3302 S. Dort Highway	0.112	0.127	0.033	0.0168	0.072	0.049
DBP3 North Flint Auto 6204 N. Saginaw St.	0.097	0.118	0.041	0.0149	0.068	0.047
DBP4 University Market 2501 Flushing Road	0.106	0.196	0.094	0.0245	0.105	0.085
DBP5 Taco Bell 3606 Corunna Road	0.079	0.181	0.034	0.0151	0.078	0.063
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.088	0.144	0.054	0.0192	0.076	0.059
DBP7 Salem Housing 3216 MLK Boulevard	0.082	0.112	0.050	0.0285	0.068	0.055
DBP8 BP Gas Station 822 S. Dort Highway	0.075	0.112	0.036	0.0199	0.061	0.047

Our investigation consisted of a review of ODWMA files for laboratory reports received for compliance monitoring. Our investigation is considered complete. This violation began on March 1, 2015, and will continue until TTHM LRAA is below the MCL at all sample sites.

We are encouraged by the results from the most recent round of compliance samples collected on February 17, 2015, which now show individual TTHM levels at less than half of the 0.080 mg/L standard at all locations throughout the City's system. Operational Evaluation Reports from December 2014, and February 2015, have identified possible causes and corrective measures for the previous elevated TTHM levels which we encourage the City to continue implementing. These modifications have likely contributed in part to the reduction in TTHM levels reported in the most recent quarter, and suggest the City may be able to achieve compliance with the TTHM standard at all sites by continuing these efforts.

Our office is currently reviewing the Operational Evaluation Report dated February 27, 2015, and will provide the City and their consultant with comments, as needed, to help address this MCL violation.

Water systems that exceed the OEL must complete and submit an Operational Evaluation in accordance with Administrative Rule 719I (R 325.10719I) within 90 days of being notified of the violation. **An updated Operational Evaluation report, which incorporates the most recent sample results, must now be completed and received by our office by no later than Friday, May 29, 2015.**

If you have any other factual information you would like us to consider regarding the violation identified in this VN, please provide them in a written response by March 19, 2015.

Mr. Brent Wright

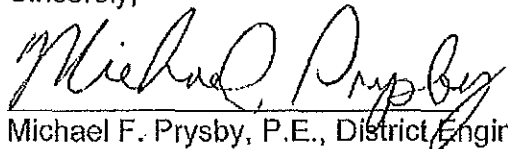
3

March 5, 2015

Administrative rule R 325.10403 of Act 399 requires that suppliers provide public notice (PN) as soon as practical, but no later than thirty (30) days after the supplier learns of this type of violation, by mail or direct delivery and by any other means reasonably calculated to reach customers not normally reached by mail. Enclosed is a sample PN which contains the minimum required language. The City is encouraged to include additional information regarding its response efforts to this violation. **Please notify your consumers by April 1, 2015, and send us a signed and dated copy of the notice that you issued within ten (10) days of distributing the public notice.** This violation must also be included in your 2015 Consumer Confidence Report, due by July 1, 2016. The PN must be repeated every quarter until you no longer exceed the TTHM standard. Failure to issue a PN for this violation will result in a fine of at least \$1,000 per event, with a maximum of \$5,000 per violation.

We anticipate and appreciate your continued cooperation in resolving this matter. If you have any questions regarding this VN, please contact us at the numbers below; at prysbym@michigan.gov; or rosenthala@michigan.gov; or at DEQ, P.O. Box 30242, Lansing, Michigan 48909-7742.

Sincerely,



Michael F. Prysby, P.E., District Engineer
Lansing District Office
Office of Drinking Water and Municipal
Assistance
517-290-8817



Adam Rosenthal, Environmental Quality
Analyst
Lansing District Office
Office of Drinking Water and Municipal
Assistance
517-284-6644

Enclosure

cc: Ms. Jennifer Crooks, U.S. Environmental Protection Agency, Region 5
Mr. Jerry Ambrose, Emergency Manager, City of Flint
Mr. Robert Bincsik, City of Flint
Mr. Howard Croft, City of Flint
Mr. Daughtry Johnson, City of Flint
Genesee County Health Department
Ms. Liane Shekter Smith, DEQ
Mr. Richard Benzie, DEQ
Mr. Stephen Busch, DEQ

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

City of Flint Did Not Meet Treatment Requirements

Our water system recently violated a drinking water standard. Although this incident was not an emergency, as our customers, you have a right to know what happened and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Samples were collected for total trihalomethanes (TTHM) analysis from eight locations on a quarterly basis (May 21, August 21, November 20 of 2014, and February 17, 2015). The average of the results at ANY of the eight locations must not exceed the maximum contaminant level (MCL) for TTHMs, otherwise our water system exceeds the MCL. The standard for TTHMs is 80 micro grams per liter ($\mu\text{g/L}$). The location reporting the highest TTHM level was 105 $\mu\text{g/L}$; thus, our water system exceeds the TTHM MCL.

What should I do?

- There is nothing you need to do unless you have a severely compromised immune system, have an infant, or are elderly. These people may be at increased risk and should seek advice about drinking water from their health care providers.
- You do not need to boil your water or take other corrective actions. If a situation arises where the water is no longer safe to drink, you will be notified within 24 hours.

What does this mean?

This is not an emergency. If it had been an emergency, you would have been notified within 24 hours.

People who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer.

What is being done?

We are currently working on solutions to correct the problem. We anticipate resolving the problem in 2015. Our most recent individual sample results were all less than half the 80 $\mu\text{g/L}$ standard, however since compliance is calculated using a locational running annual average (LRAA) of the most recent four quarters, we are still out of compliance with the MCL at two of eight locations.

For more information, please contact Mr. Brent Wright at 517-787-6537, or the Flint Water Plant at 4500 North Dort Highway, Flint, Michigan 48505.

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by the City of Flint.

CERTIFICATION:

WSSN: 02310

I certify that this water supply has fully complied with the public notification requirements in the Michigan Safe Drinking Water Act, 1976 PA 399, as amended, and the administrative rules.

Signature	Title	Date Distributed
Reminder to water supplier: This notice/certification must be sent to the Department of Environmental Quality.		

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Thursday, March 05, 2015 1:11 PM
To: Brent Wright; Daugherty Johnson; Dayne Walling; donna. cole; gdn2@aol.com; Howard Croft; James Henry; jmikewright; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Laura Sullivan; Michael Glasgow; Mike Lane; Prysby, Mike (DEQ); Natasha Henderson; Norb Birchmeier; Pete Levine; rob.nicholas@veolia.com; rosejo@msu.edu; Russell Hudson; Samir Matta; Warren Green; Elizabeth Murphy
Subject: Tech Committee Follow up
Attachments: Water Advisory Cmte 030515.zip; COF TTHM Data.pdf; COF Improvements Since November.pdf; Tech Committee Presentation - Veolia.pdf

All,

I want to thank everyone for attending our first Technical Committee Meeting yesterday, by all measurements this was a very successful first gathering. I am forwarding everyone an electronic copy of the materials shared yesterday including the presentation by Veolia.

As for next steps, I am looking for literature form DR. Rose and from Michael Wight of the EPA to come within the next day or two. I also would like to have specific questions that anyone feels should be included in a bullet point list so that we can move quickly to generate the best responses.

Next week I will look to vet with this group the information that we intend to send to the community along with the next violation notice. Our goal is to have documented information in everyone's hands prior to the mailing of the violation.

We will also plan to have another meeting very early in April to assess the community response to the upcoming notice, evaluate if there are items coming from the community advisory group that need to be addressed, share the internal water plant progress, and to determine our next steps.

Thank you again,

--

Howard Croft
 Public Works Director
 City of Flint
 1101 S. Saginaw Street
 Flint, MI 48502
 PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com

**Flint Water Advisory Committee First Meeting
March 5, 2015 2-4pm MTA Auditorium**

Agenda

Committee Members will receive a packet at the entry with their name tag, question sticky notes, pencil and other sources of information.

- I. **Welcome and Introduction of Facilitators**

- II. **Facilitator Ground Rules and Agenda Review**
Purpose of the Water Advisory Committee: Provide a respectful means of sharing factual information between the City of Flint and the Flint Water and Sewer Customers

The meeting will follow the printed agenda.

The meeting must conclude at 4pm today. The Facilitator will keep us on track.

- III. **Expected Outcomes:**
Today's meeting: that all of the water questions have been identified – we may not be able to answer all today, but we would like to set up a means of communicating with this committee on a regular basis.

Through 2016 – That the transition to KWA water processing and distribution is a smooth, satisfactory process resulting a safe, consistent water supply.

- IV. **Status of Water and Distribution System Today – H. Croft, Director Department of Public Works**

Evaluation of Flint Water Treatment Plant and Distribution System – Veolia, City of Flint Consultant

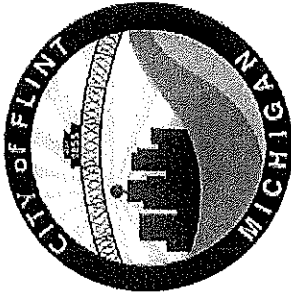
- V. **Questions from Committee Members and Sort by Category: Safety, Quality, Affordability, Sustainability, History, and Miscellaneous**

- VI. **Response to most frequently asked questions.**

- VII. **Next Steps**
The next meeting has been scheduled for Thursday, March 19, 2015 here at the MTA Auditorium from 2-4pm.

How often would the committee like to meet? How did this format work?

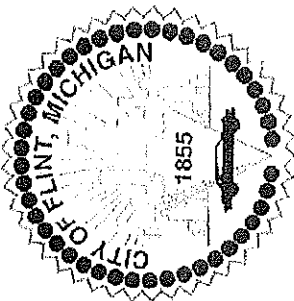
- VIII. **Adjourn**



City of Flint

Water Forum

5/30/2012



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City Of Flint Water History Facts

Current Treatment Plant was put into service in 1954.

Current 72" main pipeline was completed in 1970.

Flint signed a 30 year contract with Detroit water and Sewer Department in the mid 1960's.

The contract with DWSD has expired and we are currently operating on a yearly extension.

In 2006 Flint completed a \$48,000,000 upgrade of the existing Water Plant. (Required by the MDEQ & for backup only).

Flint's Water & Sewer System is approximately a 300,000,000 Enterprise.

Flint's Water & Sewer System is designed to deliver water to over 200,000 people with over 1,500 miles of infrastructure.

Flint's most recent census count shows a population of approximately 102,000 in 2010.

Flint's census population in 2000 was approximately 124,000.

The water system had over 45,000 customers in June of 1999.

The water system had just over 36,000 customers by June 2011.

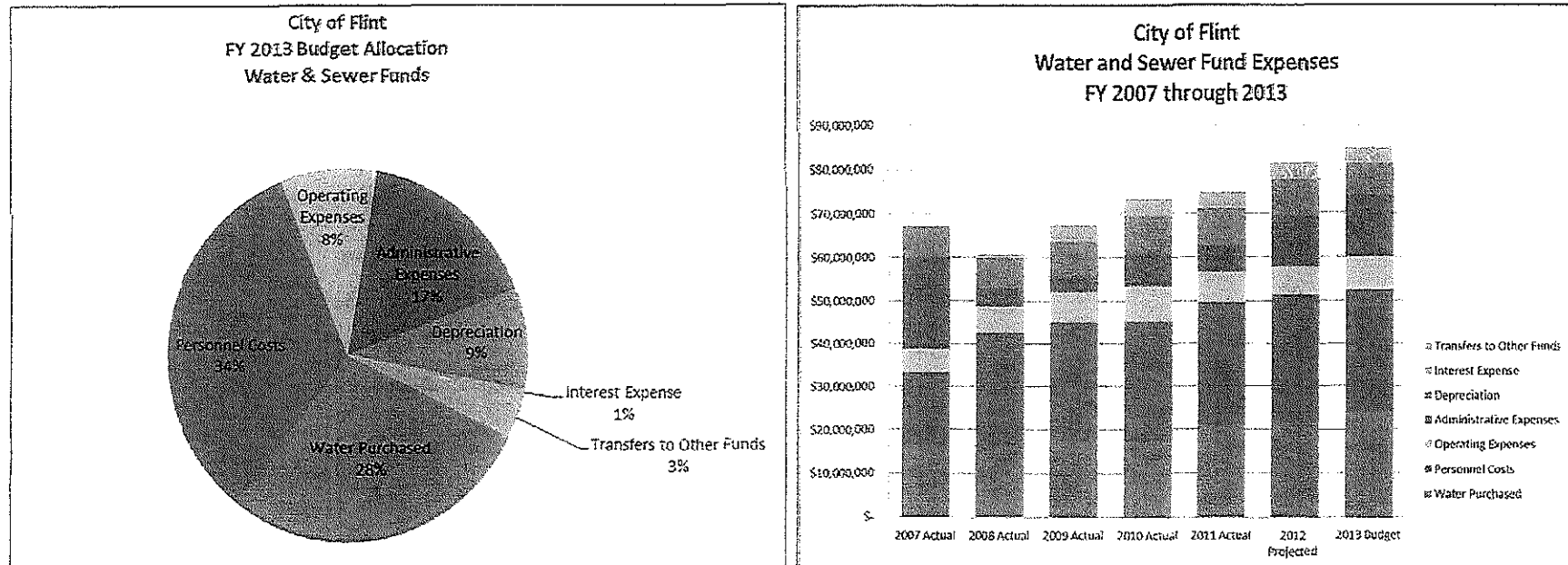
The "Fixed Costs" that must be covered to maintain the system and deliver quality water have increased over time.

City Of Flint
Most Frequently Asked Questions about Water

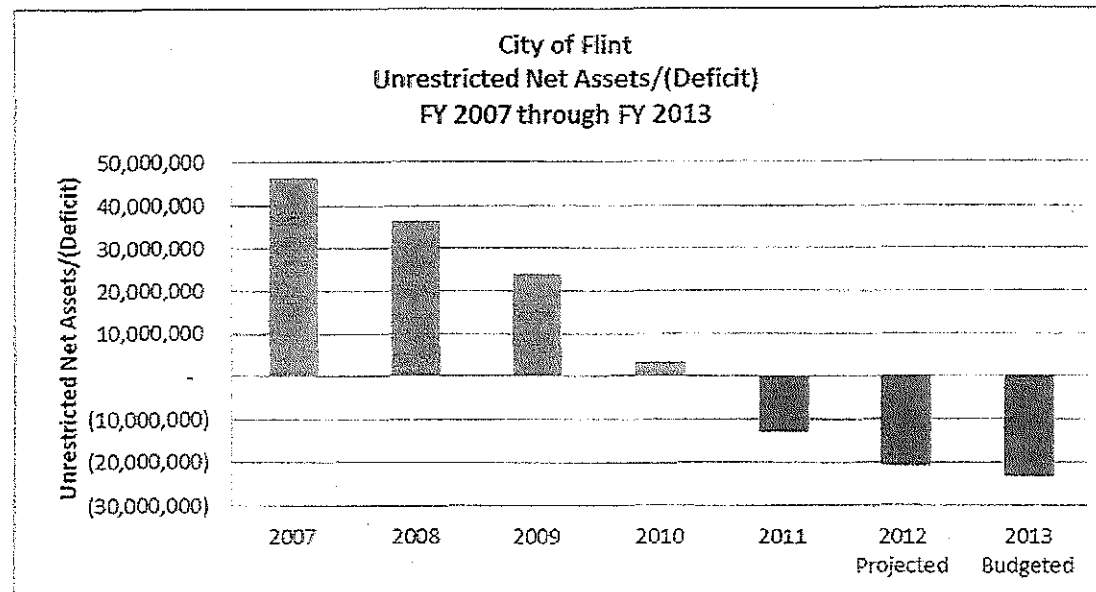
- ☐ Why are the water rates so high ?
- ☐ How does my water bill work (Explanation of charges) ?
- ☐ Why do others in the area pay less for the same amount of water ?
- ☐ Where has all of the water and sewer fund money gone ?
- ☐ What do I do if I think my bill is incorrect ?
- ☐ What effect does leakage or theft have on my bill ?
- ☐ How can I report water theft ?
- ☐ Why don't we go back to using the Flint River like we once did ?

City of Flint

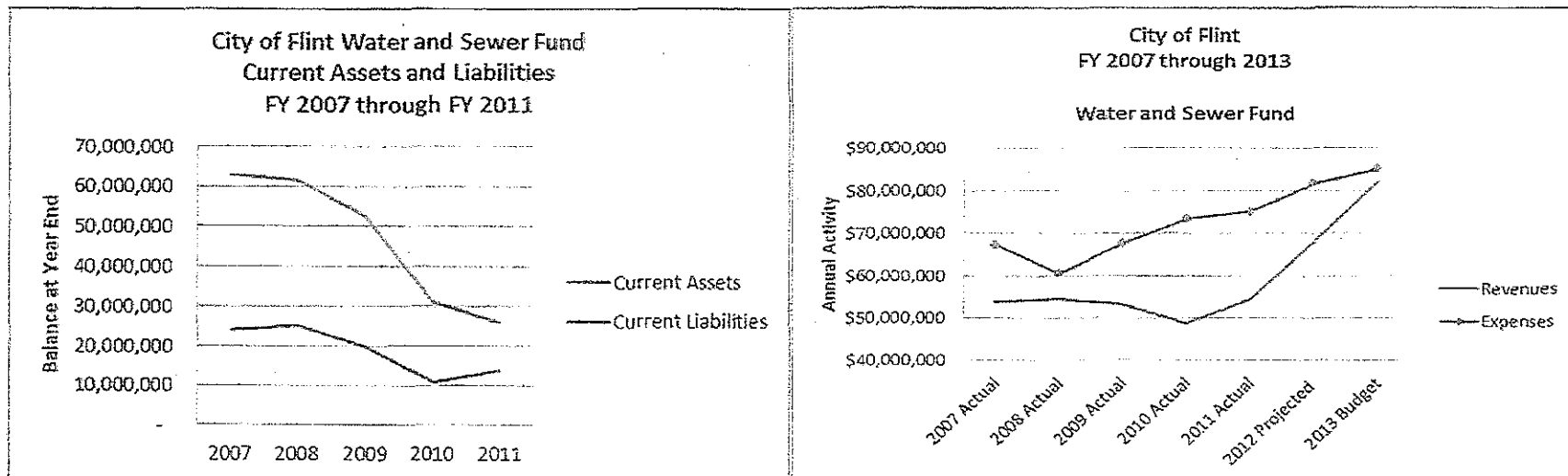
Budget Allocation and Fund Expenses



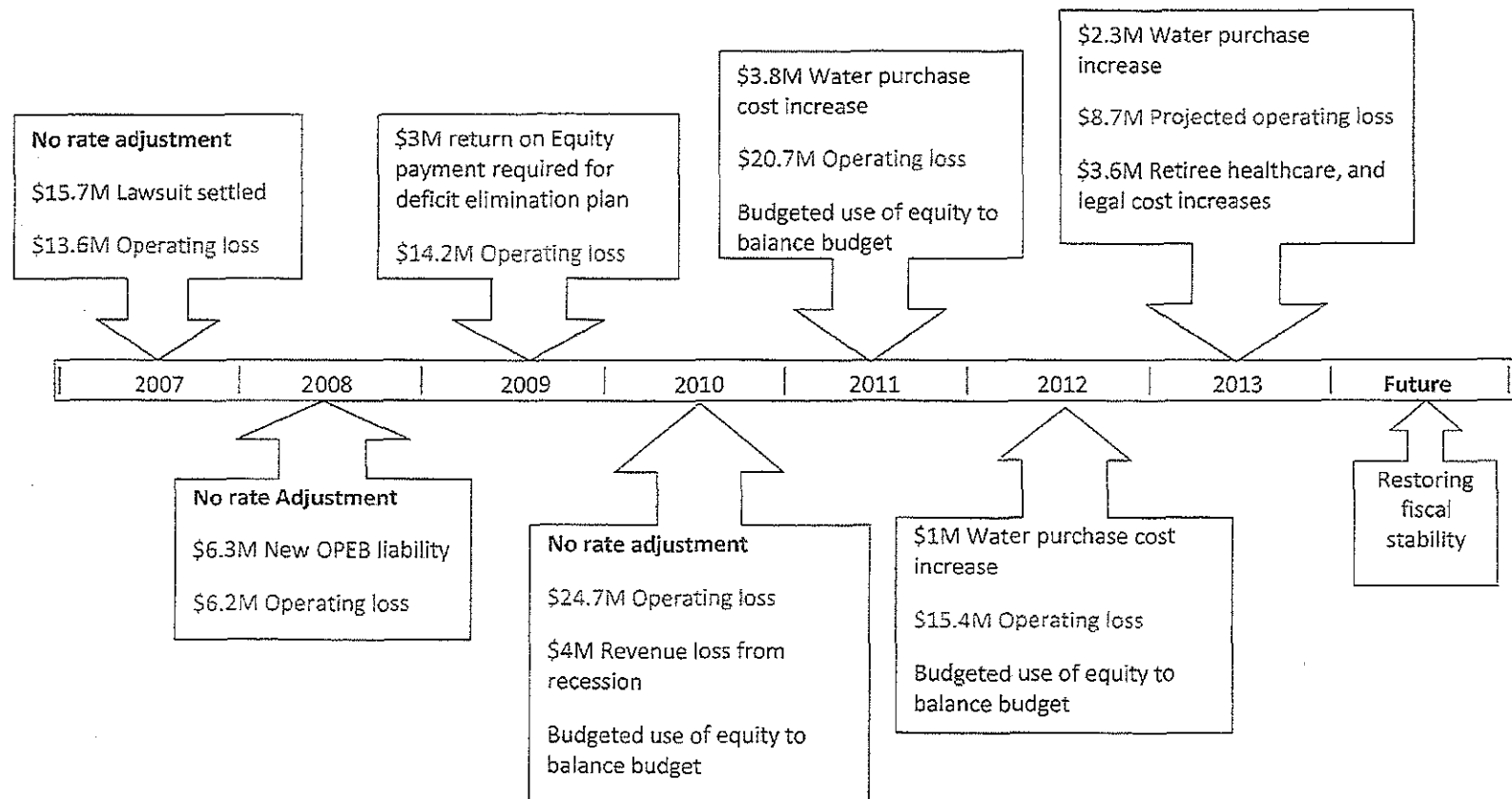
	Audited						
	2007 Actual	2008 Actual	2009 Actual	2010 Actual	2011 Actual	2012 Projected	2013 Budget
Operating Revenues	51,090,679	51,100,332	51,906,553	47,926,589	54,385,644	67,983,044	81,734,552
Other Revenues	2,627,939	3,274,450	1,442,383	764,886	68,645	126,670	455,867
Annual Revenues	53,718,618	54,374,782	53,348,936	48,691,475	54,454,289	68,109,714	82,190,419
Water Purchased	16,052,006	16,297,871	17,421,663	17,103,752	20,919,987	21,756,787	24,031,417
Personnel Costs	17,292,444	26,302,590	27,591,206	28,149,946	28,618,817	29,640,499	28,546,350
Operating Expenses	5,355,638	6,145,119	6,950,534	8,146,390	6,917,964	6,420,260	7,259,290
Administrative Expenses	21,300,900	4,229,382	3,403,231	7,327,630	6,221,627	11,465,462	14,140,047
Depreciation	7,217,142	7,132,870	8,364,022	8,854,889	8,689,809	8,615,000	7,500,000
Interest Expense	86,632	485,499	868,031	812,270	754,890	705,150	644,314
Transfers to Other Funds	-	-	2,990,000	2,990,000	2,990,000	2,990,000	2,990,000
Annual Expenses	67,304,762	60,593,331	67,588,687	73,384,877	75,113,094	81,593,158	85,111,418



	2007 Actual	2008 Actual	2009 Actual	2010 Actual	2011 Actual	2012 Projected	2013 Budget
Revenues	53,718,618	54,374,782	53,348,936	48,691,475	54,454,289	68,109,714	82,190,419
Expenses	67,304,762	60,593,331	67,588,687	73,384,877	75,113,094	81,593,158	85,111,418



City of Flint
Recent Timeline of Water and Sewer Funds
FY 2007 through 2013



City of Flint- Water and Sewer System Additional Asset / Revenue Data

The average annual residential water sewer bill in FY2005 was less than \$700 annually

The average annual residential water/ sewer bill in FY13 will be nearly \$1,700

Expenses have exceeded revenues every year since 2006:

FISCAL YEAR	Rate Base	Revenues	Expenses	Revenues Minus Expenses	Unreserved System Equity	FACTORS IMPACTING SOLVENCY	COST IMPACT
2006	2005	\$55,204,242	\$50,933,792	\$4,270,450	\$60,340,013		
2007	2005	\$53,856,857	\$67,442,993	(\$13,586,136)	\$46,399,452	No rate adjustment \$15.7 million lawsuit settlement	15.7 0
2008	2005	\$54,374,781	\$60,593,331	(\$6,218,550)	\$36,482,488	No rate adjustment OPEB liabilities added	3.6 2.7
2009	2009	\$53,488,463	\$67,728,218	(\$14,239,755)	\$24,023,065	ROE payment added as part of City I	1.9 1.1
2010	2009	\$48,820,329	\$73,513,725	(\$24,693,396)	\$3,531,768	No rate adjustment Use of retained earnings budgeted Revenue lost due to recession	12.5 0.5 2 2
2011	2011 2011	\$54,527,079	\$75,185,879	(\$20,658,800)	(\$12,866,607)	Use of retained earnings budgeted Water purchase cost increase	7.1 3.5 0 3.8
2012		\$68,279,187	\$83,682,840	(\$15,403,653)	(\$20,884,122)	Use of retained earnings budgeted Water purchase cost increase	5.1 0 0 0.8
2013	2013	\$82,220,420	\$90,970,420	(\$8,750,000)	(\$23,379,690)	Water purchase cost increase RHC/Legal/Admin Cost Allocation	0 2.3 2.1 1.5
				(\$99,279,840)			\$2.3 \$3.6 \$68.2

Calculation of Water and Sewer Rates for FY13 Budget

March, 2012:

	Expense Projection Based on FY12 Costs	Revenue Projection Based on FY12 Receipts	Difference Between Projected Revenues and Expenses	Rate Increase Necessary To Close Gap
Water	\$49.9	\$44.4	-\$5.5	12.4%
Sewer	\$31.0	\$21.4	-\$9.6	44.9%
TOTAL	\$80.9	\$65.8	-\$15.1	22.9%

**CITY of FLINT, MICHIGAN
WATER &/OR SEWER BILL**
Service at: 5810 BALDWIN BLVD

TREASURER
CITY OF FLINT
P.O. BOX 1950
FLINT, MI 48501

PRESORTED
FIRST CLASS MAIL
US POSTAGE PAID
CITY OF FLINT

3419 Active

Seq=3138

ACCOUNT NUMBER	DUE DATE
[REDACTED]	02/28/2012
	NET AMOUNT DUE
	147.85

RETURN THIS SLIP WITH
YOUR PAYMENT

**AUTO
[REDACTED]



0000037681000001478502282012000001491377706

KEEP THIS PORTION FOR YOUR RECORDS

LAST READ/DATE/TYP	NEW READ/DATE/TYP	CONS	SERVICE	CHARGE	Prev. Balance	161.08
341 01/05/2012 A	363 02/03/2012 A	2	Sewer Non-metered	6.62	Payments	-75.00
			Sewer Svc Chrg	22.07	Adjustments	0.00
			Water	13.36	Current Penalty	0.36
			Water Svc Chrg	19.35	New Charges	61.41
					Total Due	147.85
ACCOUNT: BALD-005810-0000-01				SERVICE AT: [REDACTED]	Due Date	02/28/2012

PENALTY ASSESSED 30 DAYS AFTER DUE DATE



**CITY OF FLINT
DEPARTMENT OF FINANCE**

Customer Service Center

**Dayne Walling
Mayor**

**Douglas Bingaman
Treasurer**

**CITY OF FLINT
WATER NON-PAYMENT TURN-OFF POLICY**

1. Water services to any customer may be shut off if the account is not paid until after 30 days after the due date. (City ordinance 46-52 (h))
2. Non-payment turn-offs are done only Monday through Thursday. The Customer Service Center does not schedule non-payment turn-offs on Fridays, Saturdays, Sundays, or most recognized holidays.
3. Illegal usage, broken payment arrangements and NSF (non-sufficient funds) turn-offs are done at any time without additional notice.
4. Turn-off notices are mailed to delinquent customers fifteen (15) days before actual turn-off.
5. The water customer is responsible for maintenance of all plumbing in the premises including connection to City water mains or sewer lines.
6. If a customer disputes a water bill and is unable to resolve the issue with Customer Service personnel, the customer may request an administrative review. Further information on any water account may be obtained by calling (810) 766-7015 or visiting the Customer Service Center at 1st Floor, City Hall, 1101 S. Saginaw St.

Preliminary Options for Future City of Flint Water Sources

Consider a New Negotiated Contract with Detroit Water and Sewer Department

PRO'S	CON'S
No upfront capital costs Possibility to negotiate a lower rate Ability to "Blend" water sources to further control costs	Lack of control over new / fixed changes Past practices

Consider a Contract with the Karegnondi Water Authority

PRO'S	CON'S
Voting member of KWA board Ability to "Blend" water sources to further control costs Raw water is an asset for attracting new businesses	Capital cost (debt service) Uncertainty of final costs

Blended Use of the Flint River

PRO'S	CON'S
Helps control cost of water	

*** CURRENTLY NO DECISIONS HAVE BEEN MADE REGARDING THE FUTURE WATER SOURCE

Improvements for City of Flint Water System

Reduce Leakage

▪Finalize a Preventative Maintenance Plan

- (Planning started in January 2012, requires funding, ... part of Operational Costs)
- Will help identify repair areas

▪Reduce water theft

▪Replace water meters

- We currently have an eighteen month plan to replace all meters with more efficient "*Smart Meters*"

▪Encourage routine household checks

- "Faulty" toilets are a significant reason for household water loss, and unexpected larger bills.

Other Leakage concerns

✓Transmission Loss

✓Fire Hydrants

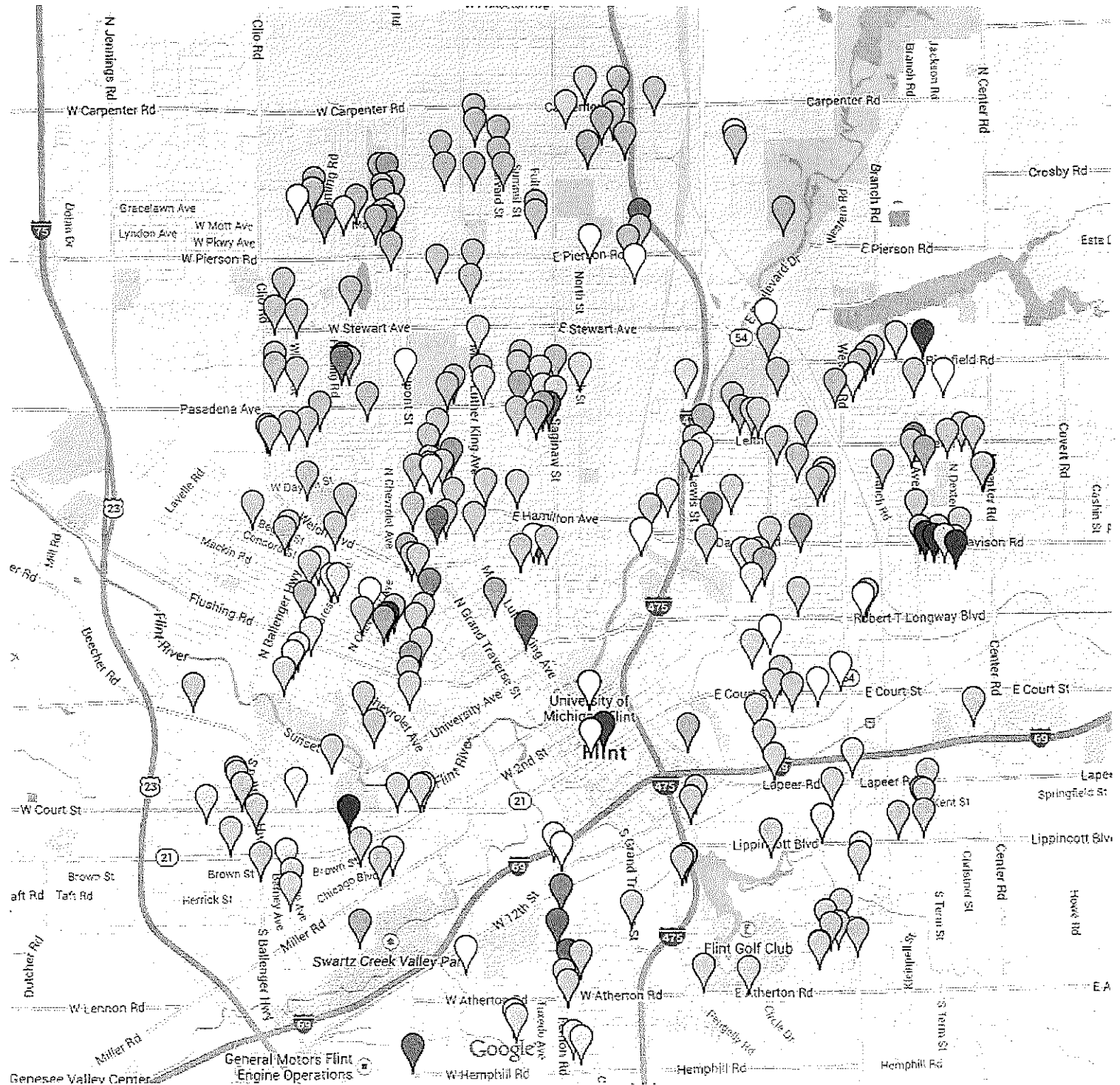
✓Incorrect water bills

✓Non-Payment

Water Main Breaks 2014

☒ Main Breaks from Leak Report

-  Clean break
-  Split at pipe bell
-  2" dia hole
-  Service line
-  Corp break
-  Pipe bell clean break
-  hole in mechanical bell
-  mechanical joint
-  3" dia hole
-  4" hole
-  Previous repair failure
-  Split pipe
-  Split tee
-  valve face
-  1" dia hole
-  2" split
-  3" split
-  3/4" lead corp
-  4" split
-  Tapping saddle
-  Other / No data





City of Flint Water System Facts

Over 600 Miles of Distribution
Mains

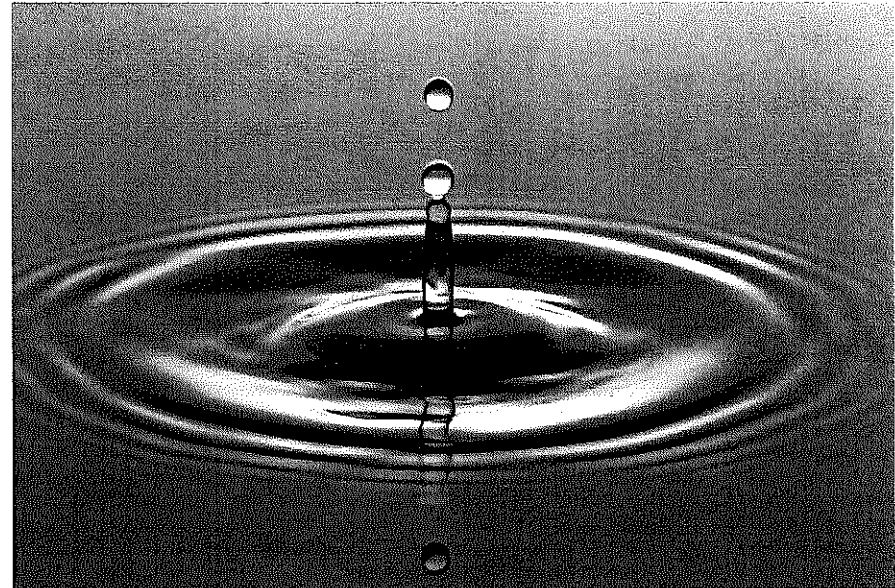
Over 7000 Valves
Over 3909 Hydrants

Over 46,000 users in 2006
Only 31,000 users in 2014



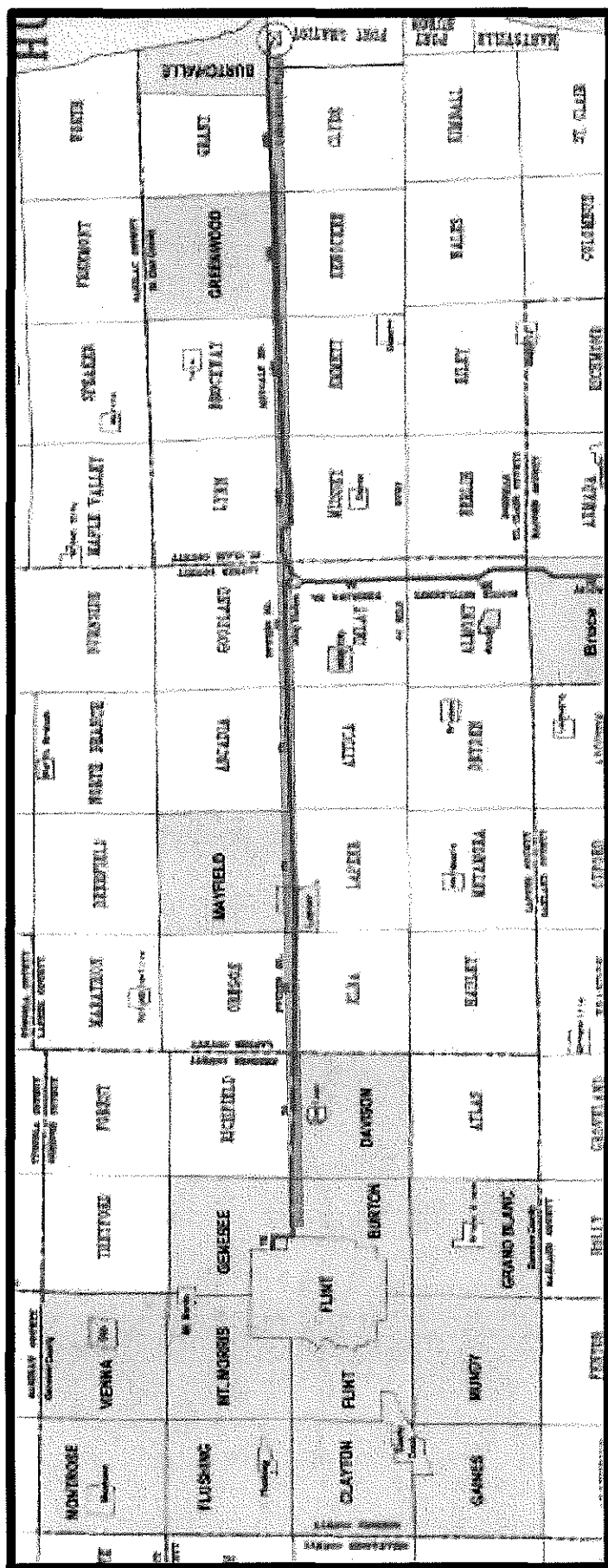
What Can Impact Water Quality ?

- Condition of source water
- Temperature
- Organic material
- Retention time in system
- Low flow
- Dead ends
- Main Breaks
- Repairs



Quality Indicators

- ❖ Chlorine residual
- ❖ Total coliforms



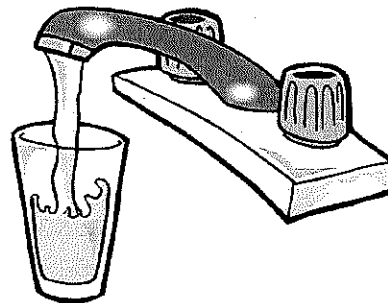
Flint River

vs.

DWSD

CITY TESTING

- ☐ 10 test sites around the city
- ☐ Tests are performed manually 2 – 3 times a week
- ☐ Over 100 Tests are performed a month
- ☐ **All** tests are reported to the DEQ for oversight
- ☐ Tests are performed **EVERY** four hours inside the Plant
- ☐ The City responds to and tests all reported concerns



Michigan DEQ State License Types

Complete Treatment	Limited Treatment	Distribution

F-1		

	D-1	

		S-1

F-2		

	D-2	

		S-2

F-3		

	D-3	

		S-3

F-4		

	D-4	

		S-4

Recent Boil Water Advisories in MICHIGAN

LOCATION	DATE	CAUSE
Edwardsburg / Lunker	Nov 12, 2014	Fire
Superior Township	May 03, 2014	Main Break
Benton Harbor	Jan 9, 2014	Water Pressure
Union Township	Nov 6, 2013	Main Break
Charlevoix	August 7, 2013	Pressure Loss
Novi	Feb 13, 2013	Pressure Loss
Muskegon Heights	Nov 17, 2012	Main Break
Commerce Township	Dec 6, 2010	Depressurization



City of Flint Contacts

Public Works Director
Utilities Administrator
Plant Supervisor
F-1 Operator in Charge
S-1 Operator in Charge

Howard Croft – hcroft@cityofflint.com
Daugherty Johnson- djohnson@cityofflint.com
Brent Wright – bwright@cityofflint.com
Mike Glasgow – mglasgow@cityofflint.com
Robert Bincsik – rbincsik@cityofflint.com

Phone Numbers

City of Flint Treatment Plant
Public Works Director
Utilities Administrator
EPA Safe Drinking Water Hotline

810-787-6537
810-766-7346 x 2403
810-766-7135 x 2602
1-800-426-4791



City of Flint

Water Improvements since November 2014

DATE	IMPROVEMENT	EFFECT
Nov.	Increased flushing efforts (as weather permits)	Reduced time of water in the system
Nov.	Adjusted operational softening to no less than 80%	Reduce chlorine demand
Dec.	Started hydraulic modeling of distribution system	Helps to identify locations of bad valves
Dec.	Started evaluation of different polymers	Removal of organic carbon
Dec.	Started SCADA upgrades inside of Water Plant	Improvement of internal software controls
Jan.	Hired vendor to upgrade efficiency of the ozone system	Better oxidation and disinfecting
Jan.	Started jar testing	Assists in dosage amounts and polymer aids
Feb.	Hired consultant Veolia for process review	Professional recommendations
Feb.	Leased and installed TTHM analyzer	Increased internal testing ability
Feb.	Adjustments to reservoir level to match demand	Reduce time of water in system

City of Flint

Water System Update

With

Questions & Answers



February 16, 2015



CITY OF FLINT

Department of Public Works

Dayne Walling
Mayor

Gerald Ambrose
Emergency Manager

Howard Croft
Director

TO: Flint City Residents
FROM: Howard Croft, DPW Director
RE: Water Questions
DATE: February 16, 2015

Over recent weeks the City of Flint has taken a number of measures to increase both the quality of water and the availability of information. Monthly Operating Reports are posted online approximately 15 days following the end of each month, a summary report is also posted with additional information of utility functions, and the City has increased the level of testing being performed on the water.

A nationally recognized vendor (Veolia North America) has been contracted to provide a detailed overview of City procedures and to make recommendations where they see areas of improvements.

The following questions and answers are provided for all interested parties, and are intended to provide transparent, detailed, and updated information that is pertinent to the City of Flint's water system.

City of Flint – Questions and Answers

Is it currently safe to drink City of Flint water?

Yes. Water from the City of Flint meets all of the EPA regulatory standards of the Safe Drinking water Act.

What can you say about the quality?

The City of Flint is committed to providing high quality drinking water to residents and businesses in the community, and has taken every precaution to ensure the water quality meets guidelines for safe drinking water. To ensure that tap water is safe to drink, the Environmental Protection Agency (EPA) prescribes regulations, which limit the amount of certain contaminants in water provided by public water systems. In addition the Food and Drug Administration regulations establish limits for contaminants in bottled water, which must provide the same protection for public health. The City of Flint tap water meets the guidelines set by both entities.

What is considered to be a contaminant?

Contaminants that may be present in water include microbial contaminants such as viruses and bacteria, and inorganic contaminants such as salts and metals, which can occur naturally. Pesticides, herbicides, organic chemical contaminants and radioactive contaminants could also be present.

It's important to note that **drinking water, including bottled water** may reasonably be expected to contain at least small amounts of some contaminants. But the presence of contaminants does not necessarily indicate that the water poses a health risk.

Will these contaminants make people sick?

The EPA requires that every water report must contain language addressing the fact that some people have comprised immune systems or conditions that make them more vulnerable to contaminants in drinking water than the general population.

A few examples are, an individual with a compromised immune system such as someone undergoing chemotherapy or an organ transplant, a person with HIV/AIDs or other immune system disorders. Some elderly people and infants can be particularly at risk from infections. These individuals and parents of infants should seek advice from their health providers. It's important to understand that this is the case with all public drinking water. It's not unique to water from the Flint River.

How often does the City monitor water quality?

The City monitors its water on a daily basis to assure that water quality remains within established guidelines. With the variances in water temperature, and the leakage and infiltration problems arising due to failure of parts of the distribution system, water quality did exceed, for a time, some of the established guidelines. This resulted in the issuance of the recent notices to the public. Once it was learned that some guidelines were not being met, the City's immediate focus was to bring water quality back within guidelines. The efforts taken to address non-compliance included increasing water flow through valve replacements and hydrant flushing and optimizing treatment processes.

What were the causes of increased levels of bacteria (including fecal) levels that I read about? Have the causes been sufficiently addressed? If not what needs to be done to prevent this from happening again?

As is the case with most systems which treat surface water, many factors contributed to the

environment which allowed bacteria to proliferate. One of the main factors in our case is that when water travels through the 600 miles of the City's distribution mains it will, at times, in certain areas of the city, reside in the system for different periods of time. Water purchased from the Detroit Water & Sewage Department is drawn from Lake Huron, chlorinated, and then it travels over 60 miles to reach the City. By the time the water reaches Flint it is stable and capable of withstanding this type of residency time with the system. Water drawn from the Flint River, specifically in summer months when the temperature is fluctuating, is more susceptible to being impacted by variables such as high residency times and increased chemical reaction. Over the recent three months the residency time of water in the system has been reduced to approximately one week.

The Department of Environmental Quality (DEQ) requires that a minimum of 100 tests be performed monthly for chlorine residuals at various locations throughout the system. When residual levels are too low, it creates an environment in which bacteria such as fecal coliform can grow. After switching sources, we encountered testing sites in June 2014 that were consistently returning low residual levels. Several of these sites became areas that total coliform was eventually detected and ultimately "boil water" notices were issued. A significant cause of this is attributed to aged infrastructure which includes broken valves.

The necessary repairs and adjustments have been made to bring bacteria to acceptable levels with the exception of one test site -- the 2500 block of Flushing Road, where low residual levels continue. The City expects and is actively searching for valve issues. The engineering firm LAN & Potter Consulting is working to develop a hydraulic model of the distribution system and have the ability to use unidirectional flushing that will assist in addressing areas where residual levels are low.

The City has done internal testing recently that shows all eight sites currently well underneath the Maximum Contaminant Level and the next official testing date is due to the DEQ by March 1st, 2015.

It was recently announced in the news that Governor Snyder gave Flint \$2 million to fix the water problems? Is this true?

Yes. Under the state's Financially Distressed Cities, Villages and Townships Grant Program, Flint was awarded \$2 million to help address some of the problems associated with an aging water distribution system. While the City of Flint is very appreciative of the grant, it's going to take a substantially greater amount to fully address the improvements needed.

The grant will cover two significant projects, one, to decommission the incinerator that will result in ~\$400,000 in savings annually to the sewer fund and two, a complete leak detection performed on all of the large transmission mains in the City that will reduce water loss, thereby creating a savings in the water fund.

This issue did not happen before the switch from Detroit water to Flint water. Why now?

Switching to the Flint River has highlighted underground inconsistencies in the distribution system that have existed for decades. Over the last few years, the City has engaged in the development of a more effective and consistent preventative maintenance program and a Capital Improvement Plan that will result in a more reliable water distribution center over time.

Was it known prior to the switch from Detroit water to Flint water that there would be problems managing certain bacteria levels?

It was understood that the Flint River would be subject to variations due to temperature changes, rain events and would have higher organic carbon levels than Lake Huron water and would be more difficult to treat. These facts were presented to and weighed by licensed staff, LAN engineering consultants and the DEQ. It was determined that Flint has the equipment and the capacity to meet the demands of treating river water.

So in the majority of cases, it's safe to drink Flint tap water?

Yes, as safe it possibly can be. However if a person has a compromised immune system then he/she should consult with her/his physician first. It is also safe to bath and brush your teeth using the water.

What about the "hardness" of the water?

The Flint River is a harder water source than water drawn from Lake Huron. Hardness is classified as having a higher mineral content than "soft water", with the main concentration being calcium and magnesium. Water hardness is not considered by the EPA to be a health hazard.

Water hardness has been known to impact things such as cleaning tasks such as laundry, dishwashing, bathing personal grooming, and has also been associated with some forms of skin irritation such as eczema.

What are the public reporting requirements for these sorts of problems, and has the City met those requirements? What can be done to communicate useful information about a public health threat in a timelier manner?

The EPA 2010 "Revised Public Notification Handbook" has a specific breakdown of the elements required in public notifications and includes usable templates. The EPA has three different tiers associated with community water systems (CWS), each with specific timeframes and requirements that trigger upon issuance of the violation.

- **Tier 1.** CWS must provide public notification within 24 hours of a violation and continue this as directed by the primary agency.
- **Tier 2.** CWS must provide public notification within 30 days of a violation and continue this every three months until the violation is resolved
- **Tier 3.** CWS must provide public notification within one year and the EPA recommends repeat occurrences be provided in an annual notice

The current violation is classified as a tier 2 violation and was issued December 16, 2014.

Besides the home notifications, where can I find official communications and any updates on the Flint water issue?

The City posts information on the City of Flint website at www.cityofflint.com. There is a special section dedicated to addressing Flint water concerns and providing up-to-the-minute updates. In

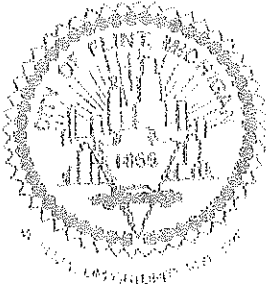
addition, updates can be found on Flint's Facebook page and citizens may also call the Flint Water Plant & Facilities at 810-787-6537 with questions.

If the water is ok to drink, why did GM stop using the water?

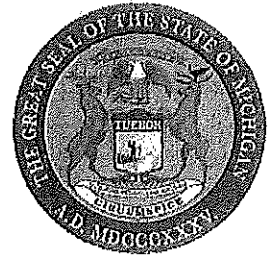
General Motors has been A great partner to the city for many years and when they recognized that an elevated level of chloride in the water was having an impact on a specific machining process they requested permission to transfer water delivery for that specific process to Flint Township. This represents only 10% of the water purchased and used by GM at the entire site. The remaining 90% of their water usage including all of the drinking water for GM employees is still purchased from the City of Flint.

Respectfully Submitted,

Howard D. Croft
Public Works Director



CITY OF FLINT
OFFICE OF THE EMERGENCY MANAGER



Gerald Ambrose
Emergency Manager

TO: Wayne Workman, Deputy Treasurer
Treasury Department
State of Michigan

FROM: Jerry Ambrose, Emergency Manager
City of Flint

DATE: March 3, 2015

As the Emergency Manager for the City of Flint, I am charged with restoring the City government to financial solvency, and working to assure that the City moves forward on a financially sustainable basis. The steps taken over the past three years have been difficult. Taxes and fees have been raised, services and workforce reduced, and ongoing costs, including legacy costs, have been constrained.

The current controversy surrounding the provision of water, and the path for resolution, has a potentially significant impact on the progress that is being made. I am satisfied that the water provided to Flint users today is within all MDEQ and EPA guidelines, as evidenced by the most recent water quality results conducted for MDEQ. We have a continuing commitment to maintain water safety and to improve water quality, and have dedicated resources to assure this commitment will be made.

The oft-repeated suggestion that the City should return to DWSD, even for a short period of time, would, in my judgment, have extremely negative financial consequences to the water system, and consequently to the rate payers. By the most conservative estimates, such a move would increase costs by at least \$12 million annually, with that amount achieved only by eliminating virtually all budgeted improvements in the system. For a system with Unrestricted Assets of only \$740,745, according to the June 30, 2014 audited financial statements, the only recourse within the City's control would be to increase revenues significantly. And in my judgment, that would come from raising rates for water by 30% or more. Further, changing the *source* of the city's water would not necessarily change any of the *aesthetics* of the water, including odor and discoloration, since those appear to be directly related to the aging pipes and other infrastructure that carry water from the treatment facility to our customers.

Wayne Workman
March 3, 2015
Page 2

This direction of discussion also deviates from what, in my judgment, should be the focus: How can we not only operate and maintain a system to assure the delivery of safe and quality water dependably, but significantly reduce the cost of water and sewer to the users? At an average of \$149 per month for water and sewer service for a residential user, the cost is extremely high in comparison to surrounding areas, as well as most areas across the state, and creates a significant financial burden for many users. In my judgment, we should all be concentrating on how to reduce rates by 50% or more. Unfortunately, there are no easy or evident answers, and continuation of the status will be an impediment to the sustainable recovery of the City of Flint. It is a conversation that I expect we will have with the recently created Water Quality Advisory Committee.

My reasoning for this conclusion is as follows:

One of the decisions made in the context of beginning to eliminate deficits and to restore financial stability to the City of Flint was to increase water and sewer rates significantly – the only choice available to financially stabilize a system that as of June 30, 2012, had a deficit of \$8,758,091. Another was to leave DWDS for the KWA because it offered the opportunity to lower future rate increases. A third decision was to utilize the Flint River on an interim basis when DWSD unilaterally terminated the City's contract for water purchase. That decision was made because it also offered an immediate cost savings opportunity which translated into the ability to upgrade the Water Treatment Plant without having to seek financing. It was a reasonable decision because of our experience in using the river in a back-up capacity, including test runs on a quarterly basis for several decades.

Unfortunately, the switch to the river as a primary source was more challenging than anticipated, and the harsh winter of 2013-2014 resulted in much more damage to the aging water infrastructure than in previous years. The result was the issuance of required notices that water exceeded established guidelines for safety as it could affect certain vulnerable populations, and some users of the system experienced unpleasant odors and discoloration. Some users also appeared to have had some negative reactions to the new source of water. However, as soon as the test results were known, City staff took immediate actions to address the concerns. These actions are evidenced today by the fact that MDEQ has certified that our most recent testing shows water from all testing sites to be well within acceptable guidelines. Additionally, the City is continuing to taking the necessary actions to assure that the water supply remains safe and that water quality continues to improve.

As the City has moved to address the situation, the suggestion continues to be made that the City should re-engage with DWSD and purchase water at least until the KWA pipeline is supplying water. As evidenced by the most recent letter from DWSD, such a decision would immediately increase the City's cost by \$846,700 per month, or \$10,160,400 per year, just for the fixed cost portion of the price. The actual *purchase* of water would be an additional fee, and dependent upon

Wayne Workman
March 3, 2015
Page 3

the quantity purchased. We estimate the actual water purchase cost to average more than \$1 million per month, for a grand total of approximately \$22 million per year. Finally, the DWSD offer is conditioned upon the City (or presumably the KWA) agreeing to negotiate a long term contract (30 years) for back-up.

The \$22 million annual estimate of increased costs to purchase water from DWSD would be minimally offset by an approximate \$3 million in reduced operating costs, and could be further offset by an additional \$9 million, but only if all funding for capital improvements to the system are eliminated. To eliminate all funding dedicated to repairing, stabilizing, and improving the system would be totally irresponsible and would have long term negative consequences to the City and to future rate payers.

As you are aware we have recently brought in outside expert assistance to evaluate the steps we have taken to assure that the water is safe and to continue to improve water quality. We are expecting specific recommendations within the next few weeks, and are committed to implementing those recommendations in a timely manner. Many steps have already been taken. I am confident that implementing their recommendations will assure a continuing supply of safe water as well as improved quality, and at far less cost than re-engaging DWSD.

We have also created a 40-member Water Advisory Committee and a 13-member Technical Advisory Committee to assure two-way communication with the public and users of the system. Those committees will begin to meet this week, and we look forward to answering their questions and receiving their input.

It is unfortunate that problems and concerns with quality have arisen, and we are working every day to address the issues that caused them. Maintaining safe water and improving quality is a top priority as we work to make the City of Flint an attractive place to live, work, study, and play.

02/09/2015

 UTILITY WIDE WATER FUND PROFESSIONAL SERVICES
 PERIOD ENDING 02/28/2015

ACCOUNT DESCRIPTION	2014-15 AMENDED BUDGET	ACTIVITY FOR MONTH 02/28/2015	YTD BALANCE 02/28/2015	ENCUMBERED YEAR-TO-DATE	UNENCUMBERED BALANCE	% BDGT USED
Dept 536.100-Utilities - Water Administration						
Fund 591 - Water Fund						
801.000 Professional Service	2,320,000.00	50,418.75	537,844.65	348,549.88	1,433,605.47	38.21
ROWE City Engineering			contract \$	79,000.00		
Dump Site Analysis			contract \$	42,892.00		
LAN Water Implementation			contract \$	244,900.00		
JFA /U.S. Dept Interior					\$ 27,295.00	
Raftelis Financial Update					\$ 23,810.00	
Bray Road					\$ 500,000.00	
TTHM Violation Letters/Mailings					\$ 25,000.00	
MDEQ Permit Fees					\$ 100,000.00	
Energy Costs/Performance Contracts					\$ 250,000.00	
Veolia Water Consultant					\$ 40,000.00	
City Works/Assest Management					\$ 350,000.00	
Operational Contingency					\$ 117,500.00	
Total Dept 536.100-Utilities - Water Administration				\$ 366,792.00	\$ 1,433,605.00	
Dept 540.100-Water Service Center Management						
Fund 591 - Water Fund						
801.000 Professional Service	374,400.00	0.00	74,877.03	250,869.51	48,653.46	87.00
Sewerlines Cty Engineering			contract \$	190,000.00		
Internal Investigations			contract \$	95,645.22		
Landfill Services					\$ 12,500.00	
Janitorial Services					\$ 4,260.00	
After Hours Water & Staking					\$ 2,500.00	
Line Stopping					\$ 25,000.00	
				285,645.22	44,260.00	

Dept 540.202-Wsc-Water Distribution Mains

Fund 591 - Water Fund

801.000	Professional Service	60,000.00	0.00	0.00	500.00	59,500.00	0.83
	Fire Extinguisher Services			contract	500.00		
					500.00		
					Balance is being used for budget adjustment to cover overruns for garage charges		
	Current garage overruns is \$100,000.00					59,500.00	

Dept 540.300-Capital Improvement

Fund 591 - Water Fund

801.000	Professional Service	2,660,000.00	0.00	0.00	60,000.00	2,600,000.00	2.26
	Water Meters			contract	60,000.00		
	Water Main Replacement Iroquois					\$ 2,500,000.00	
	Valve Exercising					\$ 100,000.00	
	Total Dept 540.300-Capital Improvement				\$ 60,000.00	\$ 2,600,000.00	

Dept 545.200-Water Plant - Operations

Fund 591 - Water Fund

801.000	Professional Service	80,000.00	0.00	8,866.98	10,323.02	60,810.00	23.99
	Lab Testing			contract	10,323.02		
	Dam inspections					\$ 11,500.00	
	Comprehensive Regulatory Compliance					\$ 40,000.00	
	Lab Proficiency Testing					\$ 6,000.00	
	All Max Data Support					\$ 2,500.00	
	Total Dept 545.200-Water Plant - Operations				\$ 10,323.02	\$ 60,000.00	

Dept 545.201-Water Plant Maintenance

Fund 591 - Water Fund

801.000	Professional Service	26,000.00	0.00	3,700.00	12,955.00	9,345.00	64.06
	Vibration Analysis			contract	\$ 5,500.00		
	Elevator Inspections & Services			contract	\$ 2,455.00		
	Diving for Dams Inspection			contract	\$ 5,000.00		
	RPZ Inspection & Repair					\$ 4,000.00	
	Generator Inspection & Services					\$ 5,000.00	
	Total Dept 545.201-Water Plant Maintenance	26,000.00	0.00	3,700.00	\$ 12,955.00	\$ 9,000.00	64.06

Dept 545.300-Water Plant - Capital Improvements

Fund 591 - Water Fund

801.000	Professional Service	2,900,000.00	0.00	927,098.07	1,296,474.81	676,427.12	76.67
	Installation of Storage Tanks			contract \$	716,272.00		
	Motor Control Upgrade			contract \$	440,157.00		
	Easement- Electrical Grounding			contract \$	4,054.00		
	Lime Residual			contract \$	135,991.81		
	Cedar Street Pump Station					\$ 500,000.00	
	Pump Station Feeder					\$ 125,000.00	
	TTHM Operational Evaluation					\$ 50,000.00	

Total Dept 545.300-Water Plant - Capital improvements	2,900,000.00	0.00		\$ 1,296,474.81	\$ 675,000.00	76.67

Total	Budgeted	YTD Balance	Encumbered	Unencumbered
	\$8,420,400.00	\$1,552,386.73	\$2,032,690.05	\$4,821,865.00

WATER FUND EXPENSES

WATER FUND EXPENSES							2015-16 BUDGET CHANGES WITH DWSD & ALL CAPITAL FUNDING ELIMINATED	
GL NUMBER	DESCRIPTION	2013-14 ACTIVITY	2014-15 AMENDED BUDGET	2015-16 APPROVED BUDGET	2015-16 BUDGET CHANGES FOR DWSD	2015-16 BUDGET CHANGES FOR DWSD	STATUS QUO REVISED 2015-16 BUDGET WITH DWSD	
Expenses - Water Fund								
Dept 536.100-Utilities - Water Administration								
	Wages and Fringes	\$76,155	\$528,777	\$445,851			\$445,851	
	Repairs and Improvements	\$2,497,397	\$2,320,000	\$2,320,000		\$0	\$2,320,000	(\$2,320,000)
	Other Expenses	\$2,295,410	\$2,248,750	\$2,248,750			\$2,248,750	
Dept 540.100-Water Service Center Management								
	Wages and Fringes	\$199,883	\$228,451	\$256,343			\$256,343	
	Repairs and Improvements	\$140,599	\$374,400	\$350,000		\$0	\$350,000	(\$350,000)
	Other Expenses	\$106,780	\$477,292	\$547,649		\$0	\$547,649	
Dept 540.200-Wsc-Meter-Reading - Water								
	Wages and Fringes	\$439,351	\$488,363	\$481,316		\$0	\$481,316	
	Other Expenses	\$151,894	\$64,000	\$64,000		\$0	\$64,000	
Dept 540.202-Wsc-Water Distribution Mains								
	Wages and Fringes	\$2,383,598	\$3,006,530	\$3,024,627		\$0	\$3,024,627	
	Repairs and Improvements	\$381	\$60,000	\$85,000		\$0	\$85,000	(\$85,000)
	Other	\$1,210,118	\$920,457	\$849,500		\$0	\$849,500	
Dept 545.200-Water Plant - Operations								
	Wages and Fringes	\$988,523	\$1,827,003	\$1,761,027	Staffing	(\$376,098)	\$1,384,929	
	Repairs and Improvements	\$48,723	\$80,000	\$60,000			\$60,000	(\$60,000)
	Supplies, Utilities and Other	\$22,779,389	\$3,445,656	\$3,318,656			\$23,960,446	
					Fixed Charge DWSD	\$10,160,400		
					Commodity Chg DWSD	\$12,818,190		
					Chemical Purchase	(\$1,486,800)		
					Electrical Power	(\$850,000)		
Dept 545.202-Water Plant - Ozm Operations		\$119,216	\$0	\$0			\$0	
Dept 545.203-Water Plant - Ozm Maintenance		\$126,623	\$0	\$0			\$0	
Dept 545.300-Water Plant - Capital Improvements								
	Repairs and Improvements	\$968,815	\$2,900,000	\$1,200,000			\$1,200,000	(\$1,200,000)
	Other	\$980,161	\$3,700,000	\$2,400,000			\$2,400,000	
Dept 900.100-Cost Allocation and Retiree Healthcare		\$3,111,662	\$5,600,242	\$6,077,577			\$6,077,577	
Dept 966.101-PILOT Payment		\$1,130,000	\$1,130,000	\$1,130,000			\$1,130,000	
Dept 966.493-Debt Service		\$2,638,071	\$2,638,071	\$2,638,071			\$2,638,071	
Dept 540.300-Capital Improvement								
	Repairs and Improvements	\$0	\$2,660,000	\$2,660,000			\$2,660,000	(\$2,660,000)
	Other	\$0	\$530,000	\$530,000			\$530,000	
Dept 233.100-Purchasing	Wages and Fringes	\$63,263	\$0	\$29,313			\$29,313	
Dept 253.202-Bad Debt Expense		\$161,939	\$0	\$0			\$0	

<u>Dept 536.205-Utilities - Water Cross Connection Prog</u>	\$100,314	\$109,945	\$108,182		\$108,182	
<u>Dept 545.201-Water Plant Maintenance</u>						
Wages and Fringes	\$1,063,567	\$1,147,846	\$1,127,386		\$1,127,386	
Repairs and Improvements	\$8,142	\$26,000	\$26,000		\$26,000	(\$26,000)
Other	\$420,048	\$671,249	\$689,000		\$689,000	
<u>591-536.100-990.200</u>						
KWA Operation Payment	\$0	\$584,000	\$584,000		\$584,000	
Reserve	\$0		\$2,873,750		\$2,873,750	(\$2,873,750)
Total Expenses	\$44,210,032	\$37,767,035	\$37,886,000	\$20,265,692	\$58,151,692	\$48,576,942

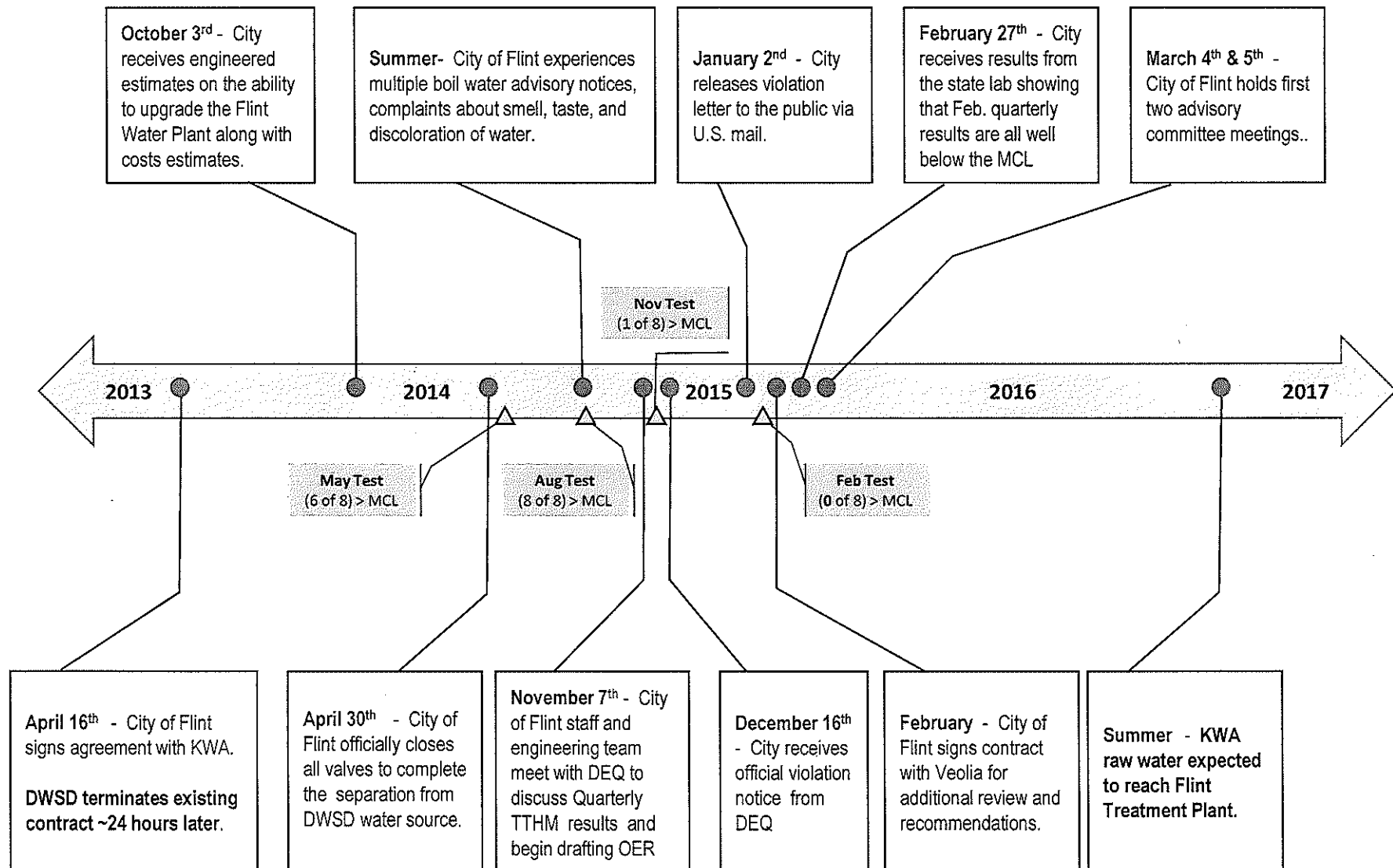
<u>WATER FUND REVENUES</u>									
GL NUMBER	DESCRIPTION	2013-14	2014-15	2015-16	2015-16	STATUS QUO	2015-16		
		ACTIVITY	AMENDED	APPROVED	BUDGET	REVISED	2015-16	WITH DWSD &	
			BUDGET	BUDGET	CHANGES	BUDGET	BUDGET	ALL CAPITAL	
					FOR DWSD	WITH DWSD	Inc.	ELIMINATED	Inc.
Revenues- Water Fund									
	Meter Water Sales	\$42,132,946	\$37,000,000	\$37,000,000	\$20,265,692	\$57,265,692	55%	\$48,576,942	31%
	Other Revenues	\$1,589,155	\$886,000	\$886,000	\$0	\$886,000		\$886,000	
	Asset Sale	\$3,493,743	\$0	\$0	\$0	\$0		\$0	
	Carry Over	\$0	\$3,263,505	\$0	\$0	\$0		\$0	
Total Revenues		\$47,215,844	\$41,149,505	\$37,886,000	\$20,265,692	\$58,151,692		\$48,576,942	



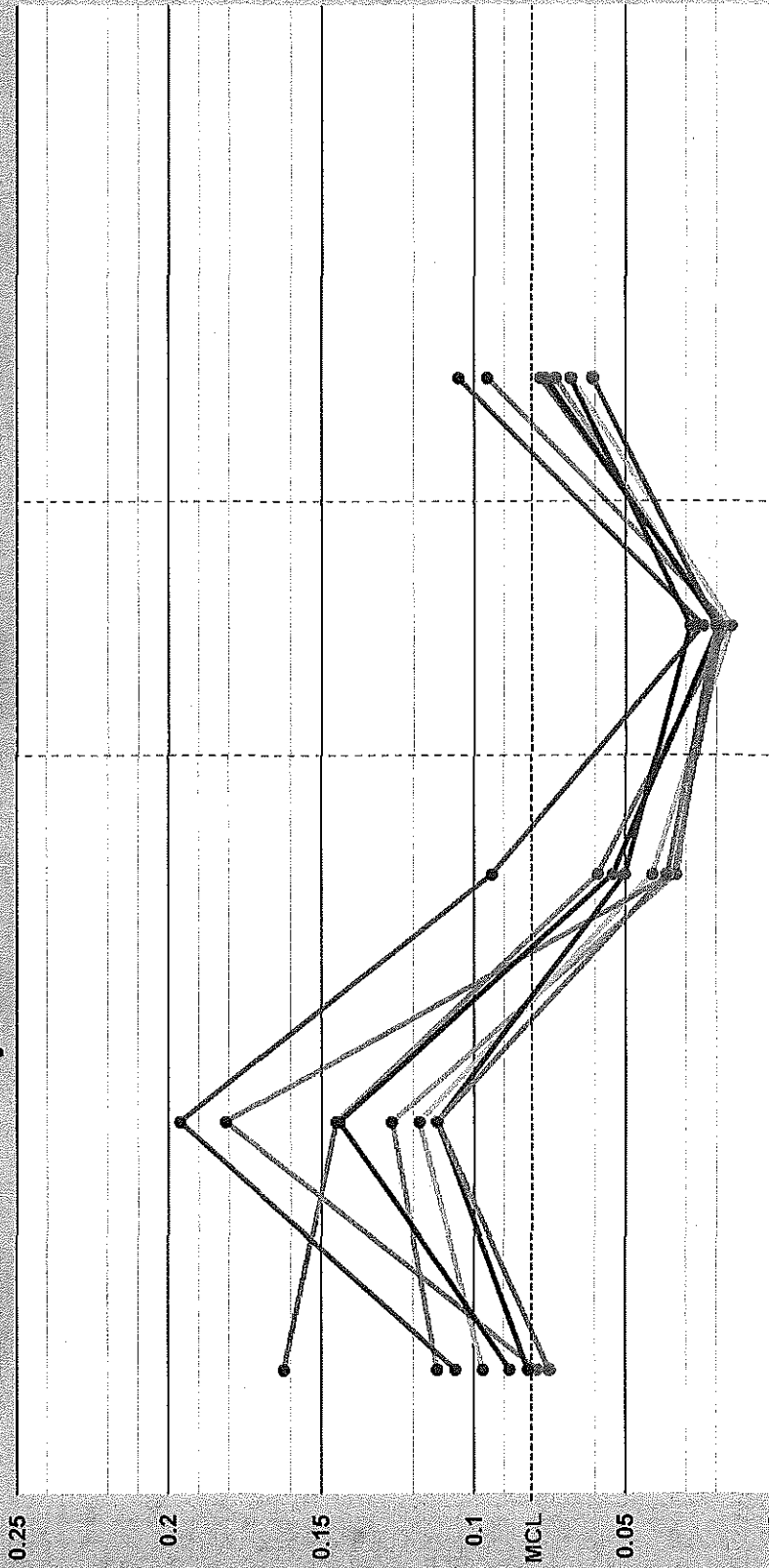
City of Flint Water Timeline

Legend

- △ TTHM Quarterly Testing
- Specific Dates of Events



City of Flint TTHM Chart



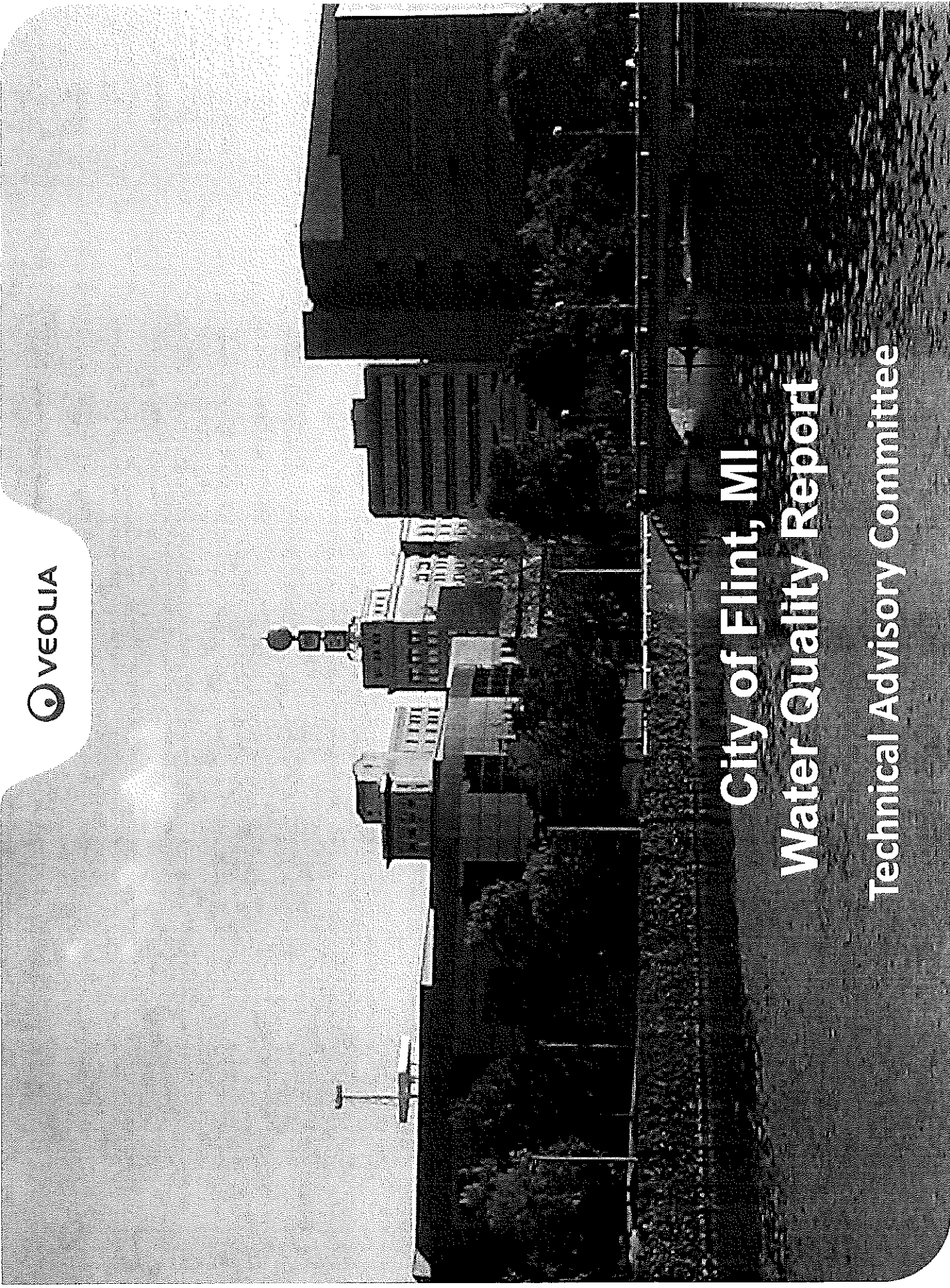
	21-May-14	21-Aug-14	20-Nov-14	15-Feb-15	Total
Series 1	0.162	0.145	0.059	0.016	0.0955
Series 2	0.112	0.127	0.033	0.0199	0.072975
Series 3	0.097	0.118	0.041	0.0149	0.067725
Series 4	0.106	0.196	0.094	0.0245	0.105125
Series 5	0.079	0.181	0.034	0.0181	0.078025
Series 6	0.088	0.144	0.054	0.0192	0.0763
Series 7	0.082	0.112	0.05	0.0285	0.068125
Series 8	0.075	0.112	0.036	0.0199	0.060725
Current Quarterly Result					4 Quarter Average



City of Flint

Water Improvements since November 2014

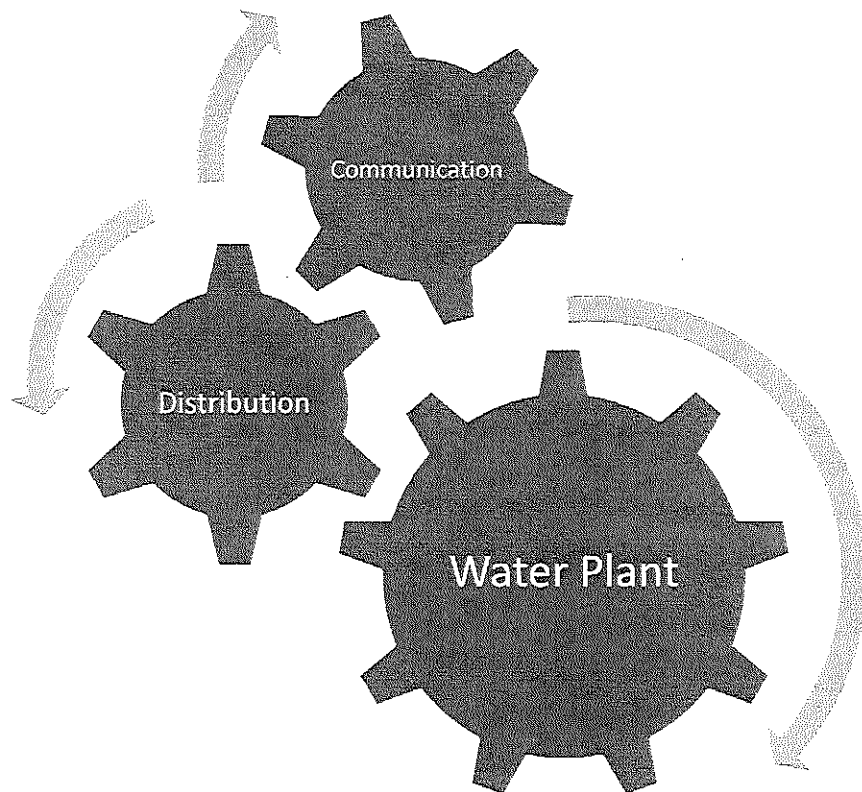
DATE	IMPROVEMENT	EFFECT
Nov.	Increased flushing efforts (as weather permits)	Reduced time of water in the system
Nov.	Adjusted operational softening to no less than 80%	Reduce chlorine demand
Dec.	Started hydraulic modeling of distribution system	Helps to identify locations of bad valves
Dec.	Started evaluation of different polymers	Removal of organic carbon
Dec.	Started SCADA upgrades inside of Water Plant	Improvement of internal software controls
Jan.	Hired vendor to upgrade efficiency of the ozone system	Better oxidation and disinfecting
Jan.	Started jar testing	Assists in dosage amounts and polymer aids
Feb.	Hired consultant Veolia for process review	Professional recommendations
Feb.	Leased and installed TTHM analyzer	Increased internal testing ability
Feb.	Adjustments to reservoir level to match demand	Reduce time of water in system

A black and white photograph of the Flint, Michigan skyline. The city's buildings, including the prominent clock tower of the Spirit of Detroit building, are reflected in the calm water of the Flint River. The image has a grainy, high-contrast aesthetic.

City of Flint, MI Water Quality Report

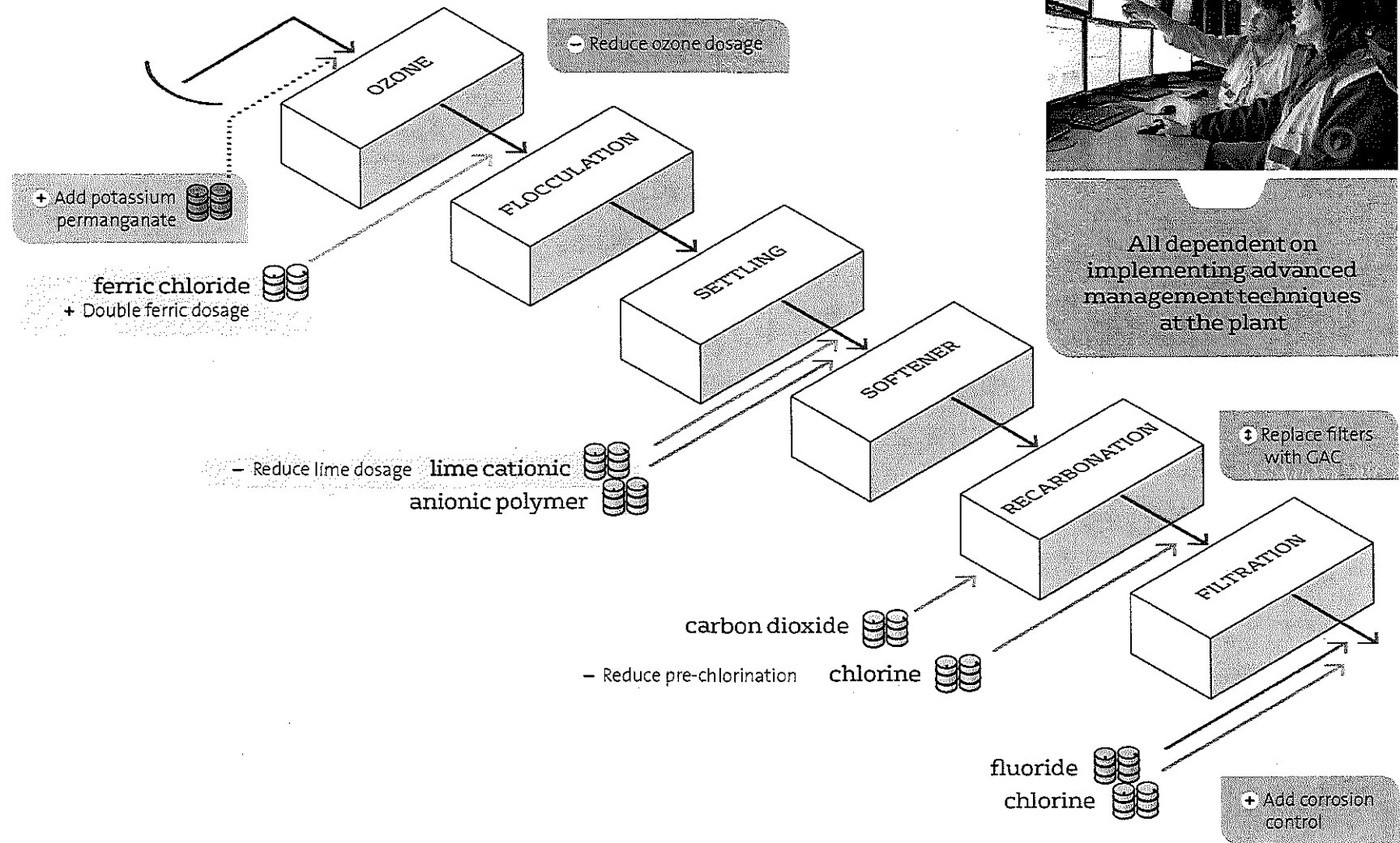
Technical Advisory Committee

Solution Involves Coordination of 3 Activities

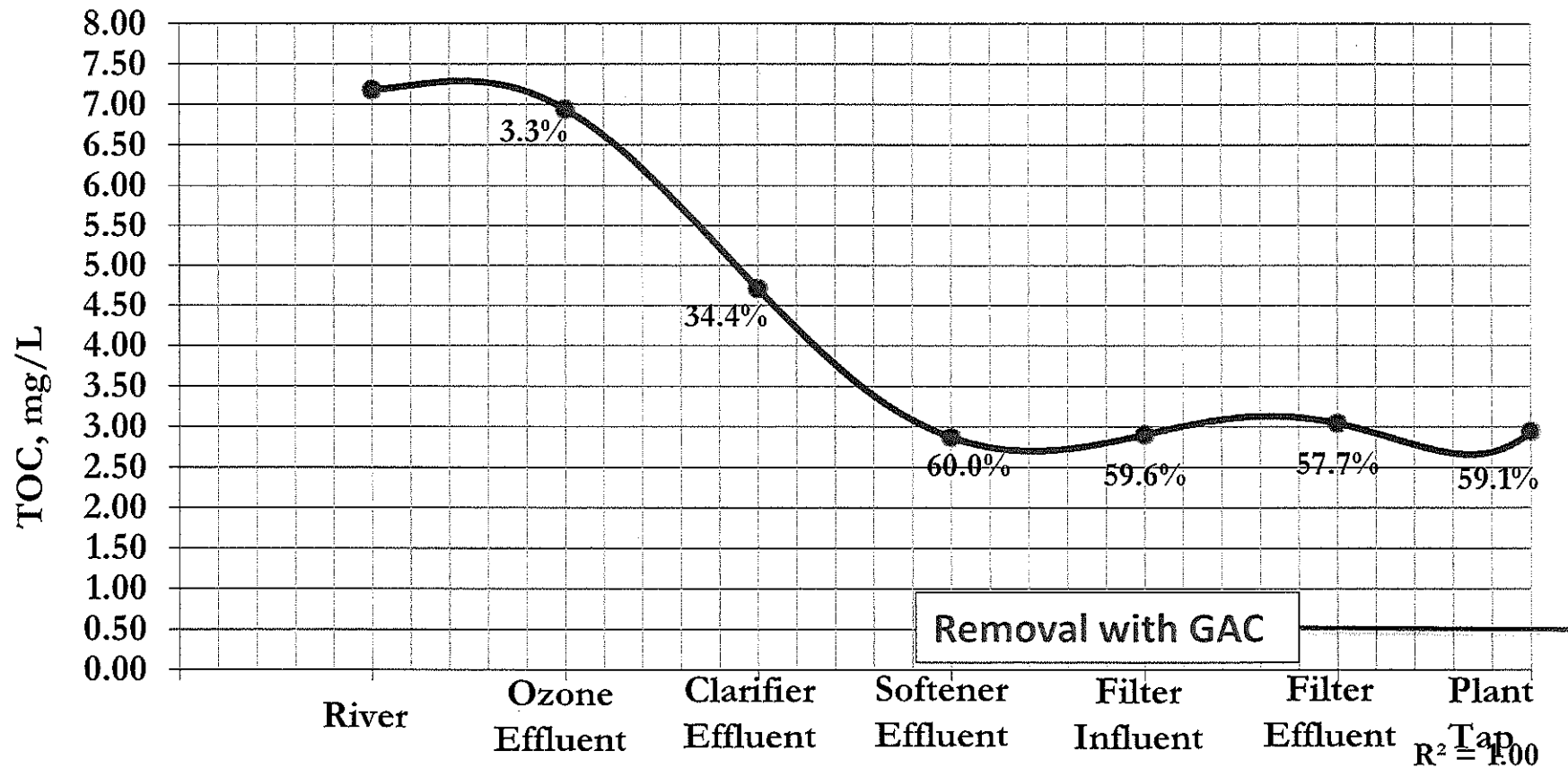


- **Water plant improvements**
 - *Optimize chemical dosages*
 - *Consider different chemicals*
 - *Install granulated activated carbon*
 - *Complete plant upgrades*
 - *Implement best mgt practices*
- **Distribution system improvements**
 - *Fix broken valves*
 - *Ask for customer feedback*
 - *Reduce tank storage*
 - *Target line flushing*
 - *Run a hydraulic model*
- **Better communication with customers**
 - *Engage advisory committees*
 - *More accessible utility*
 - *Make it easy to access information*
 - *Better customer communication*

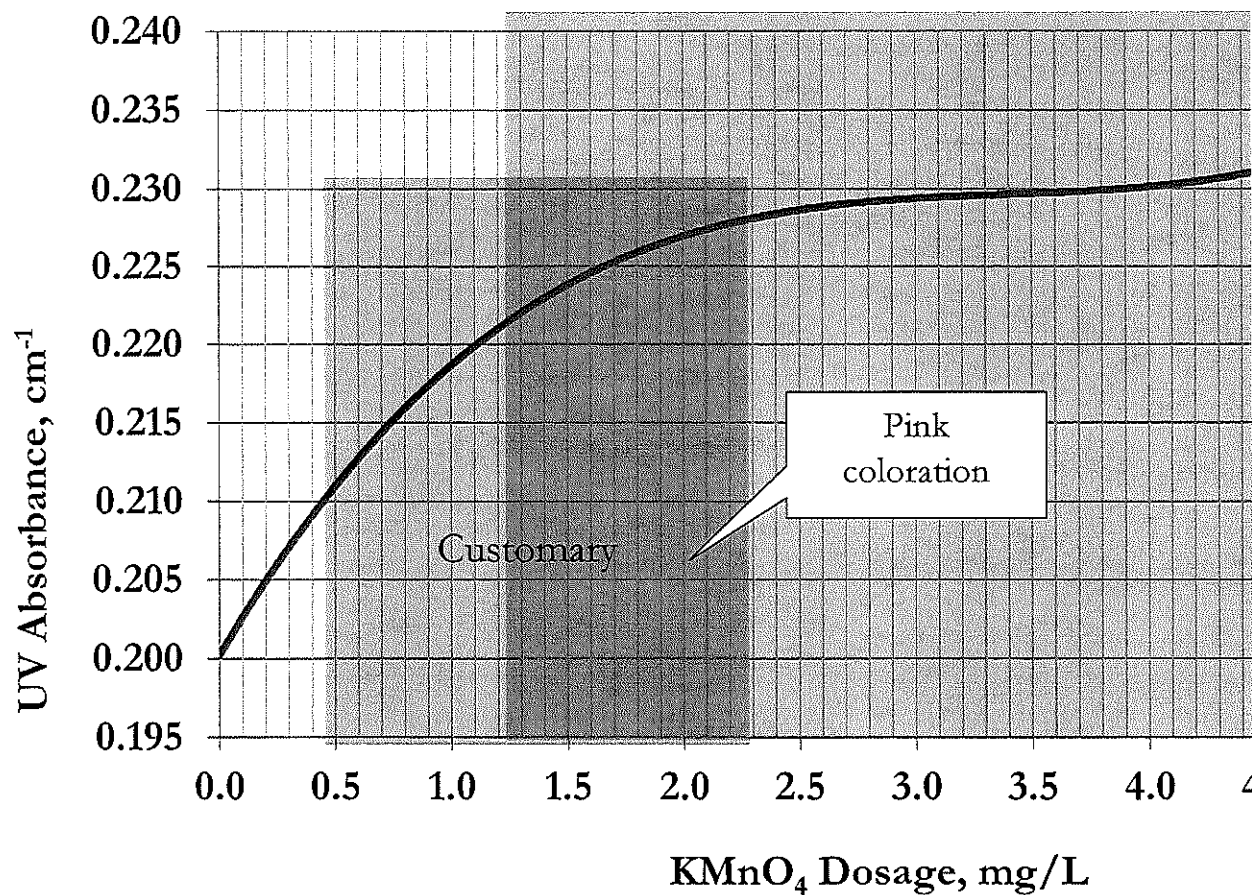
Optimize Plant Processes



TOC Removal Efficiency Optimizing Current Plant



Potassium Permanganate Dosing Graph



JAR TEST BENCH SHEET

FACILITY NAME Flint, Michigan DATE February 16, 2015

CHEMICAL DATA		ALUM	FeCl ₃	Fe ₂ (SO ₄) ₃	POLYMER	LIME	KMnO ₄
Specific gravity							1.16
Percent dry chemical							20
Stock volume, mL							100
Chemical added, mL or grams							0.9
Stock concentration, mg/L							2,000
Solution volume, mL							
Stock solution added, mL							
Solution concentration, mg/L							

TEST

CONDITION	STIRRER RPM	DURATION	Simulated Conditions
NS			
Rapid Mixing	300	seconds	G -
Flocculation	30	15 minutes	G -
Settling	0	minutes	Coag. 0.3
Filtered distilled water time		seconds	Soft. 1.16

RAW WATER CHARACTERISTICS

Temperature °C	pH	Alkalinity	Hardness	Turbidity	Color	TOC	DOC	POC
						7.05		

Filterability Index

Calcium	Magnesium	Iron	Manganese	THMFP	UV ₂₅₄
					0.198

JAR NUMBER

Raw water volume, mL	Alum solution added, mL	Alum dosage, mg/L	Ferric solution added, mL	Ferric dosage, mg/L	Polymer solution added, mL	Polymer dosage, mg/L	KMnO ₄ solution added, mL	KMnO ₄ dosage, mg/L	Lime solution added, mL	Lime dosage, mg/L
1	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000

FLOC FORMATION OBSERVATIONS

5 minutes	10 minutes	15 minutes	20 minutes	25 minutes

SETTLING CHARACTERISTICS OBSERVATIONS

1 minute	2 minutes	3 minutes	4 minutes	5 minutes	6 minutes

SETTLED WATER RESULTS

Turbidity, NTU	Water pH	Alkalinity, mg/L	Hardness, mg/L	TOC, mg/L	UV ₂₅₄ , cm ⁻¹	Filtered water time	Filterability index

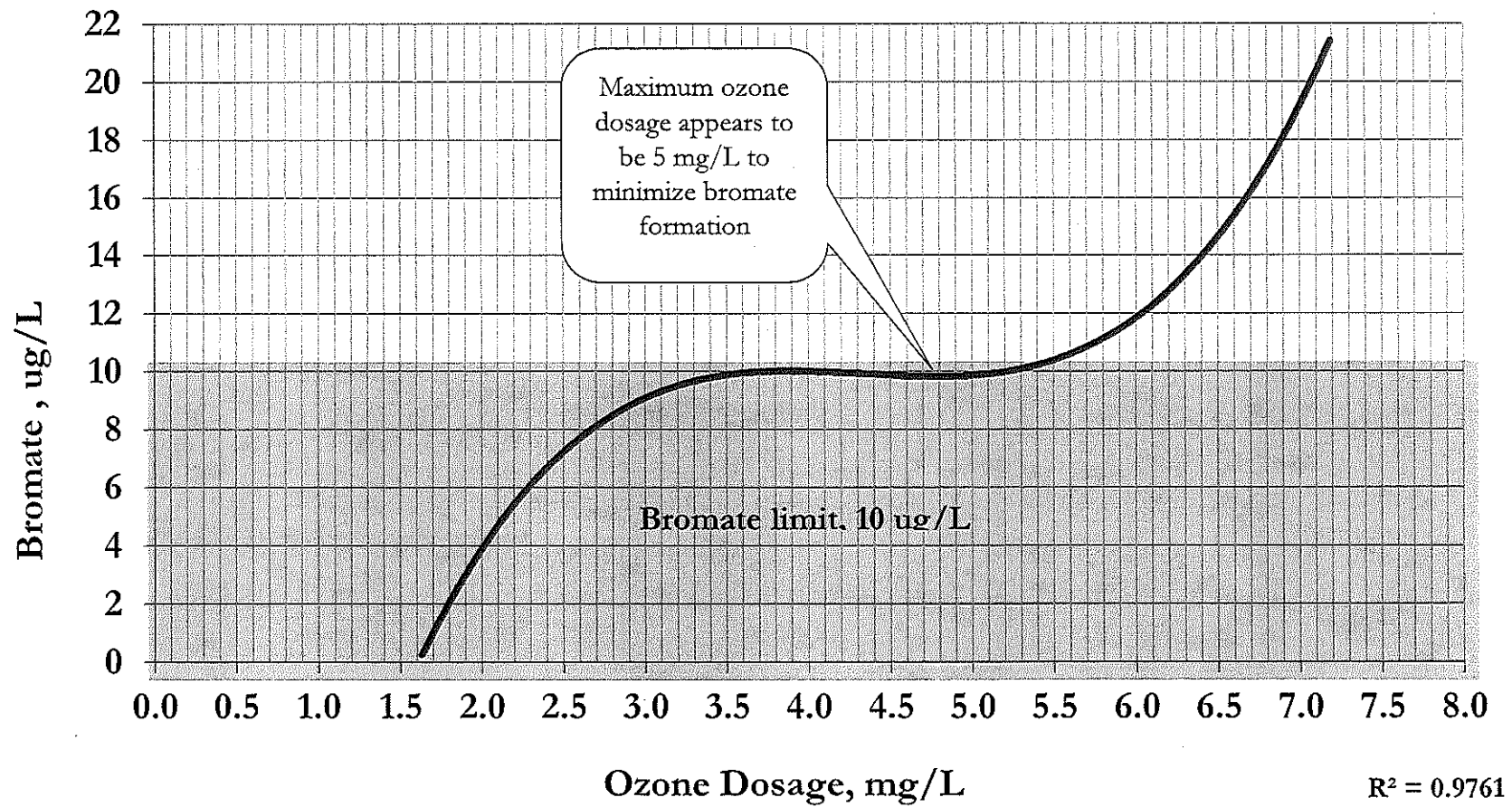
NOTES:

Veolia Water North America

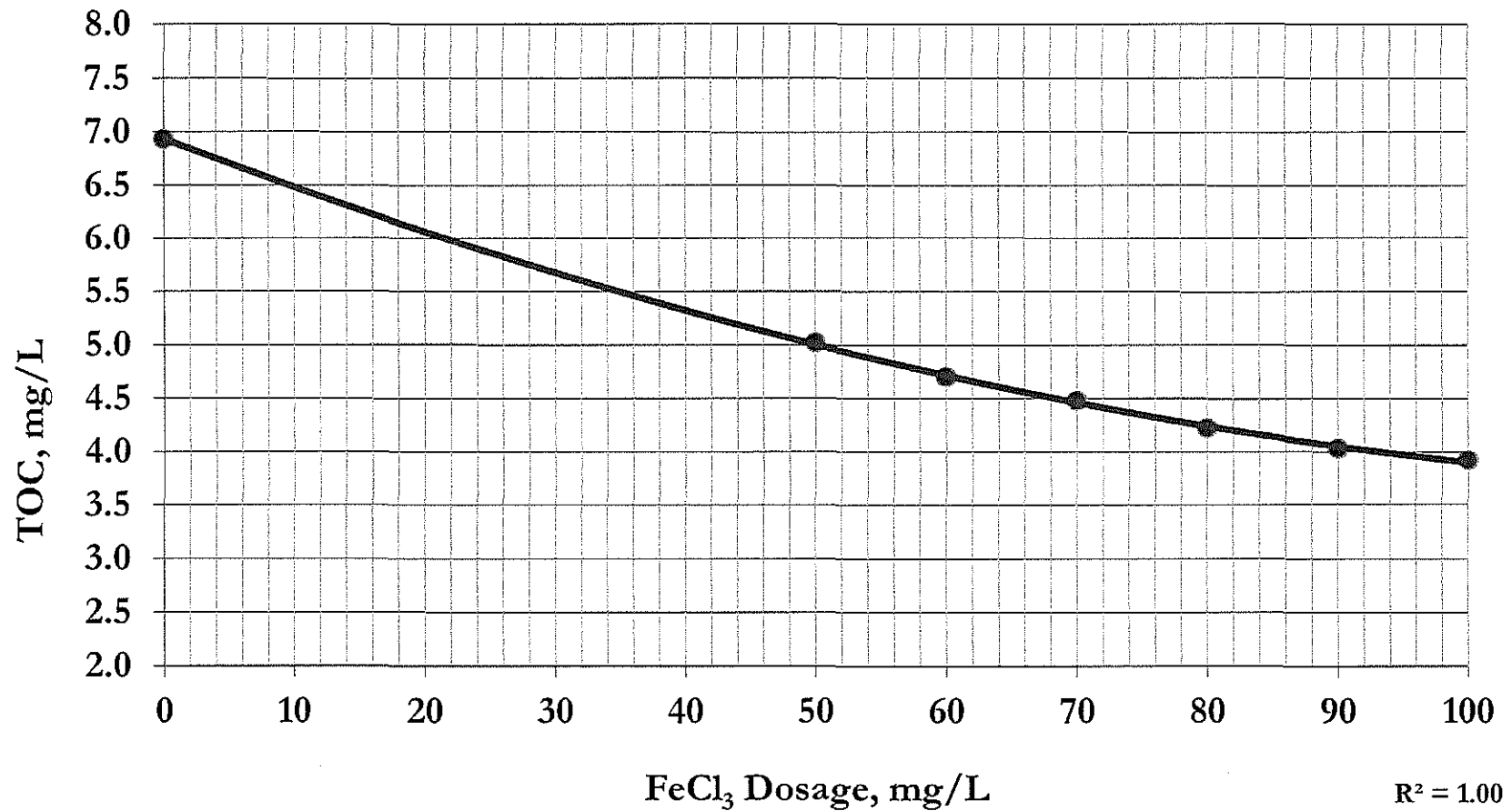
$$R^2 = 0.9753$$



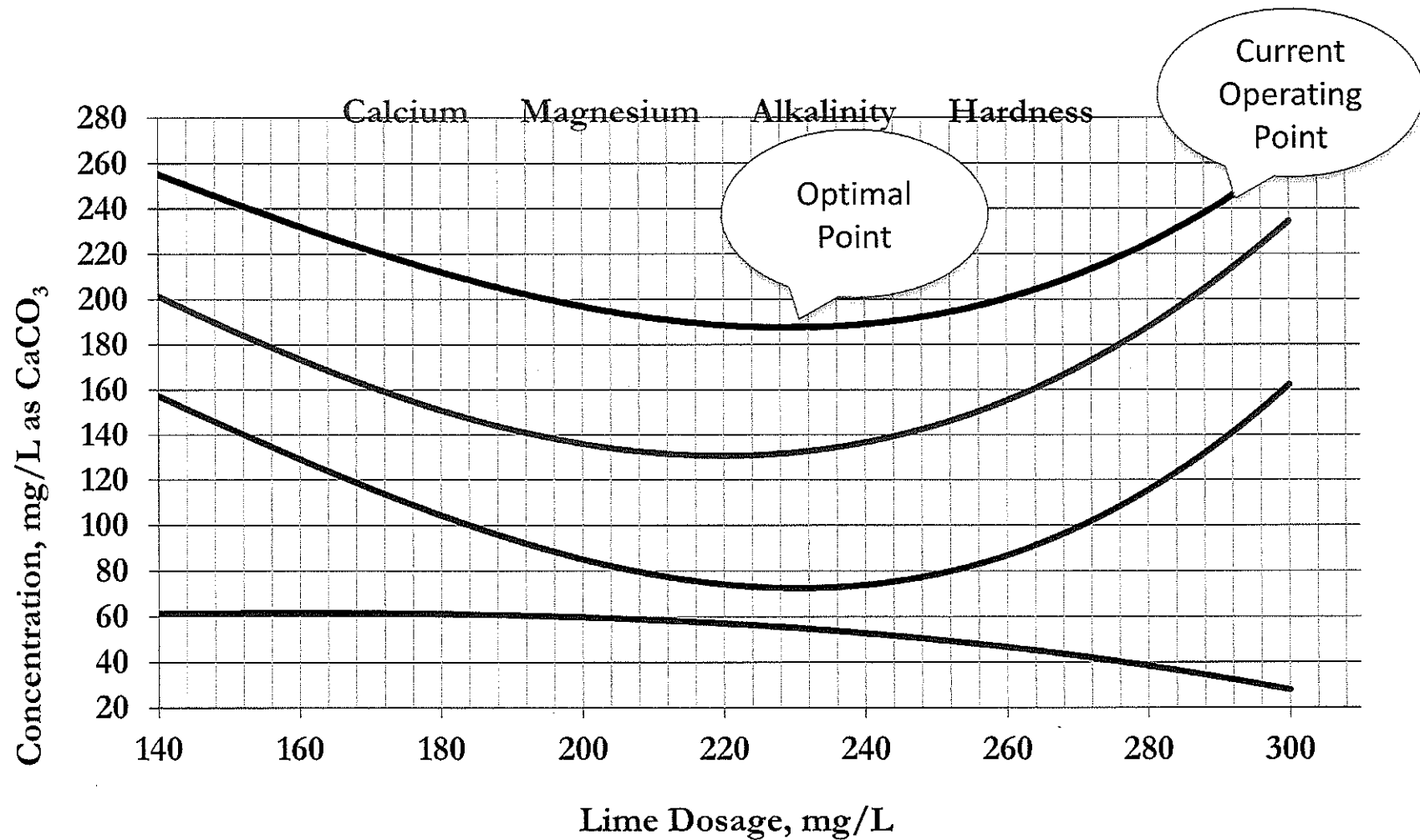
Bromate Dosing Graph



Dosage of Ferric Chloride



Lime Dosage Graph



Implement Best Management Practices

Activities to Help Operators Maintain Good Water Quality

- Process Control Management Plan
- Lab QA/QC Program
- Computerized Maintenance Management System
- Asset Management System
- Training and Certification Program
- Vulnerability Plan



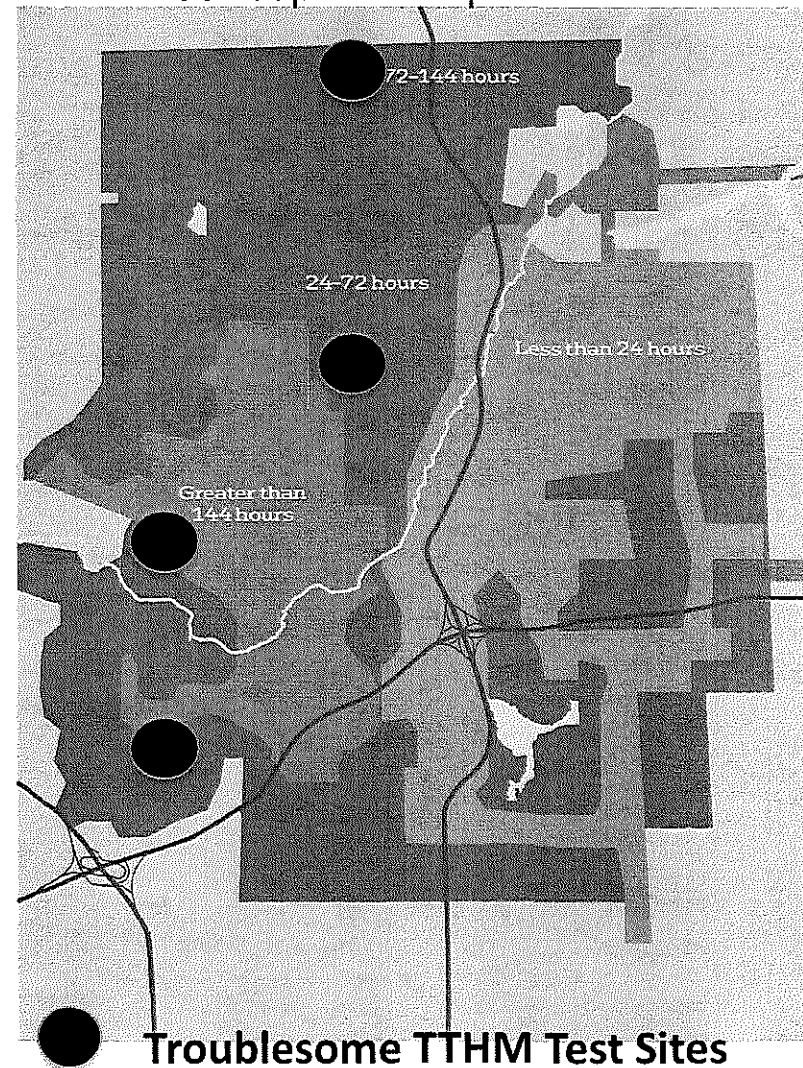
Water Age Map

- Speed up flow of water from plant to homes – 2 weeks plant to house
 - *Find closed valves & open them*
 - *Replace broken valves*
 - *Update hydraulic model*
 - *Reduce system storage*
- Track customer complaints
 - *Test customer water*
 - *Spot flush hydrants to clean areas of stagnant water in the system*



© March 4, 2015 Technical Advisory Committee

Conceptual Map



Make It Easy to Access Information and People

Develop a proactive customer communication plan

- Create advisory committees to help direct efforts and improve flow of information
- Add additional communication personnel for the utility
- Develop a pro active communication program
- Establish a single point of contact to manage all water quality complaints
- Provide additional customer service training and tools to staff
- Expand neighborhood and community outreach
- Change monthly billing statements from card to envelope with information



Questions?

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Thursday, March 05, 2015 10:46 AM
To: Rennaker, Joanne (DEQ)
Cc: Prysby, Mike (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: Flint VN letter to final

Has this been signed yet? I would like to get it over to Sarah this morning if possible.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

From: Busch, Stephen (DEQ)
Sent: Wednesday, March 04, 2015 3:46 PM
To: 'Rennaker, Joanne (DEQ) (RENNAKERJ@michigan.gov)'
Cc: prysbym@michigan.gov; Adam Rosenthal (rosenthala@michigan.gov)
Subject: Flint VN letter to final

Jo Anne,

Attached is the Flint Violation notice letter.

Please final the letter and have Mike and Adam sign it.
Then scan and email me a signed copy.
I will be emailing Sarah Howes for legislative distribution
Hold off on mailing the letter until the end of the day so we can be sure to allow Sarah time to inform legislative members. Thanks.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
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Cc: Prysby, Mike (DEQ); Rosenthal, Adam (DEQ)
Subject: Flint VN letter to final
Attachments: Flint DBP MCL 1Q15.doc

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Office of Drinking Water and Municipal Assistance

MDEQ

517-643-2314



RICK SNYDER
GOVERNOR

STATE OF MICHIGAN
DEPARTMENT OF ENVIRONMENTAL QUALITY
LANSING DISTRICT OFFICE



DAN WYANT
DIRECTOR

March 5, 2015 - DRAFT

Mr. Brent Wright, Operation Supervisor
City Of Flint - DPW
Flint Water Plant
4500 North Dort Highway
Flint, MI 48505

WSSN: 02310

Dear Mr. Wright:

SUBJECT: Violation Notice – Maximum Contaminant Level for Total Trihalomethanes
Operational Evaluation – Total Trihalomethanes
1st Quarter 2015 Monitoring Period

The Department of Environmental Quality (DEQ), Office of Drinking Water and Municipal Assistance (ODWMA), records show that the City of Flint is in violation of the Safe Drinking Water Act, 1976 PA 399, as amended (Act 399); R 325.10610, *Maximum contaminant levels (MCL) for disinfection byproducts*, of the 1979 Administrative Code.

In accordance with R.325.10610, *MCLs for disinfection byproducts*, of the 1979 Administrative Code, the MCL for disinfection byproduct total trihalomethanes (TTHM) is 0.080 milligrams per liter (mg/L) as a Locational Running Annual Average (LRAA) at each monitoring location. As listed in the table below, our records show that the City of Flint's highest TTHM locational running annual average (LRAA), based on the last four quarters, ending February 28, 2015, is 0.105 mg/l which exceeds the standard, and that two of the eight sample site locations exceed the standard of 0.080 mg/L.

Further, in accordance with R325.10719I, *Disinfection byproducts: operational evaluation levels*, of the 1979 Administrative Code, when an operational evaluation level (OEL) at a monitoring location for TTHM exceeds 0.080 mg/L, a supply shall conduct an operational evaluation and submit a written report of the evaluation to the department not later than 90 days after being notified of the analytical result that causes the supply to exceed the operational evaluation level. As listed in the table below, our records show that TTHM operational evaluation levels for the City of Flint exceed 0.080 mg/L at one of the City's eight sample site locations.

TTHM Results (mg/L)						
	5/21/14	8/21/14	11/20/14	2/17/15	LRAA	OEL
DBP1 McDonalds 3719 Davison	0.162	0.145	0.059	0.0162	0.096	0.059
DBP2 Liquor Palace 3302 S. Dort Highway	0.112	0.127	0.033	0.0168	0.072	0.049
DBP3 North Flint Auto 6204 N. Saginaw St.	0.097	0.118	0.041	0.0149	0.068	0.047
DBP4 University Market 2501 Flushing Road	0.106	0.196	0.094	0.0245	0.105	0.085
DBP5 Taco Bell 3606 Corunna Road	0.079	0.181	0.034	0.0151	0.078	0.063
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.088	0.144	0.054	0.0192	0.076	0.059
DBP7 Salem Housing 3216 MLK Boulevard	0.082	0.112	0.050	0.0285	0.068	0.055
DBP8 BP Gas Station 822 S. Dort Highway	0.075	0.112	0.036	0.0199	0.061	0.047

Our investigation consisted of a review of ODWMA files for laboratory reports received for compliance monitoring. Our investigation is considered complete. This violation began on March 1, 2015, and will continue until TTHM LRAA is below the MCL at all sample sites.

We are encouraged by the results from the most recent round of compliance samples collected on February 17, 2015, which now show individual TTHM levels at less than half of the 0.080 mg/L standard at all locations throughout the City's system. Operational Evaluation Reports from December 2014 and February 2015 have identified possible causes and corrective measures for the previous elevated TTHM levels which we encourage the City continue implementing. These modifications have likely contributed in part to the reduction in TTHM levels reported in the most recent quarter, and suggest the City may be able to achieve compliance with the TTHM standard at all sites by continuing these efforts.

Our office is currently reviewing the Operational Evaluation report dated February 27, 2015, and will provide the City and their consultant comments as needed to help address this MCL violation.

Water systems that exceed the OEL must complete and submit an Operational Evaluation in accordance with Administrative Rule 719I (R325.10719I) within 90 days of being notified of the violation. **An updated Operational Evaluation report, which incorporates the most recent sample results, must now be completed and received by our office by no later than Friday May 29, 2015.**

If you have any other factual information you would like us to consider regarding the violation identified in this Violation Notice (VN), please provide them in a written response by March 19, 2015.

Administrative rule R 325.10403 of Act 399 requires that suppliers provide public notice (PN) as soon as practical, but no later than thirty (30) days after the supplier learns of

this type of violation, by mail or direct delivery **and** by any other means reasonably calculated to reach customers not normally reached by mail. Enclosed is a sample PN which contains the minimum required language. The City is encouraged to include additional information regarding its response efforts to this violation. **Please notify your consumers by April 1, 2015, and send us a signed and dated copy of the notice that you issued within ten (10) days of distributing the public notice.** This violation must also be included in your 2015 Consumer Confidence Report (CCR), due by July 1, 2016. The PN must be repeated every quarter until you no longer exceed the TTHM standard. Failure to issue a PN for this violation will result in a fine of at least \$1,000 per event, with a maximum of \$5,000 per violation.

We anticipate and appreciate your continued cooperation in resolving this matter. If you have any questions regarding this VN, please contact us at the numbers below.

Sincerely,

Michael F. Prysby, P.E., District Engineer
Lansing District Office
Office of Drinking Water & Municipal
Assistance
517-290-8817

Adam Rosenthal, EQA
Lansing District Office
Office of Drinking Water & Municipal
Assistance
517-284-6644

mfp/ar/jlr
Enclosure

cc: Mr. Jerry Ambrose, Emergency Manager, City of Flint
Mr. Daughtry Johnson, City of Flint
Mr. Howard Croft, City of Flint
Mr. Robert Bincsik, City of Flint
Ms. Jennifer Crooks, U.S. Environmental Protection Agency, Region 5
Genesee County Health Department
Ms. Liane Shekter Smith, P.E., DEQ
Mr. Richard Benzie, P.E., DEQ
Mr. Stephen Busch, P.E., DEQ

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

City of Flint Did Not Meet Treatment Requirements

Our water system recently violated a drinking water standard. Although this incident was not an emergency, as our customers, you have a right to know what happened and what we are doing to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Samples were collected for total trihalomethanes (TTHM) analysis from eight locations on a quarterly basis (May 21, August 21, November 20 of 2014 and February 17, 2015). The average of the results at **ANY** of the eight locations must not exceed the maximum contaminant level (MCL) for TTHMs, otherwise our water system exceeds the Maximum Contaminant Level (MCL). The standard for TTHMs is 80 µg/L. The location reporting the highest TTHM level was 105 µg/L; thus, our water system exceeds the TTHM MCL.

What should I do?

- There is nothing you need to do unless you have a severely compromised immune system, have an infant, or are elderly. These people may be at increased risk and should seek advice about drinking water from their health care providers.
- You do not need to boil your water or take other corrective actions. If a situation arises where the water is no longer safe to drink, you will be notified within 24 hours.

What does this mean?

This is not an emergency. If it had been an emergency, you would have been notified within 24 hours.

People who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer.

What is being done?

We are currently working on solutions to correct the problem. We anticipate resolving the problem in 2015. Our most recent individual sample results were all less than half the 80 µg/L standard, however since compliance is calculated using a locational running annual average (LRAA) of the most recent 4 quarters, we are still out of compliance with the MCL at 2 of 8 locations.

For more information, please contact Mr. Brent Wright at 517-787-6537 or the Flint Water Plant at 4500 North Dort Highway, Flint, MI 48505.

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by the City of Flint.

CERTIFICATION:

WSSN: 02310

I certify that this water supply has fully complied with the public notification requirements in the Michigan Safe Drinking Water Act, 1976 PA 399, as amended, and the administrative rules.

Signature

Title

Date Distributed

Reminder to water supplier: This notice / certification must be sent to the DEQ.

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Friday, February 27, 2015 3:11 PM
To: Hansen, Jeff
Cc: Prysby, Mike (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: DEQ-Laboratory Report-50201563

Jeff,

The Site codes listed by the City do not match that of their approved plan. We have properly aligned the sample results based on the site address to the DBP site code. We have notified the City of this issue previously but it has not been corrected.

Therefore, our results listings and calculations provided in my previous email are correct and should be used.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Hansen, Jeff [<mailto:jrhansen@lan-inc.com>]
Sent: Friday, February 27, 2015 2:34 PM
To: Busch, Stephen (DEQ)
Cc: Prysby, Mike (DEQ)
Subject: FW: DEQ-Laboratory Report-50201563

Steve,

Thanks for the table. Flint passed the info on to me earlier today.

I see a discrepancy between your table and Flint's records and we have used Flint's data in the report. I have double checked the lab results and I believe the error is on your end, but that is something to resolve. I've attached what I believe is correct. We have already printed and sent out the report since it is due to you guys Sunday. Samir is hand delivering and will probably be by soon.

Jeffrey R. Hansen
 Senior Project Manager



**Lockwood, Andrews
& Newnam, Inc.**
 A LEO A DALY COMPANY

1311 South Linden Road, Suite B • Flint, MI 48532
 T 810.820.2682 C 810.333.3201
www.lan-inc.com • JRHansen@lan-inc.com

From: Brent Wright [<mailto:bwright@cityofflint.com>]
Sent: Friday, February 27, 2015 9:43 AM
To: Hansen, Jeff
Subject: Fwd: DEQ-Laboratory Report-50201563

----- Forwarded message -----

From: **Michael Glasgow** <mglasgow@cityofflint.com>
Date: Fri, Feb 27, 2015 at 8:09 AM
Subject: Fwd: DEQ-Laboratory Report-50201563
To: Brent Wright <bwright@cityofflint.com>

Here are the DBP results. Everything is great, but this still leaves us in violation at 3 sites, as shown in the other attachment.

----- Forwarded message -----

From: **DEQ-DWR-LABREPORTS** <DEQ-DWR-LABREPORTS2@michigan.gov>
Date: Thu, Feb 26, 2015 at 4:43 PM
Subject: DEQ-Laboratory Report-50201563
To: "**MGLASGOW@CITYOFFLINT.COM**" <MGLASGOW@cityofflint.com>

Dear Drinking Water Laboratory Client,

A PDF file containing your analytical results has been attached to this e-mail.

Please do not reply directly to this e-mail. It is an automated account that does not respond to incoming messages.

Please contact the laboratory directly at (517) 335-8184 with questions regarding your report.

Thank you for using the MDEQ Drinking Water Laboratory.

--

Brent Wright
Water Plant Supervisor
City of Flint
4500 N. Dort Hwy.
Flint, MI. 48505
Ph: 810.787.6537 ext. 3510
Fx: 810.787.3710

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Friday, February 27, 2015 2:11 PM
To: Shekter Smith, Liane (DEQ); Benzie, Richard (DEQ); Wurfel, Brad (DEQ)
Cc: Prysby, Mike (DEQ); Rosenthal, Adam (DEQ)
Subject: Updated Flint TTHM Results
Attachments: FLINT TTHM RESULTS.docx

Updated TTHM results from Flint are attached, and are as we expected.

The highest sample individual result from February 2015 was 28.5 ppb, less than half the standard of 80 ppb.

The same two sites still exceed the LRAA MCL standard of 80 ppb due to high results from last summer, but the other 6 comply with the LRAA.

(FYI, if we were still under Stage 1 this wouldn't have ever been a standard violation, the RAA would have calculated out to 78 ppb.)

We are in the process of preparing a violation notice to the City and will have a copy to review and distribute to legislative members and other departments early next week.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

FLINT TTHM RESULTS

TTHM Results (mg/L)						
	5/21/14	8/21/14	11/20/14	2/17/15	LRAA	OEL
DBP1 McDonalds 3719 Davison	0.162	0.145	0.059	0.0162	0.096	0.059
DBP2 Liquor Palace 3302 S. Dort Highway	0.112	0.127	0.033	0.0168	0.072	0.049
DBP3 North Flint Auto 6204 N. Saginaw St.	0.097	0.118	0.041	0.0149	0.068	0.047
DBP4 University Market 2501 Flushing Road	0.106	0.196	0.094	0.0245	0.105	0.085
DBP5 Taco Bell 3606 Corunna Road	0.079	0.181	0.034	0.0151	0.078	0.063
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.088	0.144	0.054	0.0192	0.076	0.059
DBP7 Salem Housing 3216 MLK Boulevard	0.082	0.112	0.050	0.0285	0.068	0.055
DBP8 BP Gas Station 822 S. Dort Highway	0.075	0.112	0.036	0.0199	0.061	0.047

Rennaker, Joanne (DEQ)

From: Rosenthal, Adam (DEQ)
Sent: Friday, February 27, 2015 1:57 PM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: FW: Lead Copper Cert form
Attachments: 212 Browning Pb & Cu sample info.pdf

FYI

From: Michael Glasgow [<mailto:mglasgow@cityofflint.com>]
Sent: Friday, February 27, 2015 1:53 PM
To: Rosenthal, Adam (DEQ)
Subject: Re: Lead Copper Cert form

Adam,

Here is the copy of the lead & copper sample info from 212 Browning.

Mike

On Fri, Feb 27, 2015 at 1:26 PM, Michael Glasgow <mglasgow@cityofflint.com> wrote:
Adam,

Here are the 4th Qtr WQM results & the Lead & Copper Report. This hit for 104 ppb on lead come from the current 2015 monitoring period, I am attempting to get more samples from the neighbors around this site. This is a new Pb & Cu site, that was not sampled during the 2014 monitoring period.

Mike

On Fri, Feb 27, 2015 at 9:13 AM, Rosenthal, Adam (DEQ) <ROSENTHALA@michigan.gov> wrote:

Morning Mike, I need your lead/copper cert form – it was due by 1/10/15. I also need your 4th quarter WQPs for 2014. EPA is asking due to your 104 hit on lead. If you can, I need them today.

thanks,

Adam Rosenthal, EQA

MDEQ – Office of Drinking Water and Municipal Assistance

Lansing District – Constitution Hall 1SW

PO Box 30242

Lansing, MI 48909

517-284-6644

fax: 517-241-3571

For MORs, Lab Results & Reporting Forms:

DEQ-DWMA-Lansing@michigan.gov

Drinking Water Lead & Copper Sampling Instructions

Dear Resident:

Thank you for helping to monitor for lead and copper in the drinking water.

To get an accurate measurement of the lead or copper in the water, please collect your sample after the water has sat idle for 6 to 8 hours. DO NOT sample from a faucet that has not been used for an extended period of time such as a basement sink, guest bath or garden hose tap. DO NOT use taps that are connected to water softeners or point-of-use treatment devices.

1. The night before you collect the sample, turn on the COLD faucet of your kitchen or main bathroom sink and let it run for 3 to 4 minutes. If you have a single handle faucet, turn it to the COLD side.
2. Do not use the water for 6 to 8 hours.
3. In the morning, fill the sample bottle to the neck with the "first draw" of COLD water from the faucet that you flushed the previous night.
4. Please answer the following questions:

Did you run the water for 3 to 4 minutes the night before you filled the bottle? ☒ Yes ☐ No

What date and time in the evening did you run the water? Date 2/17/85 Time 11:30 P.M.

What date and time in the morning did you fill the bottle? Date 2/18/85 Time 7:15 A.M.

Did you fill the bottle from the faucet you flushed the night before? ☒ Yes ☐ No

If No, please explain: _____

Which faucet did you use to fill the bottle?

☒ Kitchen ☐ Main Bathroom ☐ Other

If Other, please describe: _____

Your Printed Name

Lee Anne Walters

Your Address

212 Browning Ave
Flint MI 48507

Your Signature

L Walters

5. Attach this form to the bottle and leave it outside your front door for pick-up.

If you have any questions call:

Or contact:

Water Supply: CITY OF FLINT WATER PLANT

Michigan Department of Environmental Quality

Manager or

Water Operator:

MIKE GREGG

DEQ contact:

Phone:

810-787-6537 ext. 3512

Phone:

Thanks again for your help. Information on this year's lead and copper monitoring will be printed in the Consumer Confidence Report that will be made available to you by July 1 of next year.

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Friday, February 27, 2015 1:48 PM
To: Crooks, Jennifer; Deltoral, Miguel
Cc: Rosenthal, Adam (DEQ); Poy, Thomas; Porter, Andrea; Prysby, Mike (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ)
Subject: RE: HIGH LEAD: FLINT Water testing Results

Miguel and Jennifer,

Thank you for this information, we will take it under consideration.

The City of Flint:

- Has a 90th percentile lead level of 6.0 ppb based on 100 samples collected in its most recent monitoring period of 7/1/2014 – 12/31/2014, with 2 samples (23 & 37 ppb) over the AL.
- Has a 90th percentile copper level of 110 ppb based on 100 samples collected in its most recent monitoring period of 7/1/2014 – 12/31/2014, with no samples over the Cu AL.
- Has an Optimized Corrosion Control Program
- Conducts quarterly Water Quality Parameter monitoring at 25 sites and has not had any unusual results.
- Has never had a 90th percentile lead AL exceedance
- Continues to meet all applicable plant tap standards and treatment technique requirements at its WTP
- Has developed and implemented an Operational Evaluation of its treatment and distribution systems, and continues to adjust and update this OE based on updated quarterly results

My understanding from Ben Grumbles and the LCR Short Term Revisions is that "EPA regulations require water systems to develop a targeted sampling pool, focused on those sites with the greatest risk of lead leaching. All compliance samples used to determine the 90th percentile must come from that sampling pool." [40 CFR 141.80(c)(1)], 56 Fed Reg. 26518 (June, 7, 1991), [40CFR 141.90(a)(1)(v), and 40 CFR 141.90(h)(2)]. Our office continues to work with our community water systems to follow these and all other requirements of the current lead and copper regulations.

212 Browning, the site in question, is not part of the City's established sample site pool. The residence consists of PVC plumbing materials, and has an iron pre-filter at the service connection.

Regarding TTHM, the most recent quarter monitoring from February 2015 was issued today by the lab. While 2 of the 8 DBP compliance sites continue to have an LRAA that exceeds the standard, quarterly results at all 8 DBP compliance sites were below less than half the standard level of 80 ppb, the highest being 28.5 ppb. Only one site now has an OEL over 80 ppb, at 85 ppb.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Friday, February 27, 2015 11:05 AM
To: Deltoral, Miguel; Prysby, Mike (DEQ)
Cc: Busch, Stephen (DEQ); Rosenthal, Adam (DEQ); Poy, Thomas; Porter, Andrea
Subject: Re: HIGH LEAD: FLINT Water testing Results

Hi, Steve and Mike. I talked with Miguel, and he said if you all would be interested in getting input from our expert, Mike Schock at EPA Cincinnati Research, on the Flint distribution system issues and dealing with lead and DBP's together, you should contact Mike directly--here is his information.

schock.michael@epa.gov

(513) 569-7412

Jennifer

From: Deltoral, Miguel

Sent: Friday, February 27, 2015 4:58 AM

To: Crooks, Jennifer; Prysby, Mike (DEQ)

Cc: Busch, Stephen (DEQ); Rosenthal, Adam (DEQ); Poy, Thomas; Schock, Michael; Porter, Andrea

Subject: Re: HIGH LEAD: FLINT Water testing Results

Jen/all - I think things got garbled in translation...

What I was saying is that where you find Pb values that high, it is usually due to particulate lead. Not always, but generally. Particulate lead is released sporadically from lead service lines, leaded solder and leaded brass in a number of ways and folks tend to discount these values as anomalies, but particulate lead release is a normal part of the corrosion process and it is universal (common) in all systems. It's just that it is not captured as often by the infrequent LCR sampling. If systems are pre-flushing the tap the night before collec on thisting LCR compliance samples (MDEQ still provides these instructions to public water systems) this clears particulate lead out of the plumbing and biases the results low by eliminating the highest lead values. If systems are pre-flushing and still finding particulate lead, the amount of particulate lead in the system can be higher than what is being detected using these 'pre-flushed' first-draw samples. My point on that was that people are exposed to the particulate lead on a daily basis, but the particulate lead is being flushed away before collecting compliance samples which provides false assurance to residents about the true lead levels in the water.

Some quick notes on particulate lead release:

- Fe/Mn can transport lead from the lead service lines into the home. The lead sorbs onto the Fe/Mn particles. In GW systems, Fe/Mn can come from the source water and more Fe from the water mains. In SW systems, the Fe typically is released from the water mains.
- Lead released from lead service lines can also 'seed' galvanized iron pipes inside the homes. Again, the lead sorbs onto the iron on the pipes and be released sporadically. Generally, the higher the flow, the more Fe and Fe+Pb particulate you will likely get.
- If there is a partial lead service line (lead connected to copper) you can get additional lead release due to galvanic corrosion.
- Leaded brasses and solder can also release particulate lead under certain circumstances.
- The particulate can contain very high concentrations of lead (hundreds to thousands of ppb Pb) which is a much higher concentration than lead paint, so even small particles can result in high lead values.
- If the lead service line was disturbed (water main repair/replacement, meter installation repair/replacement, service line leak repairs, etc.) you can have VERY high lead levels in the scale and sediment that is dislodged from the inside of lead service lines. Here in Chicago, during a partial lead service line replacement, we collected the scale and sediment that came into the home and we found 300,000+ ug/L lead in the scale; 125,000 ug/L Pb in the sediment. Very dangerous.
- Higher levels of PO4 (3-4 mg/L Ortho) seem to reduce the amount of particulate Pb that is released in the absence of physical disturbances to the lead lines. Doesn't stop it entirely, but should generally

reduce the occurrence. Caveat – Other water quality issues can change the chemical complexes that form on the pipe, so cleaner sources with more consistent WQ form more predictable scale complexes.

If I remember correctly, Detroit is feeding PO₄ for the LCR, but since Flint is no longer part of that interconnection, I was wondering what their OCCT was. They are required to have OCCT in place which is why I was asking what they were using.

Mike Schock is our resident expert and may be able to help out with the simultaneous compliance (Pb & DBPs) so I would suggest that folks give him a call.

Miguel A. Del Toral
Regulations Manager
U.S. EPA R5 GWDWB
77 West Jackson Blvd, (WG-15J)
Chicago, IL 60604
Phone: (312) 886-5253

From: Crooks, Jennifer
Sent: Thursday, February 26, 2015 04:15 PM
To: Prysby, Mike (DEQ)
Cc: Busch, Stephen (DEQ); Rosenthal, Adam (DEQ); Deltoral, Miguel; Poy, Thomas
Subject: HIGH LEAD: FLINT Water testing Results

Thank you, Mike. These results are dated 2/18/15, so they're probably different results than the results Adam had, but they still have to be included in with compliance calculation of the 90th percentile. What dates are the earlier compliance samples?

Yes, the stagnation of the water would increase the lead levels, and I'm glad you're following up with the City to get the lead levels reduced for Mrs. Walters' home—which will hopefully be effective for her neighbors because they are also most likely being exposed to these high lead levels. Miguel reminded me this morning, there are no safe levels of lead in drinking water.

I talked with Miguel Del Toral about his knowledge on research on lead. He said that high levels of iron, usually bring high levels of lead. The large amount of black sediment at Mrs. Walters' home, is most likely particulate lead, Miguel said, where the lead actually bonds to the iron sediment. While the particulates of lead/iron are small, they're very highly concentrated with lead—up to 95% lead.

Miguel was wondering if Flint is feeding Phosphates. Flint must have Optimal Corrosion Control Treatment—is it Phosphates? Or is it pH/Alkalinity Adjustment? The reason he asks, is because systems using the pH/Alkalinity adjustment have problems with lead levels in the 100's or higher—and they have problems with random lead particulate matter in the distribution system. Miguel said that we all know that flushing regularly helps reduce the lead concentrations, but not immediately. The City can't just flush in advance of taking the compliance samples, they have to flush the lines on a regular schedule.

The problem with high lead issues, is that the water has so many different variables, that it's hard to pinpoint what is causing what problem where. From a public health perspective, can we assume that the high lead levels in Mrs. Walters' neighborhood are isolated to just her area? Or are they more widespread?

Please feel free to contact Miguel directly—312-886-5253; Deltoral.miguel@epa.gov.

Jennifer

From: Prysby, Mike (DEQ) [mailto:PRYSBYM@michigan.gov]
Sent: Thursday, February 26, 2015 10:25 AM
To: Crooks, Jennifer
Cc: Busch, Stephen (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: HIGH LEAD: FLINT Water testing Results

Jennifer,

I recall Adam showing me a high lead/copper sample result (perhaps it was this one)....as part of the city's routine lead-copper monitoring. If so, it was a stagnated sample as part of the sampling protocol. Adam mentioned that all other samples were below the AL...and the city will not exceed the lead AL. I will confirm this. The city; however, needs to take further action to help address Ms. Walter's concern. The type of plumbing needs to be identified and sample tap location within the premise plumbing. They should offer to re-sample for PB after flushing the tap to demonstrate that flushing the tap will reduce the lead concentration. The city also needs to provide other lead-reduction strategies to Mrs. Walters.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Thursday, February 26, 2015 10:53 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Poy, Thomas; Deltoral, Miguel
Subject: HIGH LEAD: FLINT Water testing Results

Hi, Steve and Mike. Thanks for talking with me yesterday, Steve, about the most recent TTHM results. We'll look forward to receiving them whenever you get them back from the lab.

However, the main purpose of my email is to alert you to the high lead levels reported to a citizen yesterday by Flint Water Dept. I have been discussing the water situation with LeeAnn Walters since January, and she has been talking with Mike Glasgow at the plant about the black sediment in her water. (HUGE KUDOs to MIKE!!) He did test it to find that the iron levels were greater than his test would go; GT 3.3. But, because the iron levels were so high, he suggested testing for lead and copper. WOW!!!! Did he find the LEAD! **104 ppb**. She has 2 children under the age of 3... Big worries here.

So, Steve, this goes back to what you and I were talking about yesterday. That the different chemistry water is leaching out contaminants from the insides of the biofilms inside the pipes. I think Lead is a good indication that other contaminants are also present in the tap water, that obviously were not present in the compliance samples taken at the plant. VOC/SOC and inorganics/metals would be good samples to start with to take at the tap. And since Ms. Walters' drinking water is showing the high lead levels, her tap water would be a good place to start, I think.

We also talked about Dr. Joan Rose from Michigan State being on the Flint Tech Advisory Committee—you also mentioned that someone from the Dept of Community Health was on the Committee. I'm thinking that Dr. Rose would want to dive further into this, since there's actual evidence that the water is leaching contaminants from the biofilms; or

Dept of Community Health would want to get involved and look at this from an epidemiological perspective. (She and her family are also exhibiting the rashes when exposed to the water, and her daughter's hair is falling out in clumps.)

Maybe MSU could authorize the payment of the analyses for these samples? Or Dept of Community Health?

The citizen's name is:

LeeAnn Walters
212 Browning Ave
Flint, MI 48507
616-212-6233
Lwalters313@gmail.com

Jennifer

From: Lea Moste [<mailto:lwalters313@gmail.com>]
Sent: Thursday, February 26, 2015 9:08 AM
To: Crooks, Jennifer
Subject: Fwd: Re: Water testing Results

----- Forwarded message -----

From: "Michael Glasgow" <mglasgow@cityofflint.com>
Date: Feb 26, 2015 7:55 AM
Subject: Re: Water testing Results
To: "Lea Moste" <lwalters313@gmail.com>
Cc:
Lee,

Here are your Lead & Copper Results. This number is very high, 104 ppb of lead. In the last few months over 100 samples have been tested and only 2 were over the 15 ppb regulatory limit, and the highest level I have seen is 37 ppb. I will pass this info to Mr. Croft so he is aware. I will send the sample I collected from your kitchen faucet today for a complete metals test (12 different metals), to see what the level is without letting the water stagnate over night. I'm hoping that value will be much, but we will have to see. Sorry for this news, but I wanted to let you know right away.

Mike

On Tue, Feb 24, 2015 at 1:50 PM, Michael Glasgow <mglasgow@cityofflint.com> wrote:

Lee,

I will bring a copy of last years annual report when I stop by tomorrow. The annual report from 2014 must be delivered to residents by July 1st of this year. I imagine we may have it complete by June.

Mike

On Fri, Feb 20, 2015 at 1:00 AM, Lea Moste <lwalters313@gmail.com> wrote:

Mike,

Thank you for the water reports and we already planned to see you on the 25th at 10:00am. I was wondering if you know who I need to talk to in the water plant to obtain the Annual Drinking Water Report from last year. According to the EPA website there is link to access but when you click on it, it cannot be accessed.

Was also curious if there is an expected time frame for this years report due to the switch. If you can be of any assistance I would appreciate it.

Thank You
LeeAnne Walters

On Thu, Feb 19, 2015 at 12:47 PM, Michael Glasgow <mglasgow@cityofflint.com> wrote:

Lee & Dennis,

Here is a list of test results from water sampled at your home over the last 2 weeks. I have sent in your lead and copper sample, and also a sample from the toilet tank for manganese. I should hopefully have results from this testing early next week. I'll plan on stopping over on Wednesday (the 25th) around 10 am again to give you these results & sample again.

Mike

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Friday, February 27, 2015 10:26 AM
To: Brent Wright; Daugherty Johnson; Dayne Walling; donna.cole; gdn2@aol.com; Howard Croft; James Henry; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Laura Sullivan; mgavuli1@hurleymc.com; Michael Glasgow; Mike Lane; Prysby, Mike (DEQ); Natasha Henderson; Pete Levine; rob.nicholas@veolia.com; rosejo@msu.edu; Russell Hudson; Samir Matta; Warren Green; jmikewright
Subject: First Technical Team Meeting
Attachments: TAC Invitation Letter.pdf

Technical Team Members,

This is a reminder of our first meeting date next Wednesday March 4th at Flint City Hall at 2:00 - 4:00 pm. Please bring any questions or goals that you would like to see developed out of the group as we will create the final overarching agenda in the committee.

On a side note, our February TTHM test results were returned from the state lab this morning and all eight test sites are substantially below the MCL.

I look forward to seeing everyone on Wednesday.

Regards,

--

Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com



CITY OF FLINT

Department of Public Works

Dayne Walling
Mayor

Gerald Ambrose
Emergency Manager

Howard Croft
Director

Technical Advisory Committee Members,

On behalf of the City of Flint, I want to thank you for your willingness to participate in the City of Flint Technical Water Advisory Committee. This committee was formed to address many of the issues related to water that have arisen in our community over the past 10 months.

The first meeting is scheduled for Wednesday March 4th, 2015 from 2:00 – 4:00 pm at Flint City Hall. At our first meeting we will hear an overview from the engineer of record Lockwood Andrews & Newnam, and a review of the assessment findings and recommendations from our consultant Veolia North America.

We welcome the addition of a USEPA Representative that will be present at the first meeting as well as our other distinguished participants. For those that cannot be present in person we have established the ability to participate via a conference line.

For conference access please call 1-302-202-1102 conference number 724414.

Regards,

Howard D. Croft
Public Works Director
City of Flint

Rennaker, Joanne (DEQ)

From: Hansen, Jeff <jrhansen@lan-inc.com>
Sent: Friday, February 27, 2015 8:40 AM
To: Prysby, Mike (DEQ)
Subject: Flint Lab Results

Hi Mike,

Do you know if the DEQ lab has gotten Flint THM / HAA5 results yet? Flint has not seen anything yet but they said you normally see the results before they do.

Jeffrey R. Hansen

Senior Project Manager



**Lockwood, Andrews
& Newnam, Inc.**

A LEO A DALY COMPANY

1311 South Linden Road, Suite B • Flint, MI 48532

T 810.820.2682 C 810.333.3201

www.lan-inc.com • JRHansen@lan-inc.com

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Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Thursday, February 26, 2015 11:25 AM
To: Crooks, Jennifer
Cc: Busch, Stephen (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: HIGH LEAD: FLINT Water testing Results

Jennifer,

I recall Adam showing me a high lead/copper sample result (perhaps it was this one)....as part of the city's routine lead-copper monitoring. If so, it was a stagnated sample as part of the sampling protocol. Adam mentioned that all other samples were below the AL...and the city will not exceed the lead AL. I will confirm this. The city; however, needs to take further action to help address Ms. Walter's concern. The type of plumbing needs to be identified and sample tap location within the premise plumbing. They should offer to re-sample for PB after flushing the tap to demonstrate that flushing the tap will reduce the lead concentration. The city also needs to provide other lead-reduction strategies to Mrs. Walters.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Thursday, February 26, 2015 10:53 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Poy, Thomas; Deltoral, Miguel
Subject: HIGH LEAD: FLINT Water testing Results

Hi, Steve and Mike. Thanks for talking with me yesterday, Steve, about the most recent TTHM results. We'll look forward to receiving them whenever you get them back from the lab.

However, the main purpose of my email is to alert you to the high lead levels reported to a citizen yesterday by Flint Water Dept. I have been discussing the water situation with LeeAnn Walters since January, and she has been talking with Mike Glasgow at the plant about the black sediment in her water. (HUGE KUDOs to MIKE!!) He did test it to find that the iron levels were greater than his test would go; GT 3.3. But, because the iron levels were so high, he suggested testing for lead and copper. WOW!!!! Did he find the LEAD! **104 ppb**. She has 2 children under the age of 3... Big worries here.

So, Steve, this goes back to what you and I were talking about yesterday. That the different chemistry water is leaching out contaminants from the insides of the biofilms inside the pipes. I think Lead is a good indication that other contaminants are also present in the tap water, that obviously were not present in the compliance samples taken at the plant. VOC/SOC and inorganics/metals would be good samples to start with to take at the tap. And since Ms. Walters' drinking water is showing the high lead levels, her tap water would be a good place to start, I think.

We also talked about Dr. Joan Rose from Michigan State being on the Flint Tech Advisory Committee—you also mentioned that someone from the Dept of Community Health was on the Committee. I'm thinking that Dr. Rose would want to dive further into this, since there's actual evidence that the water is leaching contaminants from the biofilms; or Dept of Community Health would want to get involved and look at this from an epidemiological perspective. (She and her family are also exhibiting the rashes when exposed to the water, and her daughter's hair is falling out in clumps.)

Maybe MSU could authorize the payment of the analyses for these samples? Or Dept of Community Health?

The citizen's name is:

LeeAnn Walters
212 Browning Ave
Flint, MI 48507
616-212-6233
Lwalters313@gmail.com

Jennifer

From: Lea Moste [<mailto:lwalters313@gmail.com>]
Sent: Thursday, February 26, 2015 9:08 AM
To: Crooks, Jennifer
Subject: Fwd: Re: Water testing Results

----- Forwarded message -----

From: "Michael Glasgow" <mglasgow@cityofflint.com>
Date: Feb 26, 2015 7:55 AM
Subject: Re: Water testing Results
To: "Lea Moste" <lwalters313@gmail.com>
Cc:

Lee,

Here are your Lead & Copper Results. This number is very high, 104 ppb of lead. In the last few months over 100 samples have been tested and only 2 were over the 15 ppb regulatory limit, and the highest level I have seen is 37 ppb. I will pass this info to Mr. Croft so he is aware. I will send the sample I collected from your kitchen faucet today for a complete metals test (12 different metals), to see what the level is without letting the water stagnate over night. I'm hoping that value will be much, but we will have to see. Sorry for this news, but I wanted to let you know right away.

Mike

On Tue, Feb 24, 2015 at 1:50 PM, Michael Glasgow <mglasgow@cityofflint.com> wrote:

Lee,

I will bring a copy of last years annual report when I stop by tomorrow. The annual report from 2014 must be delivered to residents by July 1st of this year. I imagine we may have it complete by June.

Mike

On Fri, Feb 20, 2015 at 1:00 AM, Lea Moste <lwalters313@gmail.com> wrote:

Mike,

Thank you for the water reports and we already planned to see you on the 25th at 10:00am. I was wondering if you know who I need to talk to in the water plant to obtain the Annual Drinking Water Report from last year. According to the EPA website there is link to access but when you click on it, it cannot be accessed. Was also curious if there is an expected time frame for this years report due to the switch. If you can be of any assistance I would appreciate it.

Thank You
LeeAnne Walters

On Thu, Feb 19, 2015 at 12:47 PM, Michael Glasgow <mglasgow@cityofflint.com> wrote:

Lee & Dennis,

Here is a list of test results from water sampled at your home over the last 2 weeks. I have sent in your lead and copper sample, and also a sample from the toilet tank for manganese. I should hopefully have results from this testing early next week. I'll plan on stopping over on Wednesday (the 25th) around 10 am again to give you these results & sample again.

Mike

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From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Thursday, February 26, 2015 10:53 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Poy, Thomas; Deltoral, Miguel
Subject: HIGH LEAD: FLINT Water testing Results
Attachments: 212 Browning (Pb & Cu).pdf; Flint Technical Advisory Team List_R1.pdf

Hi, Steve and Mike. Thanks for talking with me yesterday, Steve, about the most recent TTHM results. We'll look forward to receiving them whenever you get them back from the lab.

However, the main purpose of my email is to alert you to the high lead levels reported to a citizen yesterday by Flint Water Dept. I have been discussing the water situation with LeeAnn Walters since January, and she has been talking with Mike Glasgow at the plant about the black sediment in her water. (HUGE KUDOs to MIKE!!) He did test it to find that the iron levels were greater than his test would go; GT 3.3. But, because the iron levels were so high, he suggested testing for lead and copper. WOW!!!! Did he find the LEAD! **104 ppb**. She has 2 children under the age of 3... Big worries here.

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Mike

Consumer Notice of Lead & Copper Results in Drinking Water

Water Supply Name: City of Flint

County: Genesee WSSN: 2310

Sample Location: 212 Browning Date Sampled: 2/18/2015

Thank you for participating in the lead and copper monitoring of drinking water. The levels of lead and copper found at your location are in the table below.

Key to Table	Contaminant	AL	MCLG	Your Result
Action Level (AL): The concentration of a contaminant which, if exceeded, triggers treatment or other requirements that a water system must follow. Maximum Contaminant Level Goal (MCLG): The level of a contaminant in drinking water which there is no known or expected risk to health. MCLG's allow for a margin of safety. ppb: parts per billion or micrograms per liter.	Lead (ppb)	15	0	104
	Copper (ppb)	1300	1300	Not Detected

Lead can cause serious health problem if too much enters your body from drinking water or other sources. It can cause damage to the brain and kidneys, and it can interfere with the production of red blood cells that carry oxygen to all parts of your body. The greatest risk of lead exposure is to infants, young children, and pregnant women. Scientists have linked the effects on the brain with lower IQ in children. Adults with kidney problems and high blood pressure can be affected by low levels of lead more than healthy adults. Lead is stored in the bones, and can be released later in life. During pregnancy, the child receives lead from the mother's bones, which may affect brain development.

To reduce exposure to lead in drinking water:

- *Run your water to flush out lead.* Run the water until it becomes cold.
- *Use cold water for cooking and preparing baby formula.* Do not cook with or drink water from the hot tap; lead dissolves more easily in hot water.
- *Do not boil water to remove lead.* Boiling water will not reduce lead levels.
- *Look for an alternative sources or treatment of water.* If your lead result is above 15 ppb, you may want to consider purchasing bottled water or a water filter. Read the package to be sure the filter is approved to reduce lead or contact NSF International at 800-NSF-8010, or www.nsf.org for information on performance standards for water filters.
- *Identify if your plumbing fixtures contain lead.* New faucets, fittings, and valves, may contain up to 8 percent lead including those advertised as lead-free" and may contribute lead to drinking water. Consumers should be aware of this when choosing fixtures and take appropriate precautions.

Although the primary sources of lead exposure for most children are deteriorating lead-based paint, lead-contaminated dust, and lead contaminated soil, the U.S. EPA estimates that 10 to 20 percent of human exposure to lead may come from drinking water.

For more information, contact us at: **City of Flint Water Plant (810)787-6537.**

For more information on reducing lead exposure around your home and the health effects of lead, visit the U.S. EPA's Web site at www.epa.gov/lead, call the National Lead Information Center at 800-424-LEAD, or contact your health care provider.

**MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY
DRINKING WATER LABORATORY**

USEPA Region V Drinking Water Cert. No. MI00003

P.O. Box 30270

Lansing, MI 48909

TEL: (517) 335-8184

FAX: (517) 335-8562

Sample Number

LF54945

Official Laboratory Report

Report To: **MIKE GLASGOW**
4500 N DORT HWY
FLINT MI 48505

System Name/Owner: **CITY OF FLINT**
Collection Address: **212 BROWNING AVE, FLINT**
Collected By: **LEANNE WALTERS**
Township/Well#/Section: **//**
County: **Genesee**
Sample Point: **KITCHEN**
Water System: **Treated Public Distribution System**

WSSN/Pool ID: **2310**
Source: **TYPE I**
Site Code:
Collector: **Private Citizen**
Date Collected: **02/18/2015 07:15**
Date Received: **02/19/2015 11:13**
Purpose: **Routine Monitoring**

TESTING INFORMATION			REGULATORY INFORMATION			
Analyte Name	Result (mg/L)	Date Tested	RL (mg/L)	MCL/AL (mg/L)	Method	CAS #
Copper	Not detected	02/20/2015	0.05	1.3	EPA 200.8	7440-50-8
Lead	0.104	02/20/2015	0.001	0.015	EPA 200.8	7439-92-1

The analyses performed by the MDEQ Drinking Water Laboratory were conducted using methods approved by the U. S. Environmental Protection Agency in accordance with the Safe Drinking Water Act, 40 CFR parts 141-143, and other regulatory agencies as appropriate.

Your local health department has detailed information about the quality of drinking water in your area. If you have concerns about the health risks related to the test results of your sample, please contact the Environmental Health Section through the address and telephone number listed below:

Genesee County Health Dept.
630 South Saginaw
Flint, MI 48502-1540
810 257-3603

CAS#: Chemical Abstract Service Registry Number
MCL : Maximum Contaminant Level
AL : Action Level
RL : Reporting Limit

mg/L : milligrams / Liter (ppm)
ppm : parts per million
MPN : Most Probable Number
CFU : Colony Forming Unit

Laboratory Contacts
Drinking Water Unit Mgr: Julia Pieper
Systems Mgmt. Unit Mgr: George Kriszlian

City of Flint / Veolia Technical Advisory Committee

	COMPANY	NAME	TITLE	PHONE	DESIGNEE	CONTACT INFO	
1	General Motors	Randy Tanner	Head of Engineering	810-577-8552			Yes
2	MSU - Lansing	Dr. Joan Rose	Chair in Water Research	517-432-4412	Dr. Joan Rose	rosejo@msu.edu	Yes
3	Greater Flint Health Coalition	Kirk Smith	President	810-232-2228	Kirk Smith	ksmith@flint.org	Yes
4	County Drain Commissioner	Jeff Wright	Deputy Drain Commissioner	810-732-7870	John O'Brien	jfobrien@gcdcwws.com	Yes
5	U of M Flint	Michael Lane	Dir. Environmental Health & Safety	810-766-6763	Michael Lane	mjlane@umflint.edu	Yes
6	Mott Community	Larry Kohler	Executive Director		Larry Koehler	larry.koehler@mcc.edu	Yes
7	Genesys Pace Hospital	Donna Cole	Property Manager	810-606-5611	Donna Cole	donna.cole@genesys.org	Yes
8	Hurley Hospital	Melanie Gavulic	President / CEO		Norb Birchmier	mgavuli1@hurleymc.com	Yes
9	McLaren Hospital	Don Kooy	President / CEO		Russell Hudson	don.kooy@mclaren.org	Yes
10	Genesee County Medical Society	Pete Levine	Executive Director	810-733-9925	Gerald Natzke	plevine@gcms.org	Yes
11	Dept. of Environmental Quality	Mike Prysby	District Supervisor	517-290-8817	Mike Prysby	prysbym@michigan.gov	Yes
12	Genesee Health Department	Jim Henry			Jim Henry	jhenry@gchd.com	Yes
	City of Flint	Howard Croft	DPW Director	810-577-1202	Howard Croft	hcroft@cityofflint.com	Yes
	City of Flint	Daugherty Johnson	Utilities Administrator	810-577-8906	Duffy Johnson	djohnson@cityofflint.com	Yes
	City of Flint	Brent Wright	Plant Supervisor	810-787-6537	Brent Wright	bwright@cityofflint.com	Yes
	City of Flint	Mike Glasgow	Asstant Plant Supervisor		Mike Glasgow	mglasgow@cityofflint.com	Yes

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Wednesday, February 25, 2015 12:32 PM
To: Crooks, Jennifer; Prysby, Mike (DEQ)
Subject: RE: results from recent Flint TTHM samples?

Jennifer,

As we discussed on the phone, samples are at the lab now, but no results yet. I will pass them along as soon as we have them.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

From: Crooks, Jennifer [<mailto:crooks.jennifer@epa.gov>]
Sent: Wednesday, February 25, 2015 12:19 PM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Subject: results from recent Flint TTHM samples?
Importance: High

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From: Howard Croft <hcroft@cityofflint.com>
Sent: Wednesday, February 25, 2015 10:18 AM
To: Brent Wright; Daugherty Johnson; Dayne Walling; donna.cole; gdn2@aol.com; Howard Croft; James Henry; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; Laura Sullivan; mgavuli1@hurleymc.com; Michael Glasgow; Mike Lane; Prysby, Mike (DEQ); Pete Levine; rob.nicholas@veolia.com; rosejo@msu.edu; Russell.Hudson@mclaren.org
Cc: Elizabeth Murphy; Jerry Ambrose; Natasha Henderson
Subject: City TAC Team First Meeting

Team,

We have scheduled next Wednesday March 4th as the first meeting date for the City's Technical Advisory Committee. The meeting will be at City Hall at 2:00 PM and we will have a conference number available for those who cannot make it in person.

I will be sending out an official letter along with an agenda but wanted to give everyone an opportunity to get the time and date on their calendar.

Thank you all for your participation,

--

Howard Croft
 Public Works Director
 City of Flint
 1101 S. Saginaw Street
 Flint, MI 48502
 PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Benzie, Richard (DEQ)
Sent: Tuesday, February 24, 2015 8:58 PM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ); Shekter Smith, Liane (DEQ)
Subject: Re: Emergency Service Contract

Nice summary Mike. Thanks for the update.

Sent using OWA for iPhone

From: Prysby, Mike (DEQ)
Sent: Tuesday, February 24, 2015 4:04:25 PM
To: Busch, Stephen (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ)
Subject: Emergency Service Contract

Attached is Article 5 of the Back-Up Water Agreement between Genesee County and the City of Flint. The agreement primarily spells out emergency water service from Flint to GCDC; however Article V establishes the protocol in the event that emergency water service is provided to Flint from GCDC. The appendices (included in the attachment) lists the available interconnections on the west side of the city.

Based upon further discussion with the city....

1. The city has made some ground today – repaired several main breaks (including a large break), and adding approx 2 MGAL of water to the city's storage facilities- Westside Reservoir
2. The west-side interconnections between Flint and GCDC have not been opened; however, the city and GCDC have completed preparations and the connections can be opened at the request of the city in accordance to the criteria set forth in Article V of the Back-up Water Agreement.
3. The city has requested customers (radio announcement) do discontinue "let-runs" to help reduce demands. Today's production rate is approximately 24 MGD – down from 27 MGD noted yesterday.
4. We will be contacted, as needed, for updates or technical assistance.

I will be in the field tomorrow; however, I will remain available via my I-phone for further discussions, as needed, with Flint and Genesee County concerning this situation. Any important updates will be passed on to you.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance

517 290-8817

Rennaker, Joanne (DEQ)

From: Hansen, Jeff <jrhansen@lan-inc.com>
Sent: Tuesday, February 24, 2015 4:14 PM
To: Prysby, Mike (DEQ)
Subject: THM Violation
Attachments: EPA-EOR-guidance-exerpt.pdf

Mike,

You told me that when a community had a full year of samples, the full year average is used as the OEV, but I don't see that in the guidance document anywhere. The EPA guidance document seems to say that the OEV is always calculated using 3 quarts of data, with the current quarter counted twice. See attached. Am I missing something?

Jeffrey R. Hansen
Senior Project Manager



**Lockwood, Andrews
& Newnam, Inc.**
A LEO A DALY COMPANY

1311 South Linden Road, Suite B • Flint, MI 48532
T 810.820.2682 C 810.333.3201
www.lan-inc.com • JRHansen@lan-inc.com

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1. Introduction

This chapter covers:

- 1.1 Purpose and Scope
- 1.2 Who Must Comply with the Operational Evaluation Requirements of the Stage 2 DBPR?
- 1.3 What Is an Operational Evaluation Level Exceedance?
- 1.4 What Are the Requirements If the Operational Evaluation Level Is Exceeded?
- 1.5 When Do the Operational Evaluation Requirements Take Effect?
- 1.6 Organization of this Guidance Manual
- 1.7 Additional Resources

The Environmental Protection Agency (EPA) promulgated the Stage 2 Disinfectants and Disinfection ByProducts Rule (DBPR) in January 2006. The Stage 2 DBPR provides for increased protection against the potential risks for cancer and reproductive and developmental health effects associated with disinfection byproducts (DBP). The Stage 2 DBPR establishes maximum contaminant level goals for chloroform, monochloroacetic acid and trichloroacetic acid; maximum contaminant levels (MCLs), based on a locational running annual average (LRAA)¹, for total trihalomethanes (TTHM) and haloacetic acids (HAA5); monitoring, reporting, and public notification requirements based on the TTHM and HAA5 MCLs; and revisions to the reduced monitoring requirements for bromate. The complete Stage 2 DBPR can be found at <http://www.epa.gov/safewater/disinfection/stage2/regulations.html>.

The Stage 2 DBPR also establishes operational evaluation requirements that are initiated by the TTHM and HAA5 levels found during Stage 2 DBPR compliance monitoring. Compliance with Stage 2 DBPR MCLs is based on the average of four individual quarterly DBP measurements collected at a given location (i.e., LRAA). However, a system that is in compliance with the Stage 2 DBPR MCLs, based on the LRAA, at a location may still have individual (i.e., not averaged) DPB measurements at that location that exceed the Stage 2 DBPR MCLs. EPA and the Stage 2 Microbial/Disinfection Byproducts (M/DBP) Advisory Committee were concerned about these higher levels of DBPs. The Stage 2 DBPR operational evaluation requirements were established to address these concerns.

The Stage DBPR requires systems to conduct operational evaluations, initiated by the operational evaluation levels (OEL) found in Stage 2 DBPR compliance monitoring, and to submit an operational evaluation report to the State. The OELs are determined with an algorithm, described later in this section, based on Stage 2 monitoring results. The OELs initiate a comprehensive review of system operations and act as an early warning for a possible Stage 2 DBPR violation in the following quarter. This early warning allows systems to act to prevent the violation. The Stage DBPR process for initiating an operational evaluation is not based on health effects information. **The operational evaluation requirements of the Stage 2 DBPR are**

¹ The Stage 2 DBPR requires systems to meet an LRAA of 0.080 mg/L for TTHM and 0.060 mg/L for HAA5 at each compliance monitoring location (40 CFR 141.620 (d)).

intended as an indicator of operational performance and to allow systems to take proactive steps to remain in compliance with the Stage 2 DBPR MCLs.

1.1 Purpose and Scope

EPA has developed this manual to provide guidance to water systems on identifying TTHM and HAA5 peaks and conducting operational evaluations to determine the cause(s) of and reduce such peaks, and to assist States in implementing the Stage 2 operational evaluation requirements and in reviewing operational evaluation reports. The specific objectives of this manual are to:

- Describe an OEL exceedance.
- Summarize regulatory requirements for addressing an OEL exceedance.
- Provide guidance for documenting and reporting an OEL exceedance.
- Provide a methodology for identifying the cause of an OEL exceedance.
- Present options available to reduce TTHM and HAA5 concentrations in the distribution system to minimize a future OEL exceedance.

The options presented to reduce TTHM and HAA5 concentrations in the distribution system to minimize future OEL exceedances are intended to assist systems in meeting their operational evaluation requirements and to assist States in reviewing operational evaluation reports. **An OEL exceedance requires an operational evaluation meeting specific criteria and reporting of the evaluation to the State, but does not require systems to take corrective actions. The operational evaluation and report will provide valuable information to both the system and the State.** This guidance manual focuses on common surface and ground water and treatment processes that affect formation of TTHM and HAA5. References are provided throughout the document to help you optimize other treatment processes. You should also consider contacting your State to discuss your particular system needs and concerns.

1.2 Who Must Comply with the Operational Evaluation Requirements of the Stage 2 DBPR?

All community water and non-transient non-community water systems that use a primary or residual disinfectant other than ultraviolet light (UV), or that deliver water that has been treated with a primary or residual disinfectant other than UV, must comply with the Stage 2 DBPR MCLs for TTHM and HAA5 and the Stage 2 DBPR operational evaluation requirements. This includes consecutive systems delivering water that has been treated with a primary or residual disinfectant other than UV. If you are one of these systems, you must comply with the operational evaluation requirements of the Stage 2 DBPR if you meet both of the following criteria:

- 1) You are required to conduct compliance monitoring for the Stage 2 DBPR; and

- 2) You collect Stage 2 DBPR compliance samples **quarterly**. If you are on annual monitoring, you are not subject to the operational evaluation requirements of the Stage 2 DBPR. If you are required to increase Stage 2 monitoring to quarterly (§141.625), you are also required to meet the operational evaluation requirements.

1.3 What Is an Operational Evaluation Level Exceedance?

The Stage 2 DBPR states that a system exceeds the OEL if one of the following occurs at any compliance monitoring location (40 CFR 141.626(a)):

- TTHM compliance monitoring results for the two previous quarters plus two times the TTHM result for the current quarter, divided by 4, exceeds 0.080 milligrams per liter (mg/L); or
- HAA5 compliance monitoring results for the two previous quarters plus two times the HAA5 result for the current quarter, divided by 4, exceeds 0.060 mg/L.

You can use the formula below to determine if you have an OEL exceedance. Example 1.1 shows how this formula can be used with distribution system TTHM and HAA5 data.

Formula for Determining if You Have an OEL Exceedance

For both TTHM and HAA5 and for each compliance monitoring location, calculate the following:

$$(A + B + (2 * C)) / 4 = D$$

Where:

- A = TTHM or HAA5 result for the quarter before the previous quarter (mg/L)
 B = TTHM or HAA5 result for the previous quarter (mg/L)
 C = TTHM or HAA5 result for the current quarter (mg/L)
 D = your **Operational Evaluation Value** (mg/L)

If D for TTHM is > 0.080 mg/L, you have an OEL Exceedance

If D for HAA5 is > 0.060 mg/L, you have an OEL Exceedance

Example 1.1 Determining If There Is an OEL Exceedance

A system is conducting Stage 2 compliance monitoring at four locations. TTHM and HAA5 data from the previous two quarters (February and May) and the current quarter (August) are presented below.

TTHM Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Value:
	A	B	C	$D = (A+B+(2 \times C))/4$
#1	0.065 mg/L	0.074 mg/L	0.087 mg/L	0.078 mg/L
#2	0.064 mg/L	0.072 mg/L	0.084 mg/L	0.076 mg/L
#3	0.068 mg/L	0.075 mg/L	0.093 mg/L	0.082 mg/L
#4	0.066 mg/L	0.070 mg/L	0.082 mg/L	0.075 mg/L

HAA5 Data

Stage 2 DBPR Location	February	May	August	Operational Evaluation Value:
	A	B	C	$D = (A+B+(2 \times C))/4$
#1	0.033 mg/L	0.041 mg/L	0.050 mg/L	0.044 mg/L
#2	0.042 mg/L	0.048 mg/L	0.055 mg/L	0.050 mg/L
#3	0.037 mg/L	0.043 mg/L	0.046 mg/L	0.043 mg/L
#4	0.043 mg/L	0.045 mg/L	0.052 mg/L	0.048 mg/L

In August, the system exceeds the OEL at **location #3** because the TTHM value in column D exceeds the OEL (0.080 mg/L).

1.4 What Are the Requirements If the Operational Evaluation Level is Exceeded?

If the OEL is exceeded, you **must** take the following actions (40 CFR 141.626(b)):

- 1) Conduct an operational evaluation to determine the cause of the exceedance(s).
- 2) Submit a written report of the evaluation to the State no later than 90 days after being notified of the analytical result that caused the exceedance(s).
- 3) Keep a copy of the operational evaluation report and make it available to the public upon request.

An OEL exceedance *is not* a violation of the Stage 2 DBPR. However, failure to submit an evaluation report to the State in the required time frame is a violation and requires Tier 3 public notice (as required by the Public Notification Rule). All Stage 2 DBPR compliance monitoring results must be included in the system's Consumer Confidence Report (CCR). There are no additional CCR requirements related to an OEL exceedance unless the system is in violation due to failure to complete and submit an evaluation report.

The operational evaluation must include an examination of system treatment and distribution operational practices that may contribute to TTHM and HAA5 formation including:

- Storage tank operations,
- Excess storage capacity,
- Distribution system flushing,
- Sources of supply and source water quality, and
- Treatment processes and finished water quality.

The operational evaluation must also include what steps could be considered to minimize future exceedances (40 CFR 141.626(b)(2)).

The system may request and the State may allow a limited scope of the operational evaluation if the system is able to identify the cause of the OEL exceedance to the State's satisfaction. The State **must** then approve the limited scope of the evaluation in writing and the system **must** keep the written approval with the completed report. Note that submitting this request **will not** extend the 90 day deadline for submitting the operational evaluation report.

Exhibit 1.1 presents a flow chart with the operational evaluation rule requirements.

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Tuesday, February 24, 2015 12:55 PM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ); Benzie, Richard (DEQ)
Cc: Shekter Smith, Liane (DEQ)
Subject: FYI: Flint Michigan control 2-20-15
Attachments: Flint Michigan Control 22015.pdf

You'll receive a hard copy, too.
Jen

From: Sulej, Erik
Sent: Friday, February 20, 2015 12:34 PM
To: Crooks, Jennifer; Murphy, Thomas
Subject: Flint Michigan control 2-20-15

Here is a copy for your records. Everything went out today.

Have great weekend!

Erik S. Sulej
Ground Water and Drinking Water Branch
U.S. Environmental Protection Agency, Region 5
77 W. Jackson Blvd (WG-15J), Chicago, IL 60604
Phone: (312) 886-3473 / Email: sulej.erik@epa.gov



UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

FEB 20 2015

REPLY TO THE ATTENTION OF:

WG-15J

Mrs. Stephanie Pumfrey
4071 Mitchell Drive
Flint, Michigan 48506

Dear Mrs. Pumfrey:

Thank you for your January 9, 2015 email to President Obama concerning the quality of the drinking water in the City of Flint, Michigan. Your email was forwarded to me for a response, since the City of Flint's municipal water supply is located within the geographical boundaries of the Region 5 office of the U.S. Environmental Protection Agency.

To summarize the background of your concerns with the City of Flint's drinking water, the source of drinking water for the City of Flint was changed from Detroit (which comes from Lake Huron) to the Flint River at the end of April 2014. The quality of the water in the Flint River is different than that from Lake Huron; and requires additional treatment to ensure an acceptable quality drinking water. The Michigan Department of Environmental Quality (MDEQ) has been working closely with the Operator-in-Charge at the City of Flint's Water Treatment plant to ensure that the citizens of Flint are provided drinking water that meets health standards. As you stated in your letter, the use of Flint River water as a source for your drinking water is an interim source. The City of Flint plans to connect to the Karegnondi pipeline, which will draw water from Lake Huron, in 2016.

My staff contacted the MDEQ District Supervisor for the Lansing District, Steve Busch, to discuss the City of Flint's drinking water issues. Mr. Busch is aware of the multiple complaints from citizens. He and his staff are working closely with the City of Flint's Water Department to ensure the distribution system and the water treatment processes work more efficiently and effectively. The most recent laboratory analyses obtained from MDEQ of the City of Flint's drinking water indicate that almost all regulated contaminants meet State and Federal health standards, as required under the Federal and Michigan Safe Drinking Water Acts. It is true that the City of Flint exceeded the maximum contaminant levels (MCL) for *E. coli* in August 2014, for total coliform bacteria in September 2014, and total trihalomethanes (TTHM) in the fourth quarter of 2014. The City of Flint conducted the proper follow-up to these violations as required by Federal and State regulations. The City of Flint has returned to compliance the two bacteria MCL violations that occurred in August and September 2014.

The TTHM violation is based upon the average of data from four quarters for each sampling location. The initial monitoring in early summer reported significantly elevated levels of TTHM compounds throughout the City's distribution system. The MDEQ's Lansing District office advised the City that it needed to immediately implement operational techniques at the drinking

water treatment plant and in the distribution system to reduce the formation of TTHM compounds. The City of Flint's actions have reduced TTHM concentrations to the point where the most recent results at seven of the eight sample locations are below the drinking water TTHM health standard. At this time, the City must continue to provide quarterly public notification, as it continues to work with the MDEQ engineers to reduce the TTHM levels within the distribution system.

For further information regarding MDEQ's oversight and assistance to the City of Flint regarding its drinking water quality, you can contact Mr. Busch at:

Steve Busch, District Supervisor
Lansing District Office
Office of Drinking Water and Municipal Assistance
Michigan Department of Environmental Quality
P.O. Box 30242
Lansing, Michigan 48909-7742
(517) 643-2314
buschs@michigan.gov

In your email, you suggested that the source of drinking water should be switched back to Detroit drinking water which comes from Lake Huron. Unfortunately, EPA does not have the authority to require the City to change its source of drinking water back to Detroit drinking water. The decision to change the source of the City of Flint's drinking water was a local decision, and continues to be a local decision only.

Your email also stated that you are paying high monthly bills for drinking water. A part of the water rate is based upon the amount of water the resident is using; however, the base rate/service charge includes debt service charges and operation and maintenance costs of the water supply. The Michigan Department of Treasury conducts annual financial audits of local units of government in accordance with U.S. government auditing standards and Michigan Public Act 34 of 2001, the Municipal Finance Act. This includes the City of Flint and its proprietary utility funds. While these audits do not set the rate structure, they do ensure that funds generated through water rates are accounted and directed in accordance with applicable laws.

Copies of these audits can be obtained online at the following location:

<https://treas-secure.state.mi.us/LAFDocSearch/>

There is currently no Federal regulatory oversight of water utility rates in Michigan.

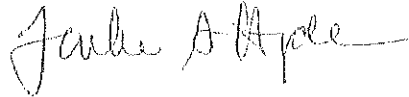
Telephone numbers for you to call if you have further concerns about your drinking water quality:

Flint Water Service Center deals with problems in the distribution system: (810) 766-7202

Water Treatment Plant deals with the actual treatment of the water prior to its pumping into the distribution system: (810) 787-6537

We appreciate your interest in this matter. If you have additional questions, please contact Jennifer Crooks of my staff at (312) 886-0244 or crooks.jennifer@epa.gov.

Sincerely,

A handwritten signature in cursive script, appearing to read "Tinka G. Hyde".

Tinka G. Hyde
Director, Water Division

cc: Mike Prysby, MDEQ
Steve Busch, MDEQ
Richard Benzie, MDEQ

bcc: J. Crooks, GWDWB
T. Murphy, GWDWB

Rennaker, Joanne (DEQ)

From: Brent Wright <bwright@cityofflint.com>
Sent: Friday, February 20, 2015 9:11 AM
To: Prysby, Mike (DEQ)
Subject: Re: call

Mike

Marvin Gnagy from Veolia wanted to talk with you about some of the suggestions they were making for treatment here at the plant. He wanted to know what could be implemented right away and what might need permit approval from the MDEQ. They were here running test all week but left yesterday. I have listed his contact number and email below. I would appreciate it if you could get in contact with him so he can finalize his report and send his recommendations to the city administration.

Marvin Gnagy
419-450-2931
marvin.gnagy@veolia.com

Thank you

On Fri, Feb 20, 2015 at 8:40 AM, Prysby, Mike (DEQ) <PRYSBYM@michigan.gov> wrote:

Brent,

Are we having a conference call today? I am available, give me a time for the call and I will make my-self available.

Michael Prysby, P.E.

District Engineer

Office of Drinking Water and Municipal Assistance

517 290-8817

--

Brent Wright
Water Plant Supervisor
City of Flint
4500 N. Dort Hwy.
Flint, MI. 48505
Ph: 810.787.6537 ext. 3510
Fx: 810.787.3710

Rennaker, Joanne (DEQ)

From: John O'Brien <jfobrien@gcdcwws.com>
Sent: Friday, February 20, 2015 8:43 AM
To: 'Howard Croft'; donna. cole; gdn2@aol.com; Kirk Smith; larry.koehler@mcc.edu; mgavuli1@hurleymc.com; Mike Lane; Prysby, Mike (DEQ); Pete Levine; rosejo@msu.edu; Russell.Hudson@mclaren.org; Brent Wright; Daugherty Johnson; Michael Glasgow; rob.nicholas@veolia.com
Cc: Flint Mayor; Gerald Ambrose; Elizabeth Murphy; David Gadis; Jason Lorenz
Subject: RE: Technical Advisory Committee Update

Howard

In review of both the Veolia and IRM they are both similar recommendations except for one item
 Water softening this item needs to be resolved to soften or not
 The technical committee can not answer this question
 Until this is decided we can not discuss the treatment process
 John O'Brien

From: Howard Croft [<mailto:hcroft@cityofflint.com>]
Sent: Thursday, February 19, 2015 3:52 PM
To: donna. cole; gdn2@aol.com; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; mgavuli1@hurleymc.com; Mike Lane; Mike Prysby (DEQ); Pete Levine; rosejo@msu.edu; Russell.Hudson@mclaren.org; Brent Wright; Daugherty Johnson; Howard Croft; Michael Glasgow; rob.nicholas@veolia.com
Cc: Flint Mayor; Gerald Ambrose; Elizabeth Murphy; David Gadis; Jason Lorenz
Subject: Technical Advisory Committee Update

Team,

I have include a list of all of the current participants in the Technical Advisory Team. We are targeting Wednesday March 4th as the first meeting and the time and place are yet to be determined. I have listed a few items to help craft the direction that we are hoping to go with this team;

1. We will likely have a conference number as well as a physical meeting place in case someone is not able to be there.
2. We will define as we go along how often to hold meetings, but we plan to continue throughout the implementation of the KWA.
2. We will start with a general scope and set of deliverables but will look for open input from the group in order to develop additional specifics as to what each member would like to accomplish.
3. Certainly with this assembled team we would want to develop a set of medical FAQ's that would assist the medical community with current and future details of chemicals and risk assessments.
4. We will discuss the treatment process and look at the national discussion on whether or not to use fluoride as well as what additional regulations are possibly being considered the EPA for the future.
5. We will look at what is upcoming with the KWA and water from Lake Huron. What will the chemical challenges be? What will the final product entail?

6. We will evaluate testing options or partners and determine if there is an avenue or demand for such.

These are some of the topics that I plan to delve into and I believe that we have assembled a professional team that can bring enlightenment to all of us. I look forward to working with each of you.

Respectfully Submitted,

--

Howard Croft

Public Works Director

City of Flint

1101 S. Saginaw Street

Flint, MI 48502

PH# 810.766.7135 Ext.2043

hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Thursday, February 19, 2015 4:00 PM
To: Busch, Stephen (DEQ)
Subject: Fwd: Technical Advisory Committee Update
Attachments: Technical Advisory Team List.pdf; ATT00001.htm

Steve,
 The city of Flint has formed their TAC with me included...fyi...see attached list....they put the wrong title for me...

Sent from my iPhone

Begin forwarded message:

From: Howard Croft <hcroft@cityofflint.com>
Date: February 19, 2015 at 3:52:07 PM EST
To: "donna. cole" <donna.cole@genesys.org>, <gd2@aol.com>, John O'Brien <jfobrien@gcdcwws.com>, Kirk Smith <ksmith@flint.org>, <larry.koehler@mcc.edu>, <mgavuli1@hurleymc.com>, Mike Lane <mjlane@umflint.edu>, "Mike Prysby (DEQ)" <prysbym@michigan.gov>, Pete Levine <plevine@gcms.org>, <rosejo@msu.edu>, <Russell.Hudson@mclaren.org>, "Brent Wright" <bwright@cityofflint.com>, Daugherty Johnson <djohnson@cityofflint.com>, Howard Croft <hcroft@cityofflint.com>, "Michael Glasgow" <mglasgow@cityofflint.com>, <rob.nicholas@veolia.com>
Cc: Flint Mayor <dwalling@cityofflint.com>, Gerald Ambrose <gambrose@cityofflint.com>, Elizabeth Murphy <emurphy@cityofflint.com>, David Gadis <david.gadis@veolia.com>, Jason Lorenz <jlorenz@cityofflint.com>
Subject: Technical Advisory Committee Update

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Respectfully Submitted,

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Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com

City of Flint / Veolia Technical Advisory Committee

	COMPANY	NAME	TITLE	PHONE	DESIGNEE	CONTACT INFO	
1	General Motors	Randy Tanner	Head of Engineering	810-577-8552			Yes
2	MSU - Lansing	Dr. Joan Rose	Chair in Water Research	517-432-4412	Dr. Joan Rose	rosejo@msu.edu	Yes
3	Greater Flint Health Coalition	Kirk Smith	President	810-232-2228	Kirk Smith	ksmith@flint.org	Yes
4	County Drain Commissioner	Jeff Wright	Deputy Drain Commissioner	810-732-7870	John O'Brien	jfobrien@gcdcwws.com	Yes
5	U of M Flint	Michael Lane	Dir. Environmental Health & Safety	810-766-6763	Michael Lane	mjlane@umflint.edu	Yes
6	Mott Community	Larry Kohler	Executive Director		Larry Koehler	larry.koehler@mcc.edu	Yes
7	Genesys Pace Hospital	Donna Cole	Property Manager	810-606-5611	Donna Cole	donna.cole@genesys.org	Yes
8	Hurley Hospital	Melanie Gavulic	President / CEO		Norb Birchmier	mgavuli1@hurleymc.com	Yes
9	McLaren Hospital	Don Kooy	President / CEO		Russell Hudson	don.kooy@mclaren.org	Yes
10	Genesee County Medical Society	Pete Levine	Executive Director	810-733-9925	Gerald Natzke	plevine@gcms.org	Yes
11	Dept. of Environmental Quality	Mike Prysby	District Supervisor	517-290-8817	Mike Prysby	prysbym@michigan.gov	Yes
	City of Flint	Howard Croft	DPW Director	810-577-1202	Howard Croft	hcroft@cityofflint.com	Yes
	City of Flint	Daugherty Johnson	Utilities Administrator	810-577-8906	Duffy Johnson	djohnson@cityofflint.com	Yes
	City of Flint	Brent Wright	Plant Supervisor	810-787-6537	Brent Wright	bwright@cityofflint.com	Yes
	City of Flint	Mike Glasgow	Asstant Plant Supervisor		Mike Glasgow	mglasgow@cityofflint.com	Yes

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Thursday, February 19, 2015 3:52 PM
To: donna. cole; gdn2@aol.com; John O'Brien; Kirk Smith; larry.koehler@mcc.edu; mgavuli1@hurleymc.com; Mike Lane; Prysby, Mike (DEQ); Pete Levine; rosejo@msu.edu; Russell.Hudson@mclaren.org; Brent Wright; Daugherty Johnson; Howard Croft; Michael Glasgow; rob.nicholas@veolia.com
Cc: Flint Mayor; Gerald Ambrose; Elizabeth Murphy; David Gadis; Jason Lorenz
Subject: Technical Advisory Committee Update
Attachments: Technical Advisory Team List.pdf

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Respectfully Submitted,

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Howard Croft
 Public Works Director
 City of Flint

1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7135 Ext.2043
heroft@cityofflint.com

City of Flint / Veolia Technical Advisory Committee

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	City of Flint	Brent Wright	Plant Supervisor	810-787-6537	Brent Wright	bwright@cityofflint.com	Yes
	City of Flint	Mike Glasgow	Asstant Plant Supervisor		Mike Glasgow	mglasgow@cityofflint.com	Yes

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, February 17, 2015 4:03 PM
To: Howard Croft
Cc: Busch, Stephen (DEQ); Benzie, Richard (DEQ)
Subject: RE: City Water Tech Team

Howard,

After further discussion with ODWMA staff, I am available to participate in the TAC. My main role will be review water system reports and provide comments and/or guidance primarily from a regulatory standpoint. Please keep me informed as to when the first meeting will be held. Finally, I wish to extend my thanks for the invitation to participate in the TAC.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Howard Croft [<mailto:hcroft@cityofflint.com>]
Sent: Saturday, February 14, 2015 8:45 AM
To: Prysby, Mike (DEQ)
Subject: City Water Tech Team

Mike,

The City of Flint has contracted with Veolia North America in order to have an additional review of the water system. As part of this review, we are working to develop a Technical Advisory Committee (TAC) that will that will receive reports and interact with the technical staff from Veolia. The City has identified 8 - 12 entities or individuals that we are extending an invitation to participate on this committee.

I would like to extend this invitation to you or your designee to be a representative on the TAC team which we hope to have established by early next week.

I understand that this is short notice but if you would consider the offer and confirm or deny your participation I would greatly appreciate it. We are hoping to announce the names of this team at a Public Works Committee meeting Wednesday February 18th. The details of the first meeting and the ongoing agenda which is anticipated to extend through the implementation of the Karegnondi Water Authority as a water source will also be unveiled next week..

Thank you,

--

Howard Croft

Public Works Director

City of Flint

1101 S. Saginaw Street

Flint, MI 48502

PH# 810.766.7135 Ext.2043

hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Saturday, February 14, 2015 8:45 AM
To: Prysby, Mike (DEQ)
Subject: City Water Tech Team

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The City of Flint has contracted with Veolia North America in order to have an additional review of the water system. As part of this review, we are working to develop a Technical Advisory Committee (TAC) that will that will receive reports and interact with the technical staff from Veolia. The City has identified 8 - 12 entities or individuals that we are extending an invitation to participate on this committee.

I would like to extend this invitation to you or your designee to be a representative on the TAC team which we hope to have established by early next week.

I understand that this is short notice but if you would consider the offer and confirm or deny your participation I would greatly appreciate it. We are hoping to announce the names of this team at a Public Works Committee meeting Wednesday February 18th. The details of the first meeting and the ongoing agenda which is anticipated to extend through the implementation of the Karegnondi Water Authority as a water source will also be unveiled next week..

Thank you,

--

Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7135 Ext.2043
hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Thursday, February 12, 2015 3:36 PM
To: Prysby, Mike (DEQ)
Cc: Busch, Stephen (DEQ); Poy, Thomas; Deltoral, Miguel
Subject: TTHM Health Effects
Attachments: TTHM PN template.pdf

Mike—Good talking with you this morning. I'm so glad I was able to snag Tom Poy to discuss the TTHM health effects issue with you.

Miguel said that TTHMs *MAY* cause miscarriages, which is more of an acute risk. Thus, the "pregnant" should be in the PN, so women know there could be risk, and can make their own decisions.

I included the link for PN Handbook, and a PDF of the PN template for TTHMs.

See page 104 of the PN Handbook (I also included as a PDF attached); here is the link:

<http://water.epa.gov/lawsregs/rulesregs/sdwa/publicnotification/upload/PNrevisedPNHandbookMarch2010.pdf>

Paul Joice, Paul.A.Joice@hud.gov

I don't have his phone number—perhaps you could call the Mayor's office to get Paul's phone number?

Eric Burneson, burneson.eric@epa.gov

202-564-5250

I think the Key Message here is that there are other studies out there that point to other Health Effects from TTHMs, but there's not enough information for EPA to say that these are definitely additional Health Effects to be concerned about, so EPA cannot put this in writing/in the PN.

Jennifer

312-886-0244

Stage 2 DBPR TTHM or HAA5 MCL Violation Notice – Template 2-19

IMPORTANT INFORMATION ABOUT YOUR DRINKING WATER

[Contaminant, i.e., Total Trihalomethanes (TTHM) or Haloacetic Acid 5 (HAA5)] MCL Violation at [System]

Our water system recently violated a drinking water standard. Although this incident was not an emergency, as our customers, you have a right to know what happened and what we did (are doing) to correct this situation.

We routinely monitor for the presence of drinking water contaminants. Testing results from [provide date range] show that our system exceeds the standard, or maximum contaminant level (MCL), for [TTHM/HAA5]. The standard for [TTHM/HAA5] is [MCL]. It is determined by averaging all the samples collected at each sampling location for the past 12 months. The level of [TTHM/HAA5] averaged at one of our system's locations for [provide date range] was [level].

What should I do?

- There is nothing you need to do. You do not need to boil your water or take other corrective actions. If a situation arises where the water is no longer safe to drink, you will be notified within 24 hours.
- If you have a severely compromised immune system, have an infant, are pregnant, or are elderly, you may be at increased risk and should seek advice from your health care providers about drinking this water.

What does this mean?

This is not an emergency. If it had been an emergency, you would have been notified within 24 hours.

[TTHM are four volatile organic chemicals] [HAA5 are five haloacetic acid compounds] which form when disinfectants react with natural organic matter in the water.

*[*People who drink water containing trihalomethanes in excess of the MCL over many years may experience problems with their liver, kidneys, or central nervous system, and may have an increased risk of getting cancer.*] Or*

*[*People who drink water containing haloacetic acids in excess of the MCL over many years may have an increased risk of getting cancer.*]*

What is being done?

[Describe corrective action.] We anticipate resolving the problem within [estimated time frame] (or the problem was resolved on [give date]).

For more information, please contact [name of contact] at [phone number] or [mailing address].

Please share this information with all the other people who drink this water, especially those who may not have received this notice directly (for example, people in apartments, nursing homes, schools, and businesses). You can do this by posting this notice in a public place or distributing copies by hand or mail.

This notice is being sent to you by [system]. State Water System ID#: _____

Date distributed: _____

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Wednesday, February 11, 2015 3:50 PM
To: Benzie, Richard (DEQ); Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Shekter Smith, Liane (DEQ)
Subject: RE: Controlled Correspondence from citizen in Flint

Thank you, Richard, for your comments below. I changed to "District Supervisor". Regarding your second comment, I came to the same conclusion a bit ago, and tried to clarify this with a citizen caller—that the water leaving the plant was fine; it was the time in the distribution system that was causing problems. But, they didn't care—the bottom line was their water "was bad". So, I don't think I'll include that comment; but I did forward to Tom Poy for his weigh in.

Jen

From: Benzie, Richard (DEQ) [<mailto:BENZIER@michigan.gov>]
Sent: Wednesday, February 11, 2015 1:03 PM
To: Crooks, Jennifer; Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: shekterl@michigan.gov
Subject: RE: Controlled Correspondence from citizen in Flint

Jen,

I'm sure Steve will reply, but I know he has been conducting interviews today.

Most of the letter looks fine. However, the title of Supervising District Engineer has not been used since we merged with the Surface Water Quality Division in 2002. Steve is currently the ***District Supervisor*** for the Lansing (and Jackson) District. You use his title several times in your final draft.

Also, it may be appropriate or beneficial to point out that at no time has the drinking water leaving the water treatment plant since the switch to the Flint River exceeded a drinking water standard. The problems the city has encountered appear to be related to distribution system issues, such as an aging pipe network, reduced customer usage, and as a result, increased stagnation of drinking water within the distribution system.

That's my two cents.

Richard

From: Crooks, Jennifer [<mailto:crooks.jennifer@epa.gov>]
Sent: Wednesday, February 11, 2015 11:49 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ)
Subject: Controlled Correspondence from citizen in Flint
Importance: High

Hi, Steve. As we discussed, I've drafted our response and included information you gave us on Monday. Tom Poy has reviewed, so this is our final draft. If you could get back to me this afternoon with any changes, I'd appreciate it. These things are like ticking time bombs around here.

Thank you!

Jennifer

Rennaker, Joanne (DEQ)

From: Michael Glasgow <mglasgow@cityofflint.com>
Sent: Tuesday, February 10, 2015 3:56 PM
To: Prysby, Mike (DEQ); Rosenthal, Adam (DEQ)
Subject: January 2015 MOR
Attachments: January 2015 MOR scan.pdf; January 2015 Bromate Results.pdf

Mike & Adam,

Here is copy of the MOR for the month of January. Brent will be sending out a hard copy in the mail today. I have also included the January monthly bromate test results.

Mike Glasgow
City of Flint Water Plant

CITY of FLINT WATER TREATMENT PLANT MONTHLY OPERATION REPORT

SUPPLY NAME: CITY of FLINT WATER PLANTWSSN: 2310Michael Glasgow

Operator-in-Charge

January 2015

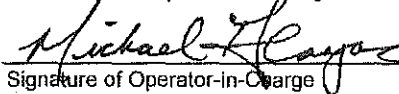
Month/Year

F-1R, F-2

Certification of Operator-in-Charge

F-1

Water Plant Classification



Signature of Operator-in-Charge

Genesee

County

Treatment Rate and Filter Data

Maximum Treatment Rate:	<u>19.3</u>	Million Gallons per Day
Rated Plant Capacity:	<u>36</u>	Million Gallons per Day
Average Filter Run:	<u>76</u>	Hours
Average Head Loss:	<u>n/a</u>	Feet *(filter head loss meters not operational)
Average Filtration Rate:	<u>2.1</u>	Gallons Per Square Feet per Minute
Maximum Filtration Rate:	<u>3.6</u>	Gallons Per Square Feet per Minute
Average Wash Water Use:	<u>3.2%</u>	Percent of Treated Water

Chemical Data

Chlorine on hand:	<u>12,000</u>	lb.	Est. supply:	<u>18</u>	days
Primary Coagulant (Ferric Chloride) on hand:	<u>110,000</u>	lb.	Est. supply:	<u>10</u>	days
Lime (CaO) on hand:	<u>257</u>	tons	Est. supply:	<u>22</u>	days
Fluoride on Hand:	<u>16,630</u>	lb.	Est. supply:	<u>42</u>	days
Cost of All Chemicals per Million Gallons:	<u>n/a</u>	dollars			
Total Power Cost per Million Gallons:	<u>n/a</u>	dollars			

Remarks

Confluence Point # 1 (N)

Confluence Point # 2 (S)

Number of filter confluence samples > 0.3 NTU:

00

Number of filter confluence samples collected:

244242

Percent of filter confluence samples > 0.3 NTU:

0.0%0.0%

Number of filter confluence samples > 1 NTU

00

Did any individual filter exceed:

1.0 NTU in two consecutive measurements taken 15 minutes apart?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

0.5 NTU in two consecutive measurements taken 15 minutes apart after 4 hours of operation?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

1.0 NTU in two consecutive measurements taken 15 minutes apart for 3 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

2.0 NTU in two consecutive measurements taken 15 minutes apart for 2 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

Was continuous (every 15 minutes) filter monitoring equipment off-line during the month?

NO

If yes, indicate date(s), duration, and individual filter grab sampling frequency on a separate sheet.

Did POE disinfectant residual fall below 0.2 ppm during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

Was minimum C*T credit achieved for the entire month?

YES

If no, indicate on a separate sheet the date(s) not achieved.

Was continuous POE chlorine residual monitoring equipment off-line during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

Filter turbidity

City of Flint Water Treatment Plant
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January 2015

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Date	Turbidity, Units												Point of Entry
	Confluence Point. No.1 (N) North						Confluence Point. No.2 (S) South						
	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	
1	8	0.07	0.08	6	0	0	8	0.06	0.09	6	0	0	0.08
2	7	0.07	0.09	6	0	0	7	0.06	0.07	6	0	0	0.07
3	8	0.06	0.08	6	0	0	8	0.06	0.07	6	0	0	0.08
4	8	0.07	0.09	6	0	0	8	0.07	0.11	6	0	0	0.07
5	8	0.06	0.09	6	0	0	8	0.06	0.09	6	0	0	0.07
6	8	0.08	0.09	6	0	0	8	0.07	0.10	6	0	0	0.07
7	8	0.09	0.15	6	0	0	8	0.07	0.09	6	0	0	0.08
8	8	0.08	0.10	6	0	0	8	0.07	0.11	6	0	0	0.08
9	8	0.06	0.08	6	0	0	8	0.05	0.07	6	0	0	0.07
10	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
11	8	0.06	0.08	6	0	0	8	0.07	0.09	6	0	0	0.07
12	8	0.07	0.09	6	0	0	8	0.07	0.10	6	0	0	0.09
13	8	0.06	0.12	6	0	0	8	0.05	0.07	6	0	0	0.06
14	8	0.07	0.09	6	0	0	8	0.06	0.09	6	0	0	0.07
15	8	0.06	0.09	6	0	0	8	0.07	0.09	6	0	0	0.07
16	8	0.07	0.09	6	0	0	8	0.07	0.10	6	0	0	0.09
17	8	0.07	0.08	6	0	0	8	0.07	0.10	6	0	0	0.07
18	8	0.08	0.11	6	0	0	8	0.07	0.08	6	0	0	0.07
19	8	0.07	0.09	6	0	0	8	0.07	0.11	6	0	0	0.07
20	8	0.07	0.08	6	0	0	8	0.07	0.10	6	0	0	0.11
21	8	0.08	0.11	6	0	0	8	0.07	0.08	6	0	0	0.09
22	8	0.09	0.11	6	0	0	8	0.08	0.09	6	0	0	0.09
23	7	0.08	0.10	6	0	0	7	0.07	0.09	6	0	0	0.08
24	8	0.07	0.09	6	0	0	8	0.06	0.10	6	0	0	0.07
25	8	0.06	0.07	6	0	0	8	0.07	0.09	6	0	0	0.07
26	8	0.07	0.09	6	0	0	6	0.08	0.10	6	0	0	0.07
27	7	0.08	0.11	6	0	0	7	0.07	0.10	6	0	0	0.08
28	7	0.07	0.09	6	0	0	7	0.07	0.10	6	0	0	0.07
29	7	0.07	0.10	6	0	0	7	0.07	0.08	6	0	0	0.07
30	8	0.07	0.09	6	0	0	8	0.07	0.08	6	0	0	0.08
31	8	0.06	0.10	6	0	0	8	0.06	0.08	6	0	0	0.07
Avg.	8	0.07	0.09	6	0	0	8	0.07	0.09	6	0	0	
Max.	8	0.09	0.15	6	0	0	8	0.08	0.11	6	0	0	0.11
Min.	7	0.06	0.07	6	0	0	6	0.05	0.07	6	0	0	

Fluoridation &
ChlorinationCity of Flint Water Treatment Plant
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Date	Fluoride Applied as F- mg/L	Fluoride Analysis (mg/L)			Chlorine Application (mg/L)			Chlorine Residual (mg/L)					
					Intermediate Chlorine	Post Chlorine	Total Chlorine	Filtered		3 MG Well		Tap	
		Raw	Tap	Dist.				Free	Total	Free	Total	Free	Total
1	0.4	0.24	0.70		1.3	3.5	4.8	0.6	0.9	2.7	3.0	2.1	2.4
2	0.4	0.21	0.62		1.4	3.5	4.9	0.6	0.8	2.6	3.1	2.2	2.6
3	0.3	0.22	0.55		1.8	2.6	4.4	0.5	0.7	2.7	3.3	2.8	3.2
4	0.4	0.20	0.60		1.8	2.5	4.3	0.8	1.0	2.8	3.0	2.9	3.2
5	0.4	0.19	0.23		1.9	2.5	4.4	0.7	1.0	2.8	3.0	2.7	3.0
6	0.3	0.19	0.49	0.39	1.9	2.7	4.6	0.6	0.9	2.7	3.2	2.5	3.2
7	0.3	0.23	0.61		1.9	2.6	4.5	0.7	0.9	2.7	3.0	2.2	2.7
8	0.3	0.19	0.51		1.9	2.6	4.5	0.6	0.9	2.4	3.1	2.1	2.6
9	0.0	0.19	0.51		2.0	3.2	5.2	0.4	0.7	2.8	3.1	2.3	2.8
10	0.0	0.22	0.44		1.8	3.1	4.9	0.4	0.4	2.4	2.9	1.8	2.3
11	0.0	0.20	0.22		1.8	3.0	4.8	0.8	1.1	2.7	3.1	2.5	2.9
12	0.0	0.21	0.21		1.6	3.2	4.8	0.5	0.8	2.8	3.1	2.4	2.8
13	0.0	0.19	0.19	0.35	1.7	3.1	4.8	0.8	1.2	2.8	3.1	2.2	2.6
14	0.0	0.21	0.21		1.6	3.0	4.6	0.4	0.6	2.8	3.1	2.3	2.8
15	0.0	0.22	0.24		1.6	3.0	4.6	0.5	0.9	2.7	3.1	2.0	2.3
16	0.1	0.20	0.20		1.6	3.0	4.6	0.5	0.9	2.3	3.0	2.0	2.5
17	0.3	0.22	0.23		1.7	3.0	4.7	0.4	0.6	2.5	3.0	1.8	2.3
18	0.4	0.19	0.55		1.8	3.2	5.0	0.5	0.8	2.7	3.0	2.5	2.9
19	0.4	0.20	0.64		1.9	3.2	5.1	0.4	0.6	2.8	3.2	2.2	2.6
20	0.0	0.22	0.45	0.31	2.0	3.0	5.0	0.5	0.9	2.9	3.4	2.1	2.7
21	0.2	0.21	0.31		1.9	2.8	4.7	0.5	0.8	2.6	3.0	2.2	2.6
22	0.4	0.20	0.67		1.9	2.9	4.8	0.4	0.7	2.8	3.2	1.9	2.2
23	0.4	0.22	0.41		2.0	3.1	5.1	0.4	0.8	2.6	3.0	1.5	1.8
24	0.4	0.21	0.67		2.0	3.2	5.2	0.7	0.9	2.8	3.0	2.7	3.0
25	0.4	0.23	0.59		2.1	3.1	5.2	0.5	0.8	2.9	3.4	2.4	2.7
26	0.4	0.21	0.57		2.0	3.0	5.0	0.4	0.7	2.7	3.1	2.4	2.7
27	0.4	0.23	0.54	0.55	2.1	3.1	5.2	0.4	0.6	2.7	3.0	2.2	2.5
28	0.4	0.22	0.59		2.0	2.9	4.9	0.8	1.0	2.4	2.7	1.9	2.3
29	0.4	0.25	0.82		2.0	2.9	4.9	0.7	0.9	2.8	3.2	2.2	2.5
30	0.4	0.22	0.63		2.0	3.0	5.0	0.7	0.8	2.5	2.9	2.0	2.5
31	0.3	0.19	0.52		1.9	3.0	4.9	0.6	0.8	2.8	3.2	2.8	3.2

Avg.	0.26	0.21	0.47	0.40	1.8	3.0	4.8	0.6	0.8	2.7	3.1	2.3	2.7
Max.	0.40	0.25	0.70	0.55	2.1	3.5	5.2	0.8	1.2	2.9	3.4	2.9	3.2
Min.	0.00	0.19	0.19	0.31	1.3	2.5	4.3	0.4	0.4	2.3	2.7	1.5	1.8

Chemical
AnalysesCity of Flint Water Treatment Plant
WSSN: 2310

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Date	pH (S.U.)		Total Hardness as CaCO ₃ (mg/L)		Total Alkalinity as CaCO ₃ (mg/L)		Non-Carbonate Hardness as CaCO ₃ (mg/L)		Calcium as Ca ²⁺ (mg/L)		Magnesium as Mg ²⁺ (mg/L)		Chloride as Cl ⁻ (mg/L)	
	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap
1	8.23	7.65	323	185	264	65	59	120	108.2	55.3	13.6	11.7	47	85
2	7.84	7.31	324	193	258	76	66	117	121.0	65.7	6.3	4.9	47	87
3	7.77	7.38	323	212	257	98	66	114	120.0	77.0	5.8	4.9	48	87
4	8.15	7.86	325	218	261	96	64	122	105.8	64.9	14.6	13.1	48	88
5	8.31	7.80	318	206	262	94	56	112	103.4	60.9	14.6	13.6	45	78
6	8.09	7.97	320	208	256	95	64	113	121.0	69.7	4.9	8.7	48	85
7	8.04	7.91	313	194	256	97	57	97	101.8	61.7	15.6	10.7	43	82
8	8.19	8.04	313	202	251	87	62	115	121.0	72.9	2.9	3.9	48	83
9	8.08	7.96	311	205	248	93	63	112	115.4	70.5	5.8	6.3	47	84
10	7.98	7.75	316	181	255	73	61	108	114.6	64.1	6.8	3.4	47	88
11	8.01	8.24	321	174	266	63	65	111	100.2	44.9	17.5	14.6	44	80
12	8.09	7.68	318	177	250	57	68	120	101.0	46.5	16.0	14.6	49	81
13	7.94	7.69	320	165	245	46	75	119	105.8	44.1	14.1	13.1	47	87
14	7.80	7.52	321	172	252	58	69	114	115.4	56.9	7.8	6.8	48	88
15	7.96	7.64	323	173	258	48	65	125	105.8	48.9	14.1	13.1	45	91
16	7.94	7.47	324	172	257	44	67	128	117.8	58.5	6.8	6.8	47	88
17	7.82	7.95	320	174	252	54	68	120	119.4	58.5	4.9	5.3	46	89
18	8.02	7.72	322	185	258	69	64	116	104.2	55.3	15.1	11.2	48	83
19	8.03	7.62	321	184	255	59	66	125	102.6	54.5	16.0	11.7	48	86
20	7.89	7.59	321	184	256	67	66	117	116.2	64.9	7.8	4.9	49	91
21	7.86	7.79	324	183	257	72	67	111	105.0	51.3	15.1	13.1	50	83
22	7.59	7.42	325	193	262	81	63	112	116.2	68.9	8.3	4.9	49	84
23	7.70	7.44	344	186	256	78	88	108	112.2	59.3	15.6	9.2	52	87
24	7.91	7.51	327	187	259	72	68	115	101.0	48.1	18.5	16.0	48	85
25	7.93	7.71	326	188	260	75	66	113	100.2	50.5	18.5	14.6	47	85
26	7.95	7.82	328	194	259	71	69	123	105.8	54.5	15.6	13.6	51	88
27	7.77	7.99	332	191	266	68	66	123	111.4	60.1	13.1	9.2	51	89
28	7.99	7.98	334	188	264	76	70	112	107.4	51.3	16.0	14.6	48	85
29	7.80	7.83	334	196	268	76	66	120	106.6	57.7	16.5	12.6	55	86
30	7.84	7.78	331	193	272	78	59	115	113.0	59.3	13.1	10.7	55	90
31	7.96	7.91	335	197	267	69	68	128	108.2	56.1	15.6	13.6	51	92

Avg.	7.95	7.74	324	189	258	73	66	116	109.9	58.5	12.2	10.2	48	86
Max.	8.31	8.24	344	218	272	98	88	128	121.0	77	18.5	16.0	55	92
Min.	7.59	7.31	311	165	245	44	56	97	100.2	44.1	2.9	3.4	43	78

Date	Total Coliform						Standard Plate Count (Simplate MPN)		Conductivity (mS)	Temp. C	Color		Odor	
	Raw (Colliert MPN)		Filter Confluence (N&S)		Plant Tap									
	# Samples	Count	# Samples	# pos	# Samples	# pos	Raw	Tap	Tap	Raw	Raw	Tap	Raw	Tap
1	1	2592	12	0	1	0	800	< 2	0.37	5.6				
2	1	1684	12	0	1	0	600	< 2	0.36	4.5				
3	1	960	12	0	1	0	2400	< 2	0.42	4.0				
4	1	718	12	0	1	0	200	< 2	0.44	3.8				
5	1	1732	12	0	1	0	5980	< 2	0.41	3.0				
6	1	874	12	0	1	0	200	< 2	0.41	4.5				
7	1	2086	12	0	1	0	200	< 2	0.39	4.2				
8	1	960	12	0	1	0	120	< 2	0.39	5.5				
9	1	1146	12	0	1	0	420	< 2	0.40	2.6				
10	1	2994	12	0	1	0	760	38	0.31	2.6				
11	1	978	12	0	1	0	520	10	0.36	2.1				
12	1	1042	12	0	1	0	600	< 2	0.36	1.9				
13	1	862	12	0	1	0	340	< 2	0.37	1.4				
14	1	646	12	0	1	0	200	< 2	0.36	1.9				
15	1	736	12	0	1	0	300	< 2	0.36	3.5				
16	1	2224	12	0	1	0	200	< 2	0.37	1.9				
17	1	320	12	0	1	0	200	< 2	0.36	4.9				
18	1	40	12	0	1	0	200	2	0.38	4.9				
19	1	148	12	0	1	0	120	< 2	0.40	5.2				
20	1	770	12	0	1	0	146	< 2	0.38	4.9				
21	1	148	12	0	1	0	80	< 2	0.37	5.9				
22	1	201	12	0	1	0	190	< 2	0.39	5.8				
23	1	345	12	0	1	0	120	< 2		4.9				
24	1	97	12	0	1	0	150	< 2	0.38	6.4				
25	1	146	12	0	1	0	60	< 2	0.39	4.4				
26	1	181	12	0	1	0	230	< 2	0.40	3.8				
27	1	146	12	0	1	0	120	< 2	0.38	4.9				
28	1	172	12	0	1	0	128	< 2	0.38	4.3				
29	1	261	12	0	1	0	137	< 2	0.49	4.2				
30	1	155	12	0	1	0	93	< 2	0.43	4.0				
31	1	41	12	0	1	0	60	< 2	0.53	4.0				

Avg.								0.39	4.0				
Max.						5980	38	0.53	6.4				
Min.								0.31	1.4				

**Distribution System
Monitoring**
**City of Flint Water Treatment Plant
WSSN: 2310**
January 2015
Page 7

Date	Free Chlorine Residual at Bacteriological Monitoring Stations mg/l										Number of Samples
	1	2	3	4	5	6	7	8	CS	WS	
1	0.7	0.1	1.3	1.6	0.7	0.2	0.2		1.5	1.4	9
2											0
3											0
4											0
5											0
6	0.6	0.7	1.5	2.0	0.8	0.1	1.4	1.8	1.8	1.8	10
7	0.6	0.7	1.7	1.5	0.7	0.2	1.1	2.0	0.8	1.7	10
8	0.8	0.3	1.0	1.3	0.8	0.1	1.4	1.8	0.8	1.7	10
9											0
10											0
11											0
12											0
13	0.4	1.0	1.7	1.4	0.7	0.2	1.4	1.7	0.4	1.7	10
14	0.2	0.5	1.8	1.6	0.5	0.1	2.1	2.2	0.4	2.0	10
15											0
16											0
17											0
18											0
19											0
20	0.1	1.6	1.7	1.4	0.9	0.3	1.9	2.0	1.3	1.8	10
21											0
22											0
23											0
24											0
25											0
26									1.6	1.8	2
27	0.9	1.3	1.2	1.7	0.7	0.2	1.3	1.8	1.4	0.8	10
28	0.8	0.5	1.4	1.5	0.8	0.2	1.8	1.8	1.5	1.8	10
29	0.9	1.7	1.6	1.7	1.0	0.1	2.0	1.9	0.9	2.0	10
30											0
31											0

Distribution Sample Summary

Total # of routine distribution samples analyzed	101
Total # of routine distribution samples required	100

Distribution Bacteriological Summary

Total # of positive routine distribution samples	0
Percent of routine distribution samples positive	0%

See page 9 for positive sample information.
Distribution Disinfectant Total Residual Summary

Percentage of samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.15

Date	Total Chlorine Residual at Bacteriological Monitoring Stations mg/l										
	1	2	3	4	5	6	7	8	CS	WS	Number of Samples
1	0.8	0.2	1.5	1.8	0.9	0.3	0.3		1.7	1.5	9
2											0
3											0
4											0
5											0
6	0.9	0.9	1.4	2.3	1.0	0.2	1.6	2.1	2.2	2.1	10
7	0.8	0.9	1.9	1.8	1.0	0.2	1.3	2.2	1.0	2.0	10
8	1.0	0.5	1.2	1.5	1.1	0.3	1.6	2.0	1.0	2.0	10
9											0
10											0
11											0
12											0
13	0.7	1.5	2.0	1.7	0.9	0.2	1.7	2.3	0.6	2.1	10
14	0.4	1.8	2.1	1.8	0.8	0.3	2.4	2.5	0.5	2.3	10
15											0
16											0
17											0
18											0
19											0
20	0.3	1.9	2.0	1.6	1.2	0.6	2.2	2.3	1.5	2.2	10
21											0
22											0
23											0
24											0
25											0
26									1.9	2.2	2
27	1.3	1.9	1.7	2.1	0.9	0.4	1.7	2.0	1.8	1.0	10
28	1.2	0.8	1.7	1.8	1.2	0.4	2.1	2.3	1.9	2.2	10
29	1.2	2.0	1.9	1.9	1.3	0.2	2.3	2.3	1.1	2.3	10
30											0
31											0

Distribution Disinfectant Total Residual Summary	
Percent samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.4

Positive Distribution Samples

[illegible]

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, February 10, 2015 2:31 PM
To: Cook, Pat (DEQ); Busch, Stephen (DEQ)
Subject: FW: EarthTec for taste and odor issues

Yes,

They claim the product Earth Tec is NFS certified....I can also talk to Kevin VanSickle (previous operator at Saginaw) regarding use of the product and their experience.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

From: Hansen, Jeff [mailto:jrhanzen@lan-inc.com]
Sent: Monday, February 09, 2015 12:37 PM
To: Prysby, Mike (DEQ)
Subject: FW: EarthTec for taste and odor issues

I'll call later today to discuss. See below.

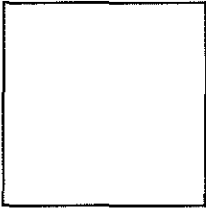
Jeffrey R. Hansen
Senior Project Manager

From: David Carrington [mailto:davidcarrington@earthsciencelabs.com]
Sent: Monday, February 09, 2015 12:26 PM
To: Hansen, Jeff
Cc: eschiebold (eschiebold@aol.com); Allan Goldschmidt
Subject: Re: EarthTec for taste and odor issues

EarthTec is NSF 60 certified for drinking water and has been approved by the state of Michigan. We used EarthTec in Saginaw, MI for a few years until they changed their source water and no longer needed it. Pricing for EarthTec is \$15.00/gallon in 275 gallon totes FOB our plant in Holdrege, NE. We have a number of plants using EarthTec around the US for river water applications for both organics and algae.

How much retention time do you have between the river water intake and the plant?

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com



From: Hansen, Jeff <jrhansen@lan-inc.com>
Sent: Monday, February 9, 2015 9:49 AM
To: David Carrington
Cc: eschiebold (eschiebold@aol.com)
Subject: RE: EarthTec for taste and odor issues

Dave and/or Eric,

Couple more questions in addition to those below: You said the product is NSF certified, but is that NSF 61 certified? Has it been approved by the MDEQ for use in drinking water applications and is it being used in any drinking water plants in MI? If so, which?

Thanks,

Jeffrey R. Hansen
Senior Project Manager

From: Hansen, Jeff
Sent: Friday, February 06, 2015 11:19 AM
To: 'David Carrington'
Cc: eschiebold (eschiebold@aol.com)
Subject: RE: EarthTec for taste and odor issues

Thanks for the data. We'll take a look at this.

Can you also give me an idea of cost and where Flint could buy it?

Jeffrey R. Hansen
Senior Project Manager

LAN Lockwood, Andrews
& Newnam, Inc.
A LEO A DALY COMPANY

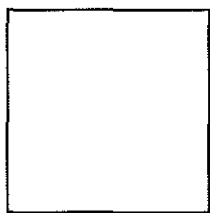
1311 South Linden Road, Suite B • Flint, MI 48532
T 810.820.2682 C 810.333.3201
www.lan-inc.com • JRHansen@lan-inc.com

From: David Carrington [<mailto:davidcarrington@earthsciencelabs.com>]
Sent: Friday, February 06, 2015 11:03 AM
To: Hansen, Jeff
Subject: Fw: EarthTec for taste and odor issues

see below.

Dave Carrington
EarthTec Business Manager
469-371-7866

EarthTecQZ.com



From: David Carrington
Sent: Friday, February 6, 2015 9:53 AM
To: eschiebold; jhansen@lan-inc.com
Cc: Allan Goldschmidt
Subject: Re: EarthTec for taste and odor issues

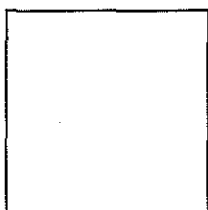
Jeff-

- EarthTec is a liquid copper based product that has been used as a municipal water pretreatment chemical for the past 20 years.
- NSF Certified.
- We have hundreds of installations.
- It essentially reacts with algae and organics to improve the water quality coming in to the plant.
- There are no resulting dbp's with our product.
- The product is normally dosed at 1 ppm at the raw water intake and reacts with the water prior to the treatment plant.
- The copper is 100% cupric Cu^{++} ions which are toxic and bioavailable. The actual copper level is only 60 ppb at 1 ppm.
- The product stays in solution indefinitely until it reacts based on water demand.
- Product has a negative charge and usually reduces the amount of coagulant required
- We have several plants running ozone. No adverse effects with any oxidant. Should be able to reduce ozone feed rates assuming EarthTec reduces the organic loading.

I have attached some general information for your review. Please feel free to contact me with any questions.

Thanks,

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com



From: eschiebold <eschiebold@aol.com>
Sent: Friday, February 6, 2015 9:01 AM
To: David Carrington
Subject: Fwd: EarthTec for taste and odor issues

Dear Dave:
 Please respond ASAP.

Sincerely,
 Eric Schiebold
 Environmental Sales, Inc.
 17348 W 12 Mile Road
 Suite 103
 Southfield, MI 48076-6325
 vox 248-569-9393
 fax 248-569-9388
 cell 248-761-7195

-----Original Message-----

From: Hansen, Jeff <jrhansen@lan-inc.com>
To: eschiebold <eschiebold@aol.com>
Sent: Fri, Feb 6, 2015 9:58 am
Subject: RE: EarthTec for taste and odor issues

Hi Eric,

We would want to know things like:

1. What is in it?
2. What are the byproducts?
3. Is it corrosive?
4. What form and what concentration does it come in?
5. What equipment is needed to feed it?

Thanks,

Jeffrey R. Hansen
 Senior Project Manager



1311 South Linden Road, Suite B • Flint, MI 48532
 T 810.820.2682 C 810.333.3201
www.lan-inc.com • JRHansen@lan-inc.com

From: eschiebold [<mailto:eschiebold@aol.com>]
Sent: Friday, February 06, 2015 9:49 AM
To: Hansen, Jeff
Cc: davidcarrington@earthsciencelabs.com
Subject: EarthTec for taste and odor issues

Dear Jeff:

Attached is a brochure on EarthTec for taste and odor issues. It's EPA approved and NSF Certified. I'm told you can expect a 20-40% reduction in organics when using EarthTec. I can get you a sample of EarthTec for evaluation in the lab. I have asked for data and references at plants where EarthTec is used in combination with ozone and I'll get that to you ASAP. Unfortunately the website is under construction so there really isn't any additional information available online.

EarthTec is also a very good chemical for zebra and quagga mussel control. I can send you several technical papers for that application. Just let me know if you'd like them.

Also attached is my Line Card.

Sincerely,
Eric Schiebold
Environmental Sales, Inc.
17348 W 12 Mile Road
Suite 103
Southfield, MI 48076-6325
vox 248-569-9393
fax 248-569-9388
cell 248-761-7195

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Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Monday, February 09, 2015 4:00 PM
To: Crooks, Jennifer; Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Poy, Thomas
Subject: RE: Letter from the White House-Flint
Attachments: Flint-Results-2013CCR.pdf

Jennifer,

The City's most recent Monthly Operation for December 2014 is available on the City website:
<http://cityofflint.com/wp-content/uploads/CoF-WTP-Monthly-Operation-Report.pdf>

It includes pH, alkalinity, hardness, distribution CI residuals, and other info we discussed.

Attached is the following additional information:

- Pages 1-3 Flint WTP plant tap results from 10/28/2014. (Includes Metals, Inorganics, VOC, SOC's).
- Page 4 Table from 2013 CCR (Issued in 2014 with results under DWSD)

I think this will cover everything we discussed this morning, but if you need something else just let us know. Thanks.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Crooks, Jennifer [<mailto:crooks.jennifer@epa.gov>]
Sent: Monday, February 09, 2015 1:33 PM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Poy, Thomas
Subject: Letter from the White House-Flint

Steve/Mike: I'm responding to the earlier email from a citizen in Flint; but now I have a Letter from the White House that I'm responding to. I'll send you a draft tomorrow afternoon or Wednesday, when I get language from Kim Harris on TTHM health effects, and I asked Richard for some info on water rates oversight in MI.

Question for you: As of January, the Flint drinking water was meeting all State/Federal health standards except for TTHMs. I think that TTHMs will continue to be out of compliance for the next couple of quarters. Do recent analytical results show that all other contaminants are meeting State/Federal health standards? Steve, you said on our call this morning that you would track down these results today. Steve, in response to Tom Poy's question about the chlorine residuals in the past Flint/Detroit drinking water vs. current Flint drinking water, you said you would track down this information too.

On another related note, Tom Poy and I have had a number of discussions this morning about Flint. He called our contact at ATSDR/CDC, this morning to discuss the large number of complaints we're getting about rashes. He said he would like to see the most recent analytical results from Flint. So, I will be able to give him the information you're sending me, Steve.

Thank you all for being so responsive; this one is a tough one.

Thank you!

Jennifer



Michigan Department of Environmental Quality

**Replicate Laboratory Report for
Lansing Drinking Water Laboratory**

Owner/Location Information:

CITY OF FLINT
4500 N DORT HWY
FLINT MI 48505

Sample Number: LLF44687

Sample/Collection Information:

WSSN: 02310

County: Genesee

Township:

Section:

Well #:

Collection Date: 10/28/2014 8:04:00 AM

Arrival Date: 10/29/2014 11:15:14 AM

Site Code:

Water Source: Public Community Water Supply

Sample Reason: Routine Monitoring

Sample Point: Treated Public Distribution System

Point Description: PLANT TAP

Collector: Public Water Supply Operator

Collected By: MIKE GLASGOW

<u>CasNo</u>	<u>Analyte</u>	<u>Result</u>	<u>Detect</u>	<u>Units</u>	<u>Method</u>
16984-48-8	FLUORIDE (AUTOMATED)	0.62	0.1	mg/L	SM 4500 FC
7439-89-6	IRON	ND	0.1	mg/L	SM 3500 FeB
HARD-00-C	HARDNESS AS CaCO ₃	143	20	mg/L	SM 2340 C
7440-23-5	SODIUM	18	5	mg/L	SM 3500 NaB
7440-38-2	ARSENIC (TOTAL)	ND	0.002	mg/L	EPA 200.8
7440-39-3	BARIUM	0.02	0.01	mg/L	EPA 200.8
7440-41-7	BERYLLIUM	ND	0.0004	mg/L	EPA 200.8
57-12-5	CYANIDE	ND	0.02	mg/L	OIA-1677
7440-43-9	CADMIUM (TOTAL)	ND	0.0003	mg/L	EPA 200.8
7647-14-5	CHLORIDE (AUTOMATED)	60	4	mg/L	SM 4500-Cl E
7440-47-3	CHROMIUM (TOTAL)	ND	0.01	mg/L	EPA 200.8
93-76-5	2,4,5-T	ND	0.002	mg/L	EPA 515.4
93-72-1	2,4,5-TP (SILVEX)	ND	0.0003	mg/L	EPA 515.4
94-75-7	2,4-D	ND	0.002	mg/L	EPA 515.4
50594-66-6	ACIFLUORFEN	ND	0.004	mg/L	EPA 515.4
25057-89-0	BENTAZON	ND	0.002	mg/L	EPA 515.4
1918-00-9	DICAMBA	ND	0.002	mg/L	EPA 515.4
88-85-7	DINOSEB	ND	0.0003	mg/L	EPA 515.4
87-86-5	PENTACHLOROPHENOL	ND	0.00006	mg/L	EPA 515.4
1918-02-1	PICLORAM	ND	0.001	mg/L	EPA 515.4
1861-32-1	TOTAL DCPA, MONO & DI-ACID DEGRADATES	ND	0.001	mg/L	EPA 515.4
116-06-3	ALDICARB	ND	0.0005	mg/L	EPA 531.2
1646-88-4	ALDICARB SULFONE	ND	0.0005	mg/L	EPA 531.2
1646-87-3	ALDICARB SULFOXIDE	ND	0.0005	mg/L	EPA 531.2
63-25-2	CARBARYL	ND	0.001	mg/L	EPA 531.2
1563-66-2	CARBOFURAN	ND	0.0005	mg/L	EPA 531.2
16655-82-6	HYDROXYCARBOFURAN,3-	ND	0.001	mg/L	EPA 531.2
2032-65-7	METHIOCARB	ND	0.001	mg/L	EPA 531.2
16752-77-5	METHOMYL	ND	0.001	mg/L	EPA 531.2
23135-22-0	OXAMYL	ND	0.001	mg/L	EPA 531.2
114-26-1	PROPOXUR (BAYGON)	ND	0.001	mg/L	EPA 531.2
34256-82-1	ACETOCHLOR	ND	0.001	mg/L	EPA 525.2

Laboratory Sample Report

Page 2 of 3

15972-60-8	ALACHLOR	ND	0.0002	mg/L	EPA 525.2
309-00-2	ALDRIN	ND	0.0004	mg/L	EPA 525.2
1912-24-9	ATRAZINE	ND	0.0002	mg/L	EPA 525.2
5103-71-9	CHLORDANE, ALPHA-	ND	0.0002	mg/L	EPA 525.2
5103-74-2	CHLORDANE, GAMMA-	ND	0.0002	mg/L	EPA 525.2
72-54-8	DOD,4,4'-	ND	0.001	mg/L	EPA 525.2
72-55-9	DDE,4,4'-	ND	0.001	mg/L	EPA 525.2
50-29-3	DDT,4,4'-	ND	0.0005	mg/L	EPA 525.2
60-57-1	DIELDRIN	ND	0.0005	mg/L	EPA 525.2
72-20-8	ENDRIN	ND	0.0001	mg/L	EPA 525.2
7421-93-4	ENDRIN ALDEHYDE	ND	0.001	mg/L	EPA 525.2
76-44-8	HEPTACHLOR	ND	0.0002	mg/L	EPA 525.2
1024-57-3	HEPTACHLOR EPOXIDE	ND	0.0001	mg/L	EPA 525.2
118-74-1	HEXACHLOROBENZENE	ND	0.0001	mg/L	EPA 525.2
319-84-6	HEXACHLOROCYCLOHEXANE (ALPHA-BHC)	ND	0.001	mg/L	EPA 525.2
319-85-7	HEXACHLOROCYCLOHEXANE (BETA-BHC)	ND	0.001	mg/L	EPA 525.2
319-86-8	HEXACHLOROCYCLOHEXANE (DELTA-BHC)	ND	0.001	mg/L	EPA 525.2
77-47-4	HEXACHLOROCYCLOPENTADIENE	ND	0.0005	mg/L	EPA 525.2
58-89-9	LINDANE (GAMMA-BHC)	ND	0.0001	mg/L	EPA 525.2
72-43-5	METHOXYCHLOR	ND	0.0001	mg/L	EPA 525.2
51218-45-2	METOLACHLOR	ND	0.001	mg/L	EPA 525.2
21087-64-9	METRIBUZIN	ND	0.001	mg/L	EPA 525.2
2212-67-1	MOLINATE	ND	0.0005	mg/L	EPA 525.2
12674-11-2	PCB (AROCLOR 1016)	ND	0.0001	mg/L	EPA 525.2
11104-28-2	PCB (AROCLOR 1221)	ND	0.0001	mg/L	EPA 525.2
11141-16-5	PCB (AROCLOR 1232)	ND	0.0001	mg/L	EPA 525.2
53469-21-9	PCB (AROCLOR 1242)	ND	0.0001	mg/L	EPA 525.2
12672-29-6	PCB (AROCLOR 1248)	ND	0.0001	mg/L	EPA 525.2
11097-69-1	PCB (AROCLOR 1254)	ND	0.0001	mg/L	EPA 525.2
11096-82-5	PCB (AROCLOR 1260)	ND	0.0001	mg/L	EPA 525.2
59536-65-1	POLYBROMINATED BIPHENYLS	ND	0.0001	mg/L	EPA 525.2
122-34-9	SIMAZINE	ND	0.0002	mg/L	EPA 525.2
8001-35-2	TOXAPHENE	ND	0.001	mg/L	EPA 525.2
71-43-2	BENZENE	ND	0.0005	mg/L	EPA 524.2
108-86-1	BROMOBENZENE	ND	0.0005	mg/L	EPA 524.2
74-97-5	BROMOCHLOROMETHANE	ND	0.0005	mg/L	EPA 524.2
75-25-2	BROMOFORM	0.0014	0.0005	mg/L	EPA 524.2
74-83-9	BROMOMETHANE	ND	0.001	mg/L	EPA 524.2
104-51-8	BUTYLBENZENE,NORMAL-	ND	0.0005	mg/L	EPA 524.2
135-98-8	BUTYLBENZENE,SEC-	ND	0.0005	mg/L	EPA 524.2
98-06-6	BUTYLBENZENE,TERT-	ND	0.0005	mg/L	EPA 524.2
56-23-5	CARBON TETRACHLORIDE	ND	0.0005	mg/L	EPA 524.2
108-90-7	CHLOROBENZENE	ND	0.0005	mg/L	EPA 524.2
124-48-1	CHLORODIBROMOMETHANE	0.0080	0.0005	mg/L	EPA 524.2
75-00-3	CHLOROETHANE	ND	0.0005	mg/L	EPA 524.2
67-66-3	CHLOROFORM	0.012	0.0005	mg/L	EPA 524.2
74-87-3	CHLOROMETHANE	ND	0.0005	mg/L	EPA 524.2
95-49-8	CHLOROTOLUENE,2-	ND	0.0005	mg/L	EPA 524.2
106-43-4	CHLOROTOLUENE,4-	ND	0.0005	mg/L	EPA 524.2
74-95-3	DIBROMOMETHANE	ND	0.0005	mg/L	EPA 524.2
96-50-1	DICHLOROBENZENE,1,2-	ND	0.0005	mg/L	EPA 524.2
541-73-1	DICHLOROBENZENE,1,3-	ND	0.0005	mg/L	EPA 524.2
106-46-7	DICHLOROBENZENE,1,4-	ND	0.0005	mg/L	EPA 524.2
75-27-4	DICHLOROBROMOMETHANE	0.012	0.0005	mg/L	EPA 524.2
75-71-8	DICHLORODIFLUOROMETHANE	ND	0.001	mg/L	EPA 524.2
75-34-3	DICHLOROETHANE,1,1-	ND	0.0005	mg/L	EPA 524.2
107-06-2	DICHLOROETHANE,1,2-	ND	0.0005	mg/L	EPA 524.2

Laboratory Sample Report

Page 3 of 3

	DICHLOROETHYLENE,1,1-	ND	0.0005	mg/L	EPA 524.2
156-59-2	DICHLOROETHYLENE,1,2-CIS	ND	0.0005	mg/L	EPA 524.2
156-60-5	DICHLOROETHYLENE,1,2-TRANS	ND	0.0005	mg/L	EPA 524.2
78-87-5	DICHLOROPROPANE,1,2-	ND	0.0005	mg/L	EPA 524.2
142-28-9	DICHLOROPROPANE,1,3-	ND	0.0005	mg/L	EPA 524.2
594-20-7	DICHLOROPROPANE,2,2-	ND	0.0005	mg/L	EPA 524.2
563-58-6	DICHLOROPROPENE,1,1-	ND	0.0005	mg/L	EPA 524.2
10061-01-5	DICHLOROPROPENE,1,3-CIS	ND	0.0005	mg/L	EPA 524.2
10061-02-6	DICHLOROPROPENE,1,3-TRANS	ND	0.0005	mg/L	EPA 524.2
100-41-4	ETHYLBENZENE	ND	0.0005	mg/L	EPA 524.2
75-69-4	FLUOROTRICHLOROMETHANE	ND	0.001	mg/L	EPA 524.2
87-88-3	HEXACHLOROBUTADIENE	ND	0.0005	mg/L	EPA 524.2
98-82-8	ISOPROPYL BENZENE	ND	0.0005	mg/L	EPA 524.2
99-87-6	ISOPROPYL TOLUENE, PARA-	ND	0.0005	mg/L	EPA 524.2
78-93-3	METHYL ETHYL KETONE	ND	0.005	mg/L	EPA 524.2
108-10-1	METHYL ISOBUTYL KETONE	ND	0.005	mg/L	EPA 524.2
1634-04-4	METHYL TERT-BUTYL ETHER	ND	0.001	mg/L	EPA 524.2
75-09-2	METHYLENE CHLORIDE	ND	0.0006	mg/L	EPA 524.2
91-20-3	NAPHTHALENE	ND	0.0005	mg/L	EPA 524.2
98-95-3	NITROBENZENE	ND	0.01	mg/L	EPA 524.2
103-65-1	PROPYLBENZENE, NORMAL-	ND	0.0005	mg/L	EPA 524.2
100-42-5	STYRENE	ND	0.0005	mg/L	EPA 524.2
630-20-6	TETRACHLOROETHANE,1,1,1,2-	ND	0.0005	mg/L	EPA 524.2
79-34-5	TETRACHLOROETHANE,1,1,2,2-	ND	0.0005	mg/L	EPA 524.2
127-18-4	TETRACHLOROETHYLENE	ND	0.0005	mg/L	EPA 524.2
109-99-9	TETRAHYDROFURAN	ND	0.005	mg/L	EPA 524.2
108-88-3	TOLUENE	ND	0.0005	mg/L	EPA 524.2
TTHM-00-C	TOTAL TRIHALOMETHANES	0.033	NA	mg/L	EPA 524.2
87-61-6	TRICHLOROBENZENE,1,2,3-	ND	0.0005	mg/L	EPA 524.2
120-82-1	TRICHLOROBENZENE,1,2,4-	ND	0.0005	mg/L	EPA 524.2
71-55-6	TRICHLOROETHANE,1,1,1-	ND	0.0005	mg/L	EPA 524.2
79-00-5	TRICHLOROETHANE,1,1,2-	ND	0.0005	mg/L	EPA 524.2
79-01-6	TRICHLOROETHYLENE	ND	0.0005	mg/L	EPA 524.2
96-18-4	TRICHLOROPROPANE,1,2,3-	ND	0.0005	mg/L	EPA 524.2
95-63-6	TRIMETHYLBENZENE,1,2,4-	ND	0.0005	mg/L	EPA 524.2
108-67-8	TRIMETHYLBENZENE,1,3,5-	ND	0.0005	mg/L	EPA 524.2
75-01-4	VINYL CHLORIDE	ND	0.0004	mg/L	EPA 524.2
XYLMP-00-C	XYLENE,META-&PARA-	0.0005	0.0005	mg/L	EPA 524.2
95-47-6	XYLENE,ORTHO-	ND	0.0005	mg/L	EPA 524.2
1330-20-7	XYLENES (TOTAL)	0.0005	NA	mg/L	EPA 524.2
7439-97-6	MERCURY	ND	0.0001	mg/L	EPA 200.8
7440-02-0	NICKEL	ND	0.01	mg/L	EPA 200.8
14797-65-0	NITRITE AS N (AUTOMATED)	ND	0.05	mg/L	10-107-04-2-B
14797-55-8	NITRATE AS N (AUTOMATED)	ND	0.4	mg/L	10-107-04-2-B
7439-92-1	LEAD (TOTAL)	ND	0.001	mg/L	EPA 200.8
7440-36-0	ANTIMONY	ND	0.0006	mg/L	EPA 200.8
7782-49-2	SELENIUM (TOTAL)	ND	0.001	mg/L	EPA 200.8
14808-79-8	SULFATE (AUTOMATED)	22	10	mg/L	SM 4500 SO4E
7440-28-0	THALLIUM	ND	0.0002	mg/L	EPA 200.8

Laboratory Comments:

A trip blank was not available for analysis with this sample.

By authority of PA 368 of 1978 as amended.

Print Date: Mon Feb 9 13:50:23 EST
2015

Lake Huron Water Treatment Plant 2013 Regulated Detected Contaminants Tables

Regulated Contaminant	Test Date	Units	Health Goal MCLG	Allowed Level MCL	Highest Level Detected	Range of Detection	Violation	Major Sources in Drinking Water
Inorganic Chemicals – Monitoring at Plant Finished Water Tap								
Fluoride	05/13/2013	ppm	4	4	0.55	n/a	No	Erosion of natural deposits; Water additive, which promotes strong teeth; Discharge from fertilizer and aluminum factories.
Nitrate	05/13/2013	ppm	10	10	0.32	n/a	No	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits.
Barium	6/9/2008	ppm	2	2	0.01	n/a	No	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits

Disinfection By-Products – Monitoring in Distribution System								
Contaminant	Test Date	Units	Health Goal MCLG	Allowed Level MCL	Highest LRAA	Range of Detection	Violation	Major Sources in Drinking Water
Total Trihalomethanes (TTHM)	2013	ppb	n/a	80	37.8	11.5 – 43.8	No	By-product of drinking water chlorination
Halooacetic Acids (HAA5)	2013	ppb	n/a	60	17.0	6.0 – 19.0	No	By-product of drinking water disinfection

Disinfectant Residuals Monitoring in Distribution System								
Contaminant	Test Date	Units	Health Goal	Allowed Level	Highest RAA	Range of Detection	Violation	Major Sources in Drinking Water
Disinfectant Total Chlorine Residual	Jan-Dec 2013	ppm	MRDGL 4	MRDL 4	0.81	0.65-0.93	No	Water additive used to control microbes

2013 Turbidity – Monitored every 4 hours at Plant Finished Water Tap			
Highest Single Measurement Cannot exceed 1 NTU	Lowest Monthly % of Samples Meeting Turbidity Limit of 0.3 NTU (minimum 95%)	Violation	Major Sources in Drinking Water
0.26 NTU	100%	No	Soil Runoff
Turbidity is a measure of the cloudiness of water. We monitor it because it is a good indicator of the effectiveness of our filtration system.			

2013 Microbiological Contaminants – Monthly Monitoring in Distribution System								
Regulated Contaminant	MCLG	MCL		Highest Number Detected		Violation	Major Sources in Drinking Water	
Total Coliform Bacteria	0	Presence of Coliform bacteria > 5% of monthly samples		In one month 1		No	Naturally present in the environment.	
<i>E. coli</i> or Fecal Coliform Bacteria	0	A routine sample and a repeat sample are total coliform positive, and one is also fecal or <i>E. coli</i> positive.		entire year 0		No	Human waste and animal fecal waste.	

2011 Lead and Copper Monitoring at Customers' Tap								
Regulated Contaminant	Test Date	Units	Health Goal MCLG	Action Level AL	90 th Percentile Value*	Number of Samples Over AL	Violation	Major Sources in Drinking Water
Lead	2011	ppb	0	15	< 2.0	0	No	Corrosion of household plumbing system; Erosion of natural deposits.
Copper	2011	ppm	1.3	1.3	0.10	0	No	Corrosion of household plumbing system; Erosion of natural deposits; Leaching from wood preservatives.

*The 90th percentile value means 90 percent of the homes tested have lead and copper levels below the given 90th percentile value. If the 90th percentile value is above the AL, additional requirements must be met.

Regulated Contaminant	Treatment Technique		Typical Source of Contaminant
Total Organic Carbon (ppm)	The Total Organic Carbon (TOC) removal ratio is calculated as the ratio between the actual TOC removal and the TOC removal requirements. The TOC was measured each month and because the level was low, there is no requirement for TOC removal.		Erosion of natural deposits

2013 Special Monitoring

Contaminant	MCLG	MCL	Level Detected	Source of Contamination
Sodium (ppm)	n/a	n/a	4.52	Erosion of natural deposits

Collection, sampling result information and table provided by Detroit Water and Sewerage Department (DWSD) Water Quality Division, ML Semegen

Additional sample result information provided by the City of Flint Water Plant Laboratory, M Glasgow

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Monday, February 09, 2015 2:30 PM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: RE: question on flushing/water rates in MI

Thank you, Richard. Yes, Steve B explained to me this morning, that the commodity charge is based upon the amount of water the resident is using; however, the base rate/service charge would include operation and maintenance costs, including flushing.

Jen

From: Benzie, Richard (DEQ) [mailto:BENZIER@michigan.gov]
Sent: Monday, February 09, 2015 12:57 PM
To: Crooks, Jennifer; Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: RE: question on flushing/water rates in MI

There currently is no regulatory oversight of rates in Michigan.

But be careful about saying residents aren't paying for water used for flushing – as the overall costs of operating the water system have to be reflected in the revenue stream somewhere. The rates probably reflect the cost of producing "lost" water, just not in an accountable manner. If you say they are paying for it (even directly), it may still generate a negative reaction if they realize the costs are "hidden" and being borne by all customers.

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Monday, February 09, 2015 12:12 PM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: question on flushing/water rates in MI

Richard—I have a couple of questions for you regarding the citizen complaint on Flint, that I'm responding to.

Regarding the water rates part of this email, "Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, **then charging consumers double for their mistake**"

I was going to remind the citizen that they are only charged based upon what the water meter reads at individual connection (home). The citizens aren't directly paying for what is being flushed. I was going to say that the flushing program removes stagnant water in the system, which can increase levels of trihalomethanes and increase bacteria growth, among other activities.

Also, who regulates water rates in Michigan? I don't think MI has a rate commission, right? Any oversight on individual water supply rates?

Jennifer

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:22 AM
To: Richard Benzie; Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: FYI: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Forgot to cc you all. Jen

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:09 AM
To: Dee, Rhiannon
Cc: Poy, Thomas
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon—Let me tell you, this Flint situation is a nasty issue—I've had people call me 4 letter words over the phone, yell at me, and call me a crook—yes, the last one was a play on my last name—I didn't think it was funny, though I'm developing a thick skin 😊.

I can respond to the Flint drinking water issue, and the water rate issue, and refer them back to the State if they have further questions. But I cannot respond to the sewerage dump (who receives the report when there is a sewer overflow?) or the chemical—though Richard is probably right—the 'toxic chemical' is probably chlorine—and that's what I'll say in my response. One citizen was confused about 'chlorides' being 'chlorine'....

Let me know if you would like me to respond to this citizen complaint as I explained above.

Jennifer

From: Dee, Rhiannon
Sent: Friday, February 06, 2015 10:50 AM
To: Benzie, Richard (DEQ)
Cc: ostlundp@michigan.gov; Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas; Vantil, Barbara
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Richard,

While I understand this complaint conflates various issues, my intention of forwarding it on to Pete and Barry was to relay the potential NPDES impacts of the complainants allegations.

Best,

Rhiannon Dee
 Program Analyst
 U.S. Environmental Protection Agency
 Water Division, WC-15J
 (312) 886-4882
dee.rhiannon@epa.gov

From: Benzie, Richard (DEQ) [<mailto:BENZIER@michigan.gov>]
Sent: Friday, February 06, 2015 9:38 AM
To: Dee, Rhiannon
Cc: ostlundp@michigan.gov; Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

I'm not sure what this complainant is alleging. Do you want Michigan to respond to the allegation that a "company or individual dumped millions of gallons of raw sewage into the city of Flint drinking water" or the allegation that "they(?) have dumped a potential cancer causing chemical into the city's drinking water" or the allegation that the city of Flint is flushing hydrants and charging customers double? The Office of Drinking Water and Municipal Assistance cannot address the issue surrounding the dumping of raw sewage and we don't interfere with water rates, but maybe an explanation of the issues that have confronted the city of Flint and their public water supply will help you understand the overall problem.

Last spring, the city of Flint decided to begin relying upon the Flint River as their source of drinking water using a treatment plant that was designed to do so. Last summer, they experienced difficulties with stagnation in some areas of the distribution system due to significantly reduced demands as a result of the loss of a significant percentage of their residential and industrial demands that accelerated over the last decade. During the summer of 2014, they also had a couple of monitoring periods where they detected total coliform at monitoring sites in these stagnant areas, and one time they detected E.coli present. The ensuing boil water advisories and public notification heightened customer concern about the quality of drinking water as a result of the switch from Detroit to the Flint River. Detroit supplied Flint with drinking water from Lake Huron, a much higher quality source than the Flint River. However, monitoring of the Flint water treatment plant tap has never indicated unacceptable water entering the distribution system. In response to these coliform detections and in an effort to prevent a recurrence, the city also increased flushing water mains in low flow areas and they have attempted to ensure the presence of a chlorine residual throughout the distribution system (is this the "potential cancer causing chemical" the complainant mentions?).

Compounding the problem of customer confidence was the initial monitoring for disinfection byproducts conducted by Flint under the Stage 2 DBR after their switch to the Flint River. The initial monitoring reported significantly elevated levels of total trihalomethane (TTHM) compounds throughout the city's distribution system. Our district office advised the city that they needed to immediately implement operational techniques at the treatment plant and in the distribution system to reduce the formation of these compounds. The steps the city of Flint has taken have been successful and have reduced TTHM concentrations to the point where the latest results are below the drinking water standard. However, the standard is calculated on a running annual average and it is likely to be another 3 to 6 months before the annual average at each monitoring station will (hopefully) meet the standard. Until then, the city has to continue to provide quarterly public notification, which will continue to concern residents despite the latest TTHM results.

The switch to the Flint River, the microbiological problems and the elevated TTHM concentrations experienced last year in Flint have caused a high level of customer dissatisfaction and distrust. The city is working diligently to restore that confidence, but it will not be accomplished easily or overnight. You should also know that the switch to the Flint River is an interim measure intended to last only until a 72-inch pipeline from Lake Huron to the Flint water treatment plant is completed. It is currently under construction and expected to be in operation in mid-2016. At that point, the city's drinking water should again be very similar in quality to what they were receiving from Detroit.

Although the subject(s) of this complaint are not clear to me, I suspect it is a result of the media coverage of the recent problems with the city's water supply. However, the information from your initial contact indicates a Grand Blanc, Michigan address, which is not in the city of Flint service area. As I mentioned, our Lansing district office has been dealing with city representatives on this issue. If you have further questions, feel free to contact either Michael Prysby or Steve Busch. They are receiving this message so you have their contact information. You may also wish to communicate with your Region 5 counterparts in the Office of Drinking Water & Ground Water, Jennifer Crooks or Tom Poy, who have received similar complaints and with whom we have communicated regularly on these issues.

Please let us know if someone from EPA will respond to the complainant, or if you expect Michigan DEQ to do so.

Richard Benzie, P.E., Chief
Field Operations Section
Office of Drinking Water and Municipal Assistance, MDEQ
517-284-6512

From: Ostlund, Peter (DEQ)
Sent: Friday, February 06, 2015 6:55 AM

To: Dee, Rhiannon
Cc: Selden, Barry (DEQ); Benzie, Richard (DEQ); Bartley, Cheryl (DEQ)
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon, this is a drinking water complaint, not an NPDES complaint. Flint does have SSOs, and reports those. That's not the cause of this complaint.

There are public concerns with Flint's drinking water system, which switch from the city of Detroit supply to their own supply. Detroit's source water is much better, so the public may be noticing some changes.

I've copied Richard Benzie, how is the Field Operations Chief in our division that handles drinking water. If you need more follow up, he can provide it.

Thanks, Pete

Peter Ostlund
 Field Operations Section Chief
 Water Resources Division
 Michigan Dept. of Environmental Quality
 P.O. Box 30458
 Lansing, Michigan 48909-7958
 517-898-5128 (iPhone)
ostlundp@michigan.gov

From: Dee, Rhiannon [<mailto:dee.Rhiannon@epa.gov>]
Sent: Thursday, February 05, 2015 5:11 PM
To: Ostlund, Peter (DEQ); Selden, Barry (DEQ)
Subject: FW: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Hi there,

Hope all is well. We received this complaint a while back. Complainant is alleging discharges into Flint River.

Let me know if you have any questions or if I should forward this on to someone else.

Best,

Rhiannon Dee
 Program Analyst
 U.S. Environmental Protection Agency
 Water Division, WC-15J
 (312) 886-4882
dee.rhiannon@epa.gov

From: howard.donna@epa.gov [<mailto:howard.donna@epa.gov>]
Sent: Monday, January 12, 2015 11:21 AM
To: Dee, Rhiannon
Cc: Beese, Jennifer
Subject: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

01/12/2015

SUBJECT: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

FROM: howard.donna@epa.gov
TO: Dee.Rhiannon@epa.gov
CC: Beese.Jennifer@epa.gov

-----Original Message-----

1/11/2015 10:55 AM

HQ LEAD NUMBER: FY15-124819-3709-CV

SUBJECT: Referred to Region - Michigan

FROM: sargent

TO:

Name: marcia

Address: po box 277

City: grand blanc

State: Michigan

Zip: 48480

Phone: 8103368486

Alleged Violator's Name: city of flint michigan

Alleged Violator's Address: water department

Alleged Violator's City: flint

Alleged Violator's State: Michigan

Alleged Violator's Zip: 48503

Tip or Complaint: an individual or company dumped several million gallons of raw sewage into the city of flint Michigan drinking water and now they have dumped a potential cancer causing chemical into the water to cover up their negligent act. people are getting sick and skin rashes are becoming apparent, especially in the young and elderly. we will keep going until something is done to correct this "mistake"

Specific Directions: Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, then charging consumers double for their mistake.

Violation Still Occurring? Yes

State DEP/DEQ/DEM Notified? Yes

Rennaker, Joanne (DEQ)

From: Benzie, Richard (DEQ)
Sent: Monday, February 09, 2015 1:57 PM
To: Crooks, Jennifer; Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: RE: question on flushing/water rates in MI

There currently is no regulatory oversight of rates in Michigan.

But be careful about saying residents aren't paying for water used for flushing – as the overall costs of operating the water system have to be reflected in the revenue stream somewhere. The rates probably reflect the cost of producing "lost" water, just not in an accountable manner. If you say they are paying for it (even directly), it may still generate a negative reaction if they realize the costs are "hidden" and being borne by all customers.

From: Crooks, Jennifer [mailto:crooks.jennifer@epa.gov]
Sent: Monday, February 09, 2015 12:12 PM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: question on flushing/water rates in MI

Richard—I have a couple of questions for you regarding the citizen complaint on Flint, that I'm responding to.

Regarding the water rates part of this email, "Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, **then charging consumers double for their mistake**"

I was going to remind the citizen that they are only charged based upon what the water meter reads at individual connection (home). The citizens aren't directly paying for what is being flushed. I was going to say that the flushing program removes stagnant water in the system, which can increase levels of trihalomethanes and increase bacteria growth, among other activities.

Also, who regulates water rates in Michigan? I don't think MI has a rate commission, right? Any oversight on individual water supply rates?

Jennifer

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:22 AM
To: Richard Benzie; Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: FYI: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Forgot to cc you all. Jen

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:09 AM
To: Dee, Rhiannon
Cc: Poy, Thomas
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon—Let me tell you, this Flint situation is a nasty issue—I've had people call me 4 letter words over the phone, yell at me, and call me a crook—yes, the last one was a play on my last name—I didn't think it was funny, though I'm developing a thick skin ☺.

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Let me know if you would like me to respond to this citizen complaint as I explained above.

Jennifer

From: Dee, Rhiannon

Sent: Friday, February 06, 2015 10:50 AM

To: Benzie, Richard (DEQ)

Cc: ostlundp@michigan.gov; Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas; Vantil, Barbara

Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Richard,

While I understand this complaint conflates various issues, my intention of forwarding it on to Pete and Barry was to relay the potential NPDES impacts of the complainants allegations.

Best,

Rhiannon Dee

Program Analyst

U.S. Environmental Protection Agency

Water Division, WC-15J

(312) 886-4882

dee.rhiannon@epa.gov

From: Benzie, Richard (DEQ) [<mailto:BENZIER@michigan.gov>]

Sent: Friday, February 06, 2015 9:38 AM

To: Dee, Rhiannon

Cc: ostlundp@michigan.gov; Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas

Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

I’m not sure what this complainant is alleging. Do you want Michigan to respond to the allegation that a “company or individual dumped millions of gallons of raw sewage into the city of Flint drinking water” or the allegation that “they(?) have dumped a potential cancer causing chemical into the city’s drinking water” or the allegation that the city of Flint is flushing hydrants and charging customers double? The Office of Drinking Water and Municipal Assistance cannot address the issue surrounding the dumping of raw sewage and we don’t interfere with water rates, but maybe an explanation of the issues that have confronted the city of Flint and their public water supply will help you understand the overall problem.

Last spring, the city of Flint decided to begin relying upon the Flint River as their source of drinking water using a treatment plant that was designed to do so. Last summer, they experienced difficulties with stagnation in some areas of the distribution system due to significantly reduced demands as a result of the loss of a significant percentage of their residential and industrial demands that accelerated over the last decade. During the summer of 2014, they also had a couple of monitoring periods where they detected total coliform at monitoring sites in these stagnant areas, and one time they detected E.coli present. The ensuing boil water advisories and public notification heightened customer concern about the quality of drinking water as a result of the switch from Detroit to the Flint River. Detroit supplied Flint with drinking water from Lake Huron, a much higher quality source than the Flint River. However, monitoring of the Flint water treatment plant tap has never indicated unacceptable water entering the distribution system. In response to these coliform detections and in

an effort to prevent a recurrence, the city also increased flushing water mains in low flow areas and they have attempted to ensure the presence of a chlorine residual throughout the distribution system (is this the "potential cancer causing chemical" the complainant mentions?).

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The switch to the Flint River, the microbiological problems and the elevated TTHM concentrations experienced last year in Flint have caused a high level of customer dissatisfaction and distrust. The city is working diligently to restore that confidence, but it will not be accomplished easily or overnight. You should also know that the switch to the Flint River is an interim measure intended to last only until a 72-inch pipeline from Lake Huron to the Flint water treatment plant is completed. It is currently under construction and expected to be in operation in mid-2016. At that point, the city's drinking water should again be very similar in quality to what they were receiving from Detroit.

Although the subject(s) of this complaint are not clear to me, I suspect it is a result of the media coverage of the recent problems with the city's water supply. However, the information from your initial contact indicates a Grand Blanc, Michigan address, which is not in the city of Flint service area. As I mentioned, our Lansing district office has been dealing with city representatives on this issue. If you have further questions, feel free to contact either Michael Prysby or Steve Busch. They are receiving this message so you have their contact information. You may also wish to communicate with your Region 5 counterparts in the Office of Drinking Water & Ground Water, Jennifer Crooks or Tom Poy, who have received similar complaints and with whom we have communicated regularly on these issues.

Please let us know if someone from EPA will respond to the complainant, or if you expect Michigan DEQ to do so.

Richard Benzie, P.E., Chief
Field Operations Section
Office of Drinking Water and Municipal Assistance, MDEQ
517-284-6512

From: Ostlund, Peter (DEQ)
Sent: Friday, February 06, 2015 6:55 AM
To: Dee, Rhiannon
Cc: Selden, Barry (DEQ); Benzie, Richard (DEQ); Bartley, Cheryl (DEQ)
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon, this is a drinking water complaint, not an NPDES complaint. Flint does have SSOs, and reports those. That's not the cause of this complaint.

There are public concerns with Flint's drinking water system, which switch from the city of Detroit supply to their own supply. Detroit's source water is much better, so the public may be noticing some changes.

I've copied Richard Benzie, how is the Field Operations Chief in our division that handles drinking water. If you need more follow up, he can provide it.

Thanks, Pete

Peter Ostlund
Field Operations Section Chief
Water Resources Division
Michigan Dept. of Environmental Quality
P.O. Box 30458
Lansing, Michigan 48909-7958
517-898-5128 (iPhone)
ostlundp@michigan.gov

From: Dee, Rhiannon [<mailto:dee.Rhiannon@epa.gov>]
Sent: Thursday, February 05, 2015 5:11 PM
To: Ostlund, Peter (DEQ); Selden, Barry (DEQ)
Subject: FW: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Hi there,

Hope all is well. We received this complaint a while back. Complainant is alleging discharges into Flint River.

Let me know if you have any questions or if I should forward this on to someone else.

Best,

Rhiannon Dee
Program Analyst
U.S. Environmental Protection Agency
Water Division, WC-15J
(312) 886-4882
dee.rhiannon@epa.gov

From: howard.donna@epa.gov [<mailto:howard.donna@epa.gov>]
Sent: Monday, January 12, 2015 11:21 AM
To: Dee, Rhiannon
Cc: Beese, Jennifer
Subject: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

01/12/2015

SUBJECT: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan
FROM: howard.donna@epa.gov
TO: Dee.Rhiannon@epa.gov
CC: Beese.Jennifer@epa.gov

-----Original Message-----

1/11/2015 10:55 AM

HQ LEAD NUMBER: FY15-124819-3709-CV

SUBJECT: Referred to Region - Michigan

FROM: sargent

TO:

Name: marcia

Address: po box 277

City: grand blanc

State: Michigan

Zip: 48480

Phone: 8103368486

Alleged Violator's Name: city of flint michigan

Alleged Violator's Address: water department

Alleged Violator's City: flint

Alleged Violator's State: Michigan

Alleged Violator's Zip: 48503

Tip or Complaint: an individual or company dumped several million gallons of raw sewage into the city of flint Michigan drinking water and now they have dumped a potential cancer causing chemical into the water to cover up their negligent act. people are getting sick and skin rashes are becoming apparent, especially in the young and elderly. we will keep going until something is done to correct this "mistake"

Specific Directions: Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, then charging consumers double for their mistake.

Violation Still Occurring? Yes

State DEP/DEQ/DEM Notified? Yes

Rennaker, Joanne (DEQ)

From: Crooks, Jennifer <crooks.jennifer@epa.gov>
Sent: Monday, February 09, 2015 12:12 PM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: question on flushing/water rates in MI

Richard—I have a couple of questions for you regarding the citizen complaint on Flint, that I'm responding to.

Regarding the water rates part of this email, "Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, **then charging consumers double for their mistake**"

I was going to remind the citizen that they are only charged based upon what the water meter reads at individual connection (home). The citizens aren't directly paying for what is being flushed. I was going to say that the flushing program removes stagnant water in the system, which can increase levels of trihalomethanes and increase bacteria growth, among other activities.

Also, who regulates water rates in Michigan? I don't think MI has a rate commission, right? Any oversight on individual water supply rates?

Jennifer

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:22 AM
To: Richard Benzie; Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: FYI: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Forgot to cc you all. Jen

From: Crooks, Jennifer
Sent: Monday, February 09, 2015 8:09 AM
To: Dee, Rhiannon
Cc: Poy, Thomas
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon—Let me tell you, this Flint situation is a nasty issue—I've had people call me 4 letter words over the phone, yell at me, and call me a crook—yes, the last one was a play on my last name—I didn't think it was funny, though I'm developing a thick skin ☺.

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From: Dee, Rhiannon
Sent: Friday, February 06, 2015 10:50 AM

To: Benzie, Richard (DEQ)

Cc: ostlundp@michigan.gov; Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas; Vantil, Barbara

Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

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Sent: Friday, February 06, 2015 9:38 AM

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P.O. Box 30458
Lansing, Michigan 48909-7958
517-898-5128 (iPhone)
ostlundp@michigan.gov

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U.S. Environmental Protection Agency
Water Division, WC-15J
(312) 886-4882
dee.rhiannon@epa.gov

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Sent: Monday, January 12, 2015 11:21 AM
To: Dee, Rhiannon
Cc: Beese, Jennifer
Subject: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

01/12/2015

SUBJECT: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan
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TO: Dee.Rhiannon@epa.gov
CC: Beese.Jennifer@epa.gov

-----Original Message-----

1/11/2015 10:55 AM

HQ LEAD NUMBER: FY15-124819-3709-CV

SUBJECT: Referred to Region - Michigan

FROM: sargent

TO:

Name: marcia

Address: po box 277

City: grand blanc

State: Michigan

Zip: 48480

Phone: 8103368486

Alleged Violator's Name: city of flint michigan

Alleged Violator's Address: water department

Alleged Violator's City: flint

Alleged Violator's State: Michigan

Alleged Violator's Zip: 48503

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Violation Still Occurring? Yes

State DEP/DEQ/DEM Notified? Yes

Rennaker, Joanne (DEQ)

From: Cook, Pat (DEQ)
Sent: Monday, February 09, 2015 10:36 AM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: RE: EarthTec

I have heard of EarthTec, but to my knowledge there are no MI WTP's using it. Every year or so we get an inquiry about it, but nobody ever follows through and actually uses it. I think some WTP superintendents get scared off by adding a product that contains copper, but as you can see in the product literature very little Cu is in the finished product. As long as it's NSF approved, we can allow it.

pat

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 4:00 PM
To: Busch, Stephen (DEQ)
Cc: Cook, Pat (DEQ)
Subject: Fwd: EarthTec for taste and odor issues

I will look at this on Monday but thought I would forward it to you in case you have dealt with this type of treatment.

Sent from my iPhone

Begin forwarded message:

From: "Hansen, Jeff" <jrhansen@lan-inc.com>
To: "Prysby, Mike (DEQ)" <PRYSBYM@michigan.gov>
Subject: FW: EarthTec for taste and odor issues

Hi Mike,

Has the DEQ had any dealings with the attached product, EarthTec? Specifically, do you know if it is approved for drinking water applications in Michigan?

Jeffrey R. Hansen
 Senior Project Manager

From: David Carrington [<mailto:davidcarrington@earthsciencelabs.com>]
Sent: Friday, February 06, 2015 11:03 AM
To: Hansen, Jeff
Subject: Fw: EarthTec for taste and odor issues

see below.

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com

[Description: Image removed by sender. Publication1]

From: David Carrington
Sent: Friday, February 6, 2015 9:53 AM
To: eschiebold; jhansen@lan-inc.com
Cc: Allan Goldschmidt
Subject: Re: EarthTec for taste and odor issues

Jeff-

- * EarthTec is a liquid copper based product that has been used as a municipal water pretreatment chemical for the past 20 years.
- * NSF Certified.
- * We have hundreds of installations.
- * It essentially reacts with algae and organics to improve the water quality coming in to the plant.
- * There are no resulting dbp's with our product.
- * The product is normally dosed at 1 ppm at the raw water intake and reacts with the water prior to the treatment plant.
- * The copper is 100% cupric CU++ ions which are toxic and bioavailable. The actual copper level is only 60 ppb at 1 ppm.
- * The product stays in solution indefinitely until it reacts based on water demand.
- * Product has a negative charge and usually reduces the amount of coagulant required
- * We have several plants running ozone. No adverse effects with any oxidant. Should be able to reduce ozone feed rates assuming EarthTec reduces the organic loading.

I have attached some general information for your review. Please feel free to contact me with any questions.

Thanks,

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com

[Description: Image removed by sender. Publication1]

From: eschiebold <eschiebold@aol.com>
Sent: Friday, February 6, 2015 9:01 AM

To: David Carrington
Subject: Fwd: EarthTec for taste and odor issues

Dear Dave:
Please respond ASAP.

Sincerely,
Eric Schiebold
Environmental Sales, Inc.
17348 W 12 Mile Road
Suite 103
Southfield, MI 48076-6325
vox 248-569-9393
fax 248-569-9388
cell 248-761-7195

-----Original Message-----

From: Hansen, Jeff <jrhansen@lan-inc.com>
To: eschiebold <eschiebold@aol.com>
Sent: Fri, Feb 6, 2015 9:58 am
Subject: RE: EarthTec for taste and odor issues
Hi Eric,

We would want to know things like:

1. What is in it?
2. What are the byproducts?
3. Is it corrosive?
4. What form and what concentration does it come in?
5. What equipment is needed to feed it?

Thanks,

Jeffrey R. Hansen
Senior Project Manager

[Description: Description: LAN]
1311 South Linden Road, Suite B • Flint, MI 48532
T 810.820.2682 C 810.333.3201
www.lan-inc.com<<http://www.lan-inc.com>> • JRHansen@lan-inc.com<<mailto:JRHansen@lan-inc.com>>

From: eschiebold [<mailto:eschiebold@aol.com><<mailto:eschiebold@aol.com>?>]
Sent: Friday, February 06, 2015 9:49 AM
To: Hansen, Jeff
Cc: davidcarrington@earthsciencelabs.com<<mailto:davidcarrington@earthsciencelabs.com>>
Subject: EarthTec for taste and odor issues

Dear Jeff:
Attached is a brochure on EarthTec for taste and odor issues. It's EPA approved and NSF

Certified. I'm told you can expect a 20-40% reduction in organics when using EarthTec. I can get you a sample of EarthTec for evaluation in the lab. I have asked for data and references at plants where EarthTech is used in combination with ozone and I'll get that to you ASAP. Unfortunately the website is under construction so there really isn't any additional information available online.

EathTec is also a very good chemical for zebra and quagga mussel control. I can send you several technical papers for that application. Just let me know if you'd like them.

Also attached is my Line Card.

Sincerely,
Eric Schiebold
Environmental Sales, Inc.
17348 W 12 Mile Road
Suite 103
Southfield, MI 48076-6325
vox 248-569-9393
fax 248-569-9388
cell 248-761-7195

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Rennaker, Joanne (DEQ)

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To: Dee, Rhiannon
Cc: Selden, Barry (DEQ); Benzie, Richard (DEQ); Bartley, Cheryl (DEQ)
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon, this is a drinking water complaint, not an NPDES complaint. Flint does have SSOs, and reports those. That's not the cause of this complaint.

There are public concerns with Flint's drinking water system, which switch from the city of Detroit supply to their own supply. Detroit's source water is much better, so the public may be noticing some changes.

I've copied Richard Benzie, how is the Field Operations Chief in our division that handles drinking water. If you need more follow up, he can provide it.

Thanks, Pete

Peter Ostlund
Field Operations Section Chief
Water Resources Division
Michigan Dept. of Environmental Quality
P.O. Box 30458
Lansing, Michigan 48909-7958
517-898-5128 (iPhone)
ostlundp@michigan.gov

From: Dee, Rhiannon [<mailto:dee.Rhiannon@epa.gov>]
Sent: Thursday, February 05, 2015 5:11 PM
To: Ostlund, Peter (DEQ); Selden, Barry (DEQ)
Subject: FW: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Hi there,

Hope all is well. We received this complaint a while back. Complainant is alleging discharges into Flint River.

Let me know if you have any questions or if I should forward this on to someone else.

Best,

Rhiannon Dee
Program Analyst
U.S. Environmental Protection Agency
Water Division, WC-15J

(312) 886-4882

dee.rhiannon@epa.gov

From: howard.donna@epa.gov [mailto:howard.donna@epa.gov]

Sent: Monday, January 12, 2015 11:21 AM

To: Dee, Rhiannon

Cc: Beese, Jennifer

Subject: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

01/12/2015

SUBJECT: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

FROM: howard.donna@epa.gov

TO: Dee.Rhiannon@epa.gov

CC: Beese.Jennifer@epa.gov

-----Original Message-----

1/11/2015 10:55 AM

HQ LEAD NUMBER: FY15-124819-3709-CV

SUBJECT: Referred to Region - Michigan

FROM: sargent

TO:

Name: marcia

Address: po box 277

City: grand blanc

State: Michigan

Zip: 48480

Phone: 8103368486

Alleged Violator's Name: city of flint michigan

Alleged Violator's Address: water department

Alleged Violator's City: flint

Alleged Violator's State: Michigan

Alleged Violator's Zip: 48503

Tip or Complaint: an individual or company dumped several million gallons of raw sewage into the city of flint Michigan drinking water and now they have dumped a potential cancer causing chemical into the water to cover up their negligent act. people are getting sick and skin rashes are becoming apparent, especially in the young and elderly. we will keep going until something is done to correct this "mistake"

Specific Directions: Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, then charging consumers double for their mistake.

Violation Still Occurring? Yes

State DEP/DEQ/DEM Notified? Yes

Rennaker, Joanne (DEQ)

From: Hansen, Jeff <jrhansen@lan-inc.com>
Sent: Friday, February 06, 2015 3:11 PM
To: Prysby, Mike (DEQ)
Subject: FW: EarthTec for taste and odor issues
Attachments: EarthTec Brochure 6-6-14.pdf; General EarthTec Info 2-6-15.pdf

Follow Up Flag: Follow up
Flag Status: Flagged

Hi Mike,

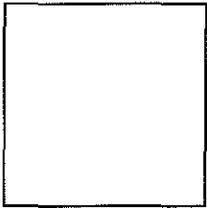
Has the DEQ had any dealings with the attached product, EarthTec? Specifically, do you know if it is approved for drinking water applications in Michigan?

Jeffrey R. Hansen
Senior Project Manager

From: David Carrington [<mailto:davidcarrington@earthsciencelabs.com>]
Sent: Friday, February 06, 2015 11:03 AM
To: Hansen, Jeff
Subject: Fw: EarthTec for taste and odor issues

see below.

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com



From: David Carrington
Sent: Friday, February 6, 2015 9:53 AM
To: eschiebold; jhansen@lan-inc.com
Cc: Allan Goldschmidt
Subject: Re: EarthTec for taste and odor issues

Jeff-

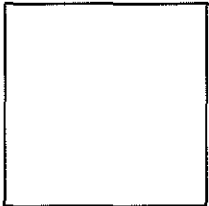
- EarthTec is a liquid copper based product that has been used as a municipal water pretreatment chemical for the past 20 years.

- NSF Certified.
- We have hundreds of installations.
- It essentially reacts with algae and organics to improve the water quality coming in to the plant.
- There are no resulting dbp's with our product.
- The product is normally dosed at 1 ppm at the raw water intake and reacts with the water prior to the treatment plant.
- The copper is 100% cupric CU++ ions which are toxic and bioavailable. The actual copper level is only 60 ppb at 1 ppm.
- The product stays in solution indefinitely until it reacts based on water demand.
- Product has a negative charge and usually reduces the amount of coagulant required
- We have several plants running ozone. No adverse effects with any oxidant. Should be able to reduce ozone feed rates assuming EarthTec reduces the organic loading.

I have attached some general information for your review. Please feel free to contact me with any questions.

Thanks,

Dave Carrington
EarthTec Business Manager
469-371-7866
EarthTecQZ.com



From: eschiebold <eschiebold@aol.com>
Sent: Friday, February 6, 2015 9:01 AM
To: David Carrington
Subject: Fwd: EarthTec for taste and odor issues

Dear Dave:
Please respond ASAP.

Sincerely,
Eric Schiebold
Environmental Sales, Inc.
17348 W 12 Mile Road
Suite 103
Southfield, MI 48076-6325
vox 248-569-9393
fax 248-569-9388
cell 248-761-7195

-----Original Message-----

From: Hansen, Jeff <jrhansen@lan-inc.com>
 To: eschiebold <eschiebold@aol.com>
 Sent: Fri, Feb 6, 2015 9:58 am
 Subject: RE: EarthTec for taste and odor issues

Hi Eric,

We would want to know things like:

1. What is in it?
2. What are the byproducts?
3. Is it corrosive?
4. What form and what concentration does it come in?
5. What equipment is needed to feed it?

Thanks,

Jeffrey R. Hansen
 Senior Project Manager



1311 South Linden Road, Suite B • Flint, MI 48532
 T 810.820.2682 C 810.333.3201
www.lan-inc.com • JRHansen@lan-inc.com

From: eschiebold [<mailto:eschiebold@aol.com>]
Sent: Friday, February 06, 2015 9:49 AM
To: Hansen, Jeff
Cc: davidcarrington@earthsciencelabs.com
Subject: EarthTec for taste and odor issues

Dear Jeff:

Attached is a brochure on EarthTec for taste and odor issues. It's EPA approved and NSF Certified. I'm told you can expect a 20-40% reduction in organics when using EarthTec. I can get you a sample of EarthTec for evaluation in the lab. I have asked for data and references at plants where EarthTech is used in combination with ozone and I'll get that to you ASAP. Unfortunately the website is under construction so there really isn't any additional information available online.

EathTec is also a very good chemical for zebra and quagga mussel control. I can send you several technical papers for that application. Just let me know if you'd like them.

Also attached is my Line Card.

Sincerely,
 Eric Schiebold
 Environmental Sales, Inc.
 17348 W 12 Mile Road
 Suite 103
 Southfield, MI 48076-6325
 vox 248-569-9393
 fax 248-569-9388
 cell 248-761-7195

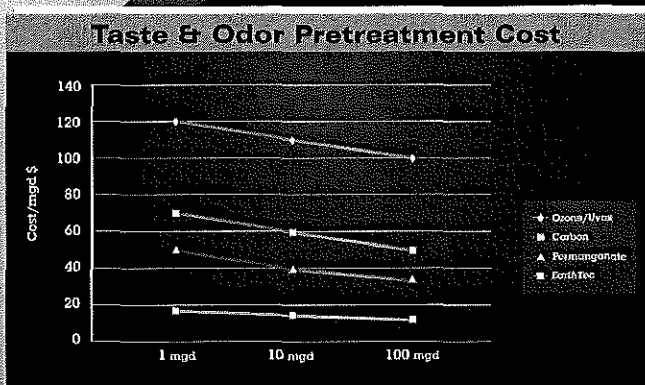
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Pretreatment solution for
Geosmin and TOC
removal

REDUCES...

- Carbon ➤ Ozone
- Alum ➤ Algae
- Permanganate
- Chlorine DBP's



NSF

EarthTec is an EPA registered algaecide/bactericide that is NSF-certified to ANSI Standard 60 for drinking water. EarthTec's unique liquid formulation is proven effective at reducing TOC, taste and odor compounds and algae prior to entering the WTP. The result is better water quality entering the plant and more importantly, a significant reduction in chemical usage (chlorine, ozone, carbon, permanganate, coagulant). For this reason most plants who use EarthTec are able to produce higher quality water for significantly less money.

EarthTec has also shown to be one of the most economical solutions for removing taste and odor compounds such as geosmin. When a plant is going through a taste and odor episode, the public outcry and cost can be overwhelming. EarthTec removal efficiencies typically range from 80-99%. This is usually enough to eliminate complaints for under \$20/mgd. For more information visit:

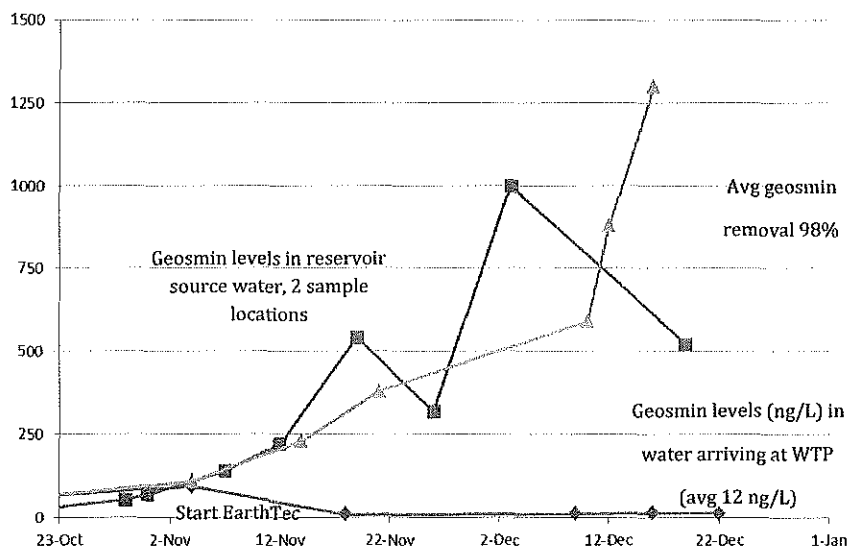
www.cleanwaterfortheplanet.com



Advantages of EarthTec:

- EarthTec is NSF-approved for drinking water. It is used in raw water intakes, sedimentation basins, reservoirs, lakes and irrigation canals.
- Long history (20+ years) of effective use. Hundreds of installations in municipal drinking water treatment plants.
- It is a liquid formulation and is self-dispersing, thus greatly reducing time and labor for application.
- Reduces TOC and precursors of THMs and HAAs, so an attractive alternative to pre-chlorination; does not lead to disinfection by-products
- Reduces taste and odor, such as geosmin by 80— 99%.
- Eliminates algae in the WTP. (sedimentation basins and filter galleries)
- Reduces demand for downstream addition of alum, activated carbon, chlorine and ozone.

Taste & Odor Data at 100 mgd WTP:



Rennaker, Joanne (DEQ)

From: Elizabeth Murphy <emurphy@cityofflint.com>
Sent: Friday, February 06, 2015 2:55 PM
To: Prysby, Mike (DEQ)
Subject: Re: Flint River Source Water Assessment

Thank you, Mike. I will share this with the Water Treatment Plant Staff and Director Croft.
LIZ

On Fri, Feb 6, 2015 at 1:48 PM, Prysby, Mike (DEQ) <PRYSBYM@michigan.gov> wrote:

Elizabeth,

Attached is a copy of the Flint River Source Water Assessment report for your information. Water treatment plant staff should have a copy of this report, if not, please provide them with a copy.

Michael Prysby, P.E.

District Engineer

Office of Drinking Water and Municipal Assistance

517 290-8817

--

Liz Murphy
Assistant to the Emergency Manager
City of Flint
810 237 2025

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 1:48 PM
To: emurphy@cityofflint.com
Cc: 'bwright@cityofflint.com'
Subject: Flint River Source Water Assessment
Attachments: Flint River Source Water Assess..doc

Elizabeth,

Attached is a copy of the Flint River Source Water Assessment report for your information. Water treatment plant staff should have a copy of this report, if not, please provide them with a copy.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

**Source Water Assessment Report for the
City of Flint Water Supply
Flint River Emergency Intake
February 2004**



*City of Flint Water Treatment Plant,
Flint, Michigan*

Prepared for:

City of Flint Water Supply; WSSN 2310

Prepared by:

U.S. Geological Survey, Water Resources Division, Michigan District
Michigan Department of Environmental Quality, Water Division
City of Flint Water Utilities Department

Michigan Source Water Assessment Report 54

Executive Summary

The purpose of the Source Water Assessment is to analyze the sensitivity and determine susceptibility of a community's source of drinking water to potential sources of contamination.

*Sensitivity is determined from the natural setting of the source water (raw water to the water treatment plant), and indicates natural protection afforded the source water. Using procedures established in the Great Lakes Protocol, Michigan Source Water Assessment Program, the **emergency** intake for the Flint Water Treatment Plant has a very high degree of sensitivity to potential contaminants. When the effects of agricultural and urban runoff in the Flint River watershed are considered, the Flint intake is categorized as very highly sensitive.*

*Susceptibility identifies factors within the community's source water area that may pose a risk to the water supply. The susceptibility determination provides information with respect to listed facilities and land areas within the source water area that should be given greater priority and oversight in implementing a source water protection program. The source water area for the Flint **emergency** intake includes 96 potential contaminant sources, 16 listed potential contaminant sources within the susceptible area, plus urban and agricultural runoff from the Flint River watershed into the Flint River. The potential contaminant sources, in combination with the very highly sensitive intake, indicate that the Flint **emergency** intake source water is very highly susceptible to potential contamination.*

*The Flint **emergency** intake source water is categorized as very highly susceptible, given land uses and potential contaminant sources within the source water area. However, it is noted that when operating, the City of Flint Water Treatment Plant has effectively treated this source water to meet drinking water standards. The City of Flint has instituted pollution prevention programs, but should be cognizant of additional potential threats to its source of drinking water that are identified in this report. This report explains the background and basis for these determinations.*

Using this Assessment

Clean, safe drinking water is fundamental to the viability of any community. Protecting the drinking water source is a wise and relatively inexpensive investment in your community's future. The overall intent of this assessment is to provide background information for your community to use in developing a local source water protection program. The assessment benefits your community by providing the following:

- *A basis for focusing limited resources within the community to protect the drinking water source(s).*

The assessment provides your community with information regarding activities within the **source water area (SWA)** that directly affect your water supply. It is within this SWA that a spill or improper use of **potential contaminants** may cause these contaminants to migrate toward the water **intake**. By examining where the source waters are most susceptible to contaminants, and where potential contaminants are located, the assessment clearly illustrates the potential risks that should be addressed.

- *A basis for informed decision-making regarding land use within the community.*

The assessment provides your community with a significant amount of information regarding where your drinking water comes from (the source) and what the risks are to the quality of that source. Knowing where the resource is allows your community planning authorities to

make informed decisions regarding proposed land uses within the SWA that are compatible with both your drinking water resource and the vision of growth embraced by your community.

- *A basis for dealing with future regulations.*

The assessment has been designed to functionally meet proposed requirements for surface-water supplies. Information needed to address regulatory needs and requirements has been collected and made available to your community through this report.

This source water assessment also provides the basis for a locally developed, voluntary source water protection program. Communities interested in voluntarily developing source water protection programs should contact the Michigan Department of Environmental Quality (MDEQ) or visit the Department web page at <http://www.deq.state.mi.us>.

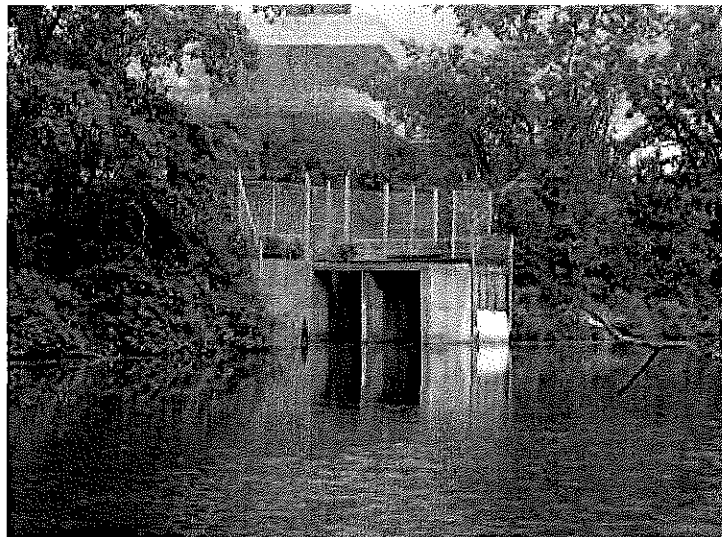
Introduction

In 1996, Congress amended the **Safe Drinking Water Act** and provided resources for state agencies to conduct source water assessments by identifying SWAs, analyzing the **sensitivity** of the source to natural conditions, conducting contaminant source inventories, and determining the **susceptibility** of the source to potential contamination. Delineations, sensitivity analyses, contaminant inventories, and susceptibility determinations comprise a "source water assessment." Assessments will be completed for every public water supply source in Michigan. To support this effort, the MDEQ Water Division established a partnership with the U.S. Geological Survey (USGS) to develop a method for conducting source water assessments for surface water supplies (Sweat and others, 2000; Sweat and others, 2001).

The requirements for public water supplies in Michigan to meet United States Environmental Protection Agency (USEPA) **maximum contaminant levels (MCLs)** provide some degree of assurance of safe drinking water; however, all systems are vulnerable to potential contamination. One of the best ways to ensure safe drinking water is to develop a local program designed to protect the source of drinking water against potential contamination. Not only does this add a margin of safety, but it also raises the awareness of consumers and/or the community of the risks of drinking water contamination. It is expected that source water assessment results will provide a basis for developing a source water protection program.

Background

Flint is located in Genesee County, about 55 miles northwest of Detroit, Michigan (fig. 1). The city of Flint water supply serves a population of 125,000. In 1967, the city connected to the Detroit Water and Sewage Department (DWSD) water supply and the Flint Water Treatment Plant (WTP) was placed on stand-by operation. The city is required by the MDEQ to maintain this treatment facility for reliability since the city obtains treated water through a single pipeline from the DWSD Lake Huron WTP which is subject to interruption of service. The present intake at the Flint WTP was constructed in 1948 and consists of a concrete box structure on the edge of the Flint River. The intake structure has a bottom elevation of 700.00 and connects through a 72-inch concrete pipe to the low service pump station. Low service pumps lift the river water through the WTP processes of conventional treatment and lime-soda softening.



*Flint WTP Emergency, Flint River Intake Structure
(Viewed from downstream)*

Treatment at the plant includes the addition ferric chloride as a coagulant, lime and soda ash for softening, chlorine for disinfection, and fluoride addition for dental health.

Water treatment plants are periodically inspected to identify construction, maintenance, operational or source defects that could make them vulnerable to contamination, particularly from contaminants that are microbial in nature, such as fecal coliforms. Water suppliers are provided a sanitary survey report that notes deficiencies in the system, and the State may direct the system to make necessary corrections. The sanitary survey is an important part of a safe drinking water program.

Climate

The Flint water supply is located in the central Lower Peninsula hydrologic province (Rheume, 1991), in the Flint River watershed (USGS, 1974, 1982). The region experiences temperate summers with moderate winters. The Flint Bishop International Airport Weather Bureau station reports that the average annual precipitation for the climatic years 1887-2001 was 30.28 inches and the average from the past 5 years is 31.42 inches (NOAA, 2001), with about 13 percent of that as snowfall between November and March. Annual average runoff for the Flint SWA, extrapolated from Miller and Twenter (1986, fig. 1) is 9 to 10 inches.

Source Water Area Geology and Hydrology

The study area for evaluating the extent of the Flint emergency intake SWA includes the upper reaches of the Flint River watershed (fig. 1). Flint is located roughly in the middle of the Flint River watershed. The



Flint River – Source Water for City of Flint WTP

SWA consists of lacustrine clays and silts; end moraines of coarse- and medium-textured till; fine-, medium-, and coarse-textured glacial tills; and postglacial alluvium. The SWA is underlain by Bayport Limestone, Marshall Sandstone and mixed shales, sandstones, and limestones of the Saginaw and Michigan Formations (Martin, 1955; Milstein, 1987). Soils underlying the Flint SWA are primarily associations of the Blount, Boyer,

Brookston, Capac, Ceresco, Celina,

Chelsea, Cohoctah, Conover, Del Ray, Kibbie, Lapeer, Lenawee, McBride, Metea, Miami, Montcalm, Sloan, Spinks series (U.S. Department of Agriculture, 1961; BASINS, 1998; MIRIS, 2000). They include loams, loamy sands, fine sandy loams, silty clay and muck.

Soil permeability is based on the calculated time of travel, in inches per hour (in/hr), for water to move vertically through a saturated soil zone. Soil thickness and permeability values are available in soil survey reports published by the National Cooperative Soil Survey and U.S. Department of Agriculture (1982, 1992, 1993, also 2 county reprints in press). Permeability ranges from less than 0.06 in/hr, rated as very slow, to more than 20 in/hr, rated as very rapid.

Source-water Area (SWA) for the City of Flint Emergency Water Supply

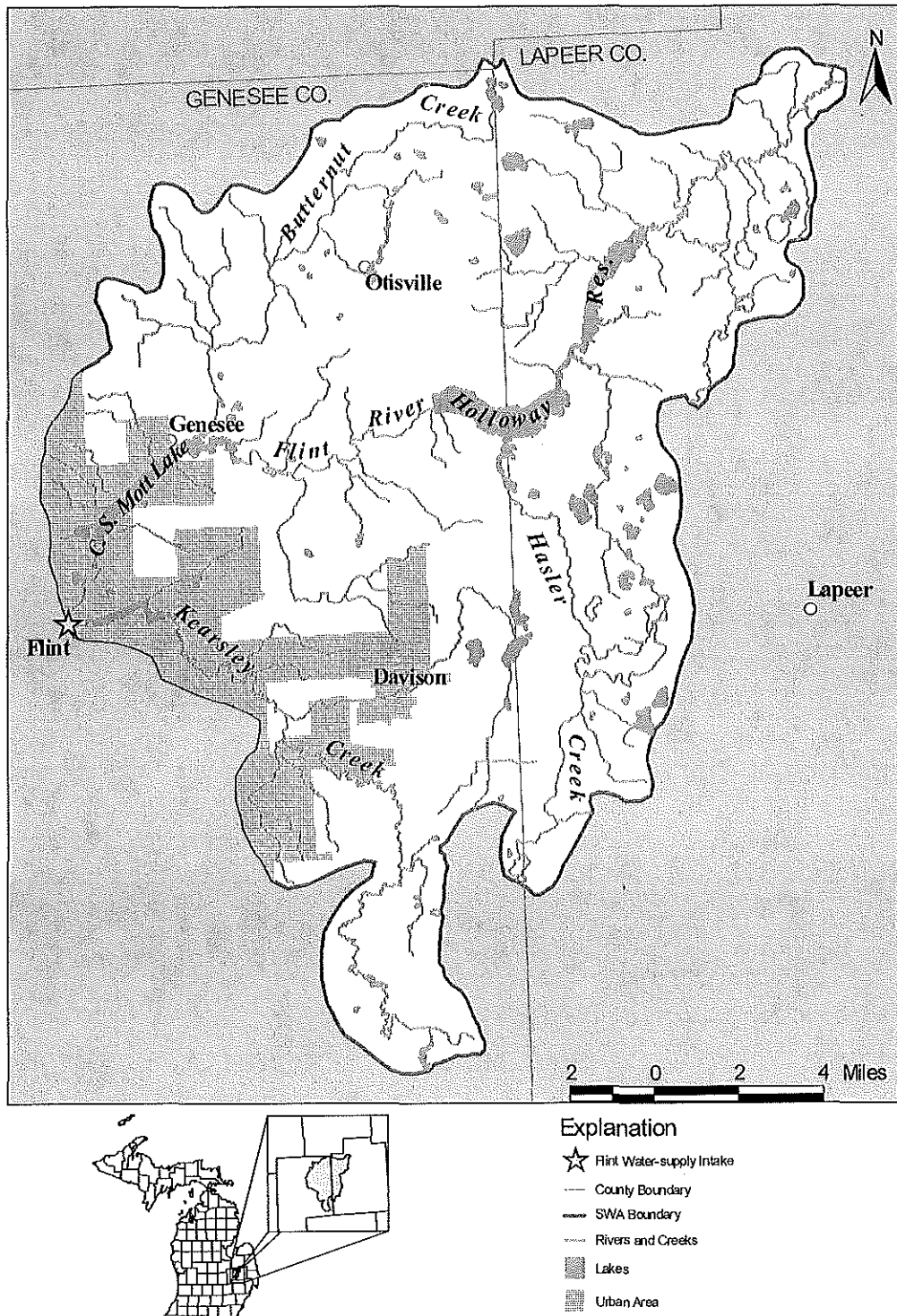
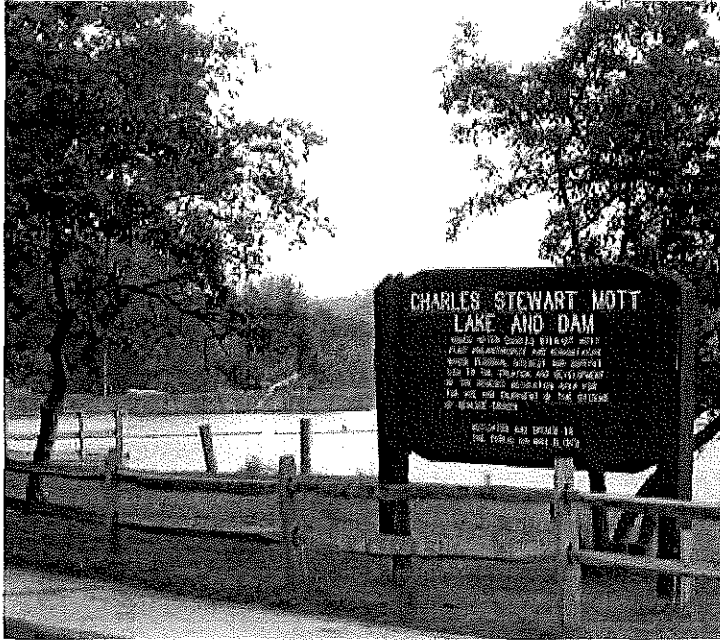


Figure 1. Source-water area (SWA) for the evaluation of the Flint emergency intake, Flint, MI.



Mott Lake and Dam on Flint River upstream of Flint WTP

3.1 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998; MIRIS, 2000). Soil permeability ranges from moderately slow in the northeastern portion of the SWA to moderate over the eastern portion of the SWA to moderately rapid throughout the central and western portions of the SWA, and rapid around the Flint River (fig. 2; U.S. Department of Agriculture, 1961; BASINS, 1998; MIRIS, 2000). Areas adjacent to the Flint River are underlain by highly sensitive drift lithologies, whereas the remainder of the SWA is underlain by least sensitive drift lithology (Lusch and others, 1992).

The Flint SWA contains an area of about 237 square miles (mi²). There is one operable gage within the Flint SWA and a Flint River gage which operates approximately 9 miles downstream from the Flint Emergency Intake. Between 1932 and 2002 discharge has been recorded at this station by the USGS (Blumer and others, 2002). Annual mean discharge at the Flint River at Flint gauging station was 339 cubic feet per second (cfs) between 1932 and 2001, and ranged from 153 to 1258

cfs. Velocity measured at this stream gage was used to estimate the distance in which contaminants could travel within 24 hours, or the 24-hour time-of-travel (TOT) for this area on the Flint River. The distance calculated for the 24-hour TOT was approximately 27 miles.

Very slowly permeable soils significantly reduce the movement of water through the soil zone and, as a result, allow greater time for natural degradation of contaminants. However, such soils also provide for rapid overland transport of contaminants directly to receiving waters, which in turn may affect the water supply intake. Erosion and transport of soils by surface waters can cause an increase in turbidity. In contrast, very rapidly permeable soils allow for rapid infiltration and passage through the soil zone from the surface. Such soils potentially allow rapid transport of contaminants with minimal contact-time available for contaminant breakdown.

Mean, area-weighted, depth-integrated permeabilities for the Flint SWA range from 0.6 to as much as 7.8 in/hr. The mean permeability is



Kearsley Lake and Dam on Kearsley Creek Upstream of Discharge to Flint River and Flint WTP Emergency Intake

Soil Permeability for the Flint Source-water Area, Flint, MI

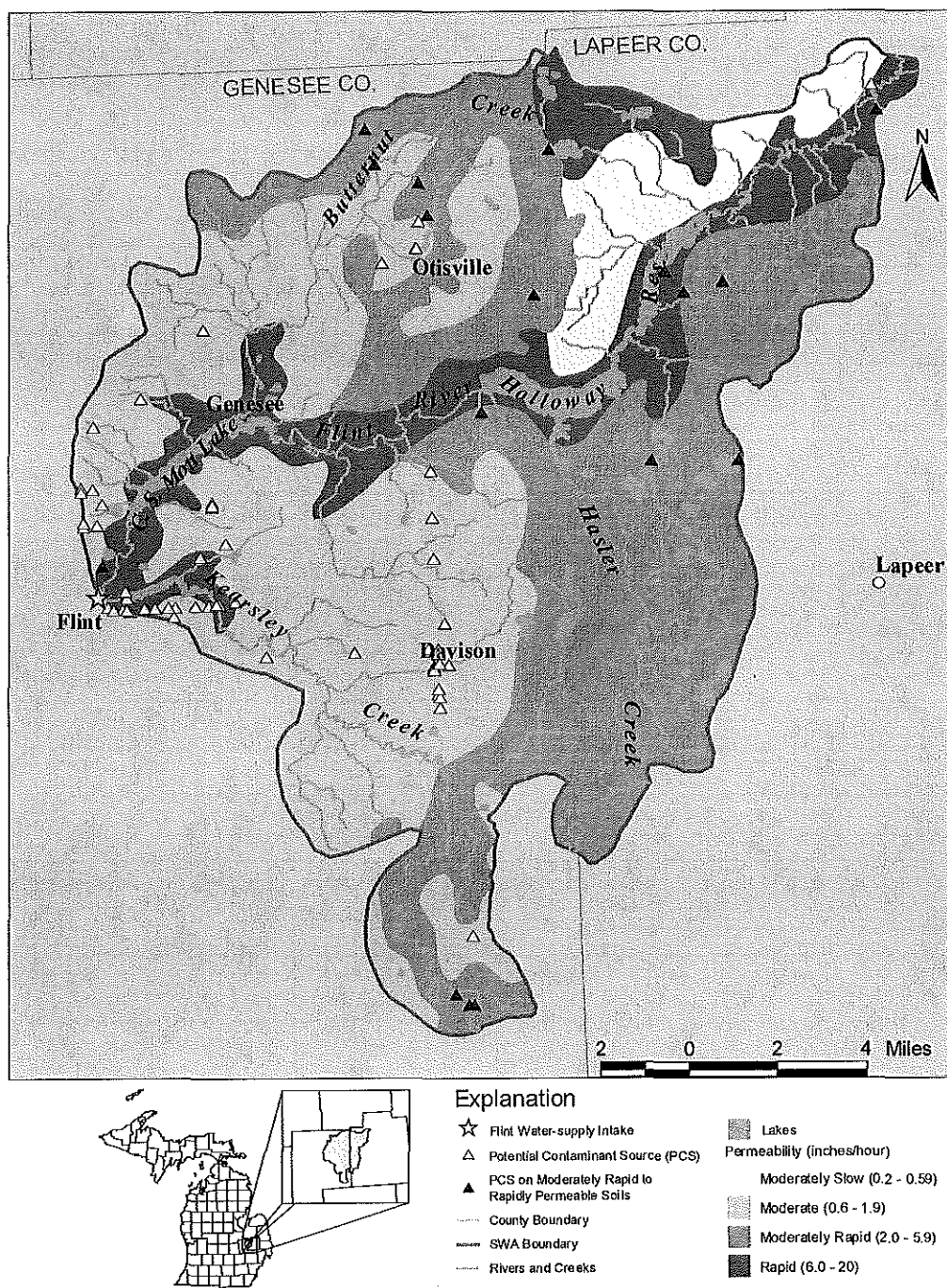


Figure 2. Soil permeability for the Flint emergency water-supply intake SWA. Flint, MI.

History of Raw Water Quality at the Source

Public water supplies are required to routinely monitor raw water quality for selected parameters to optimize treatment, and to monitor treated water quality for a list of contaminants that is determined by MDEQ and the Safe Drinking Water Act. A detection of any contaminant may indicate that a pathway exists for contaminants to reach the intake. It is important to realize that the results from a given sample only provide information regarding the water quality at the time the sample was collected. Water quality can change with time for a number of reasons. The fact that a water sample does not contain contaminants is no guarantee that contamination will not occur in the future. Conversely, the detection of a contaminant in the past does not indicate that it will occur in the future.

The Flint WTP records for the last 3 years of routine operation, 1965-1967 show that water use fluctuated between 34.4 and 46.5 million gallons per day (MGD), with an average daily use of 38.5 MGD. Raw water quality reported for these three years ranged from 5 to 183 nephelometric turbidity units (NTU) for turbidity, 203 to 375 mg/l total hardness as CaCO₃, 116 to 235 mg/l alkalinity as CaCO₃, 16 to 46 mg/l chlorides and 8.2 to 8.5 units for pH. Precipitation events were noted to increase turbidity and lower hardness. An analysis of flow duration for the Flint River and source water chemistry would probably indicate that there may be an indirect correlation between turbidity, suspended sediments, and coliforms and high flows associated with spring snowmelt and precipitation runoff events.

In recent years, the Flint WTP has undergone operational and process improvements for water treatment. Raw water quality during these testing periods when the WTP was operating but discharging to waste are noted in the table below.

Date of Tests	Turbidity (NTU)	Total Organic Carbon (mg/l)	pH (pH units)	Alkalinity (mg/l)	Hardness (mg/l)
12/5-7/2000	4.2	8.75	7.8	249	324
1/16-18/2001	2.4	8.5	7.7	275	363
3/20-21-2001	5.4	N/A	7.9	196	266
4/16-18/2001	7.6	8.6	8.2	213	284

Source Water Assessment Methodology

Technical guidelines for completing source water assessments are contained in the Michigan Source Water Assessment Program, Assessment Protocol for Great Lakes Sources (Protocol) (MDEQ, 1999, Appendix L) available at <http://www.deq.state.mi.us/dwr>. In general, an assessment is a process for evaluating a drinking water supply and the potential for its treated water to exceed an MCL due to raw water contamination. A source water assessment considers the SWA, potential sources of contamination within the SWA, conditions of the water supply intake, and susceptibility to contaminants in order to identify potential risks to drinking water quality. Although the Protocol provides the minimum requirements and instructions on how to conduct an assessment, each water supply is unique with respect to how the process is carried out, due to local conditions and information. Sweat and others (2000, 2001) have developed and documented the methodology used in the preparation of this assessment.

Delineating Source Water Areas

Delineation of the SWA is accomplished by using geographic information system (GIS) software to map the watershed(s) that have the potential to affect source water at the intake. Using information from the water supply, a critical assessment zone (CAZ) is defined for the intake (MDEQ, 1999, Appendix L). A buffer is then created along any shoreline intersected by the CAZ, and from the edge of the CAZ to the mouth of any river(s) that might influence the intake. Finally, the buffer is extended along the shoreline of any river(s) that might influence the intake, from the mouth of the river to its headwaters. The area defined by the CAZ, river and shoreline buffers is termed the susceptible area. The susceptible area within the SWA defines locations where a water supply should focus its management strategies and resources to benefit the drinking water resources.

Using the Great Lakes Protocol and the Flint water supply information:

- The CAZ for the Flint intake is assigned as 3,000 ft since the intake is located in an inland river (fig. 3).
- The susceptible area along the shoreline is determined to be: A distance of 300 ft inland along the banks of the Flint River and its tributaries (fig. 4).

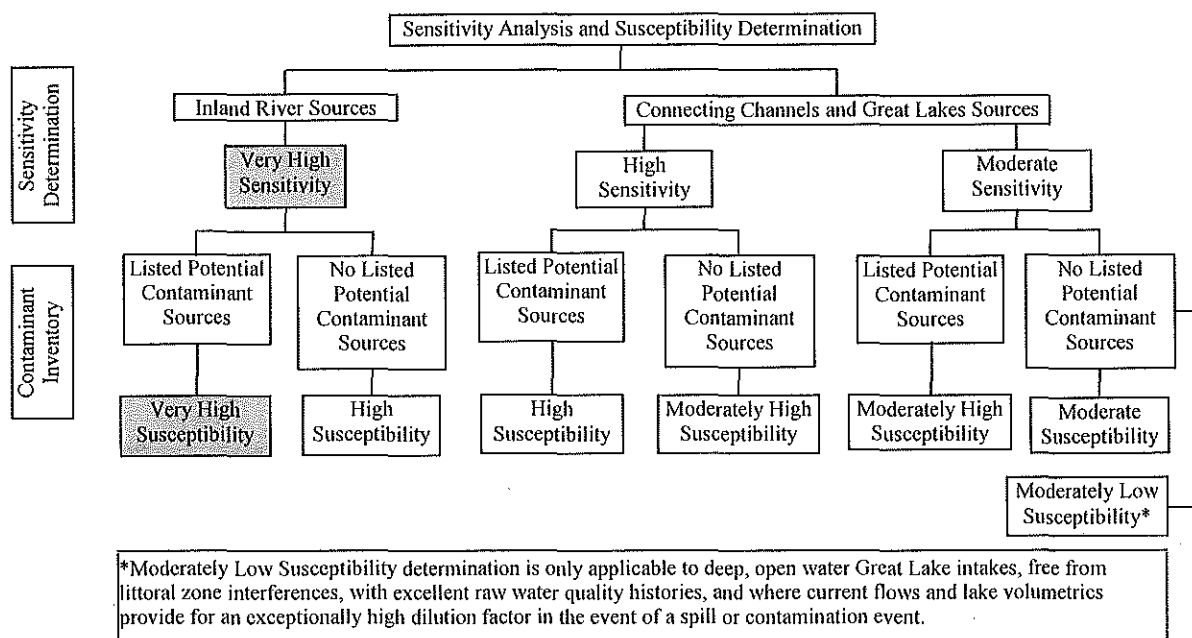


Figure 53. Surface-water Source Sensitivity Analyses and Susceptibility Determination for the Ann Arbor Flint emergency water-treatment-plant source-water areas.

Contaminant Source Inventory

Past, current, and potential future sources of contaminants were inventoried to identify several categories of potential sources of contaminants including microorganisms (bacteria, oocysts, and viruses), inorganic compounds (nitrates and metals), organic compounds (solvents, petroleum compounds, pesticides), and disinfection by-product precursors (trihalomethanes, haloacetic acids).

It is important to remember that sites and areas identified by this process are only potential contaminant sources used and managed properly. In addition, assumptions were made about particular types of land uses and risks associated with those land uses. Assumptions are discussed further in the results portion of this report.

The process for completing the inventory included several steps, which are summarized as follows:

1. Reviewed readily available land use maps and historical/current aerial photographs.
2. Plotted relevant information from applicable state and federal regulatory databases including the following lists:
 - MDEQ leaking underground storage tank (LUST) sites;
 - MDEQ registered underground storage tank (UST) sites;
 - MDEQ Environmental Cleanup Site Information System (ECSI) sites;

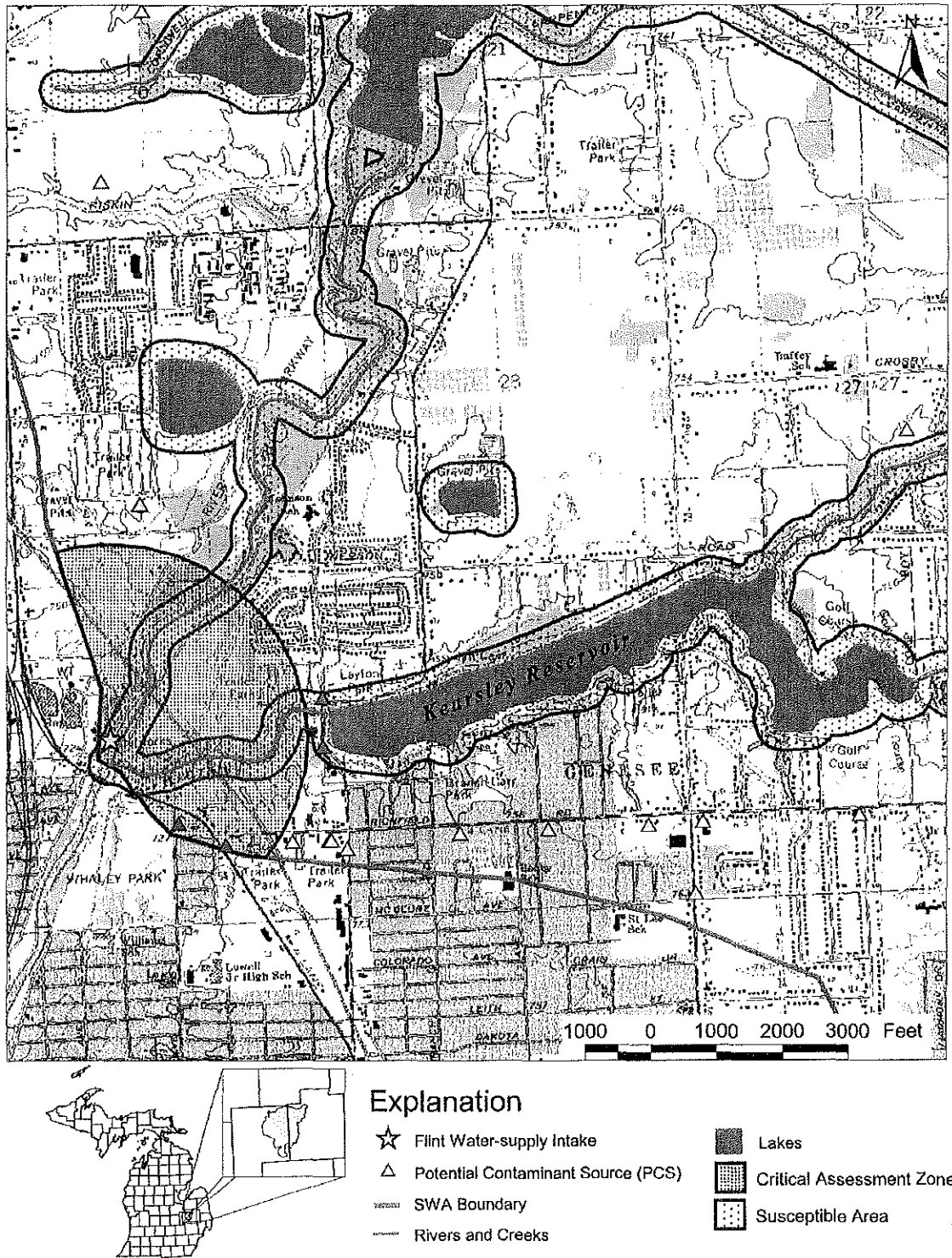


Figure 4. Critical Assessment Zone (CAZ) for the Flint emergency water-supply intake, Flint, MI.

- MDEQ Source Information System (for water discharge permit sites including National Pollutant Discharge Elimination System (NPDES) permits, Water Pollution Control Facility (WPCF) permits, storm water discharge permits, and on-site sewage (septic) system permits);
 - MDEQ Underground Injection Control (UIC) database;
 - MDEQ Active Solid Waste Disposal Permits list;
 - Michigan Department of Transportation (MDOT) - Hazardous Materials database;
 - State Fire Marshall registry of above-ground fuel storage tank sites;
 - State Fire Marshall Hazardous Material Handlers and Hazardous Material Incidents (HAZMAT) sites;
 - U.S. EPA BASINS software, version 2.1.
 - U.S. EPA Envirofacts database;
 - U.S. EPA Resource Conservation Recovery Act (RCRA) generators or notifiers list;
 - U.S. EPA RCRA Treatment, Storage, and Disposal Facility (TSDF) Permits list;
 - U.S. EPA National Priorities List (NPL);
 - U.S. EPA Comprehensive Environmental Response, Compensation and Liability Information System (CERCLA) List;
 - U.S. EPA RCRA Corrective Action Activity List (CORRACTS);
 - U.S. Department of Transportation (DOT) Hazardous Materials Information Reporting System (HMIRS);
 - U.S. EPA Toxic Chemical Release Inventory System (TRIS); and
 - U.S. EPA Oil Pollution Act of 1990 Spill Response Atlas
3. Met with public water supply and community officials on June 11, 2003 to identify potential sources not listed elsewhere in databases or on maps and completed a preliminary inventory form to be used in completing the SWA base map. Subsequent contacts by email and telephone on numerous occasions to request additional data, clarify data, and discuss results.
 4. Land use and/or ownership (for example, residential/municipal; commercial/industrial; agricultural/forest; and other land uses) was mapped and evaluated in relation to PCS, soil characteristics, and proximity to the intake(s).
 5. Conducted an informal field inventory to locate additional PCS.
 6. Completed final inventory form of PCS and plotted locations of PCS on the base map.

The purpose of the inventory is three fold: first, to provide information on the location of PCS, especially those within the susceptible area; second, to provide an effective means of educating the public about PCS; and third, to provide a reliable basis for developing a management plan to reduce potential contaminant risks to the Flint water supply.

The inventory process attempts to identify potential point-source contaminants within the SWA. It does not include an attempt to identify specific potential contamination problems at specific sites, such as facilities that do not safely store potentially hazardous materials. However, assumptions were made about particular types of land use. For example, it is assumed that rural residences associated with farming operations have specific potential contamination sources such as fuel storage, chemical storage and mixing areas, and machinery repair shops. It should also be noted that although the inventory depicts existing agricultural uses (crops grown), these are likely to undergo continual change due to normal crop rotation practices. What is irrigated farmland now may be non-irrigated farmland next year, or vice versa.

The results of the inventory were analyzed in terms of current, past, and future land uses and their relationship to the susceptible area and the supply intake. In general, land uses and PCS that are closest to the supply intake pose the greatest threat to a safe drinking water supply. Inventory results are summarized in table 1, and are shown on figure 5.

Many PCS are readily identifiable because they have a single discharge point, and often a permit is required for these discharges. However, other PCS have diffused, poorly defined discharge locations. These are known as non-point discharges because they occur over large areas and may not be quantifiable by readily accepted methods. These non-point source discharges are difficult to identify and control, and consequently to quantify, yet they are a major source of water pollution (Carpenter and others, 1998). Non-point sources also include atmospheric deposition over water and land, and include urban, rural, and

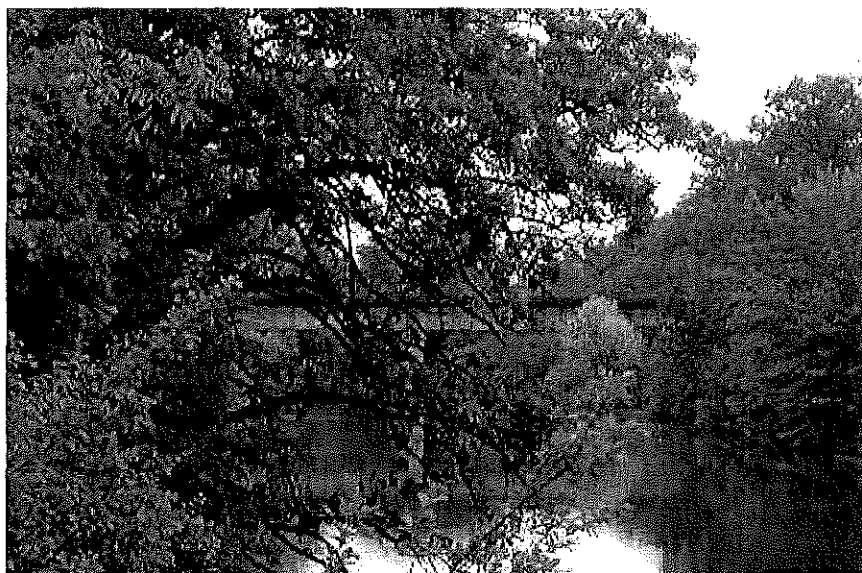
Table 1. Potential contaminant sources in the source water area

Type of Potential Contaminant Source (PCS)	Number of PCS	Number of PCS in Susceptible Area
Hazardous or solid waste site permits	71	11
Industrial facility discharge site permits	9	3
National priority list sites	1	0
Permit compliance system	12	2
Toxic release inventory permits	3	0
TOTALS	96	16

agricultural runoff from areas such as lawns, golf courses, farm fields, pastures, parking lots, and roadways. Runoff from these areas can contain many types of pollutants including sediments, metals, organic and inorganic chemicals, viral and bacterial pathogens, pharmaceuticals, and animal wastes. Transportation also represents a non-point source of contamination. Trucking and railroads transport potential contaminants through the SWA. An accident causing a spill could lead to potential contaminants entering a storm sewer, or in the case of boaters or rail transportation, directly to the Flint River. Petroleum pipeline crossing the upper reaches of the Flint River also pose contaminant threats.

Non-point sources of concern to the Flint water supply are primarily from storm sewers and from industrial, commercial, and residential sources in the SWA and communities upstream of the intake. A railroad bridge immediately upstream in the CAZ of the intake carries occasional train traffic described as hazardous. The West Boulevard storm sewer which discharges in the CAZ provides drainage to the Flint River from an industrialized area.

The Michigan Department of Agriculture is working to identify dairies and concentrated animal feedlots (greater than 1000 animal units) in the Flint River watershed upstream of the intake.



Railroad Trestle over Flint River Immediately Upstream of Flint WTP

The U.S. Environmental Protection Agency (USEPA) has identified one impaired water body in the Flint SWA on its Clean Water Act 303(d) list. The parameter of concern within the Holloway Reservoir is fish consumption advisories for PCBs. An additional impaired water body exists upstream of the SWA but not within the SWA itself. This water body is the collective of unnamed drains in Metamora, and the parameters of concern are untreated sewage discharge and pathogens (MDEQ, 2002).

In general, PCS within the susceptible area pose greater risks than those outside the susceptible area. The presence of PCS within the SWA indicates potential sources of chemicals that could, if improperly managed or released, impact the water quality at the intake. Small quantities of these chemicals, in some

Contaminant Source Inventory for the Flint Emergency Water-supply Intake, Flint, MI

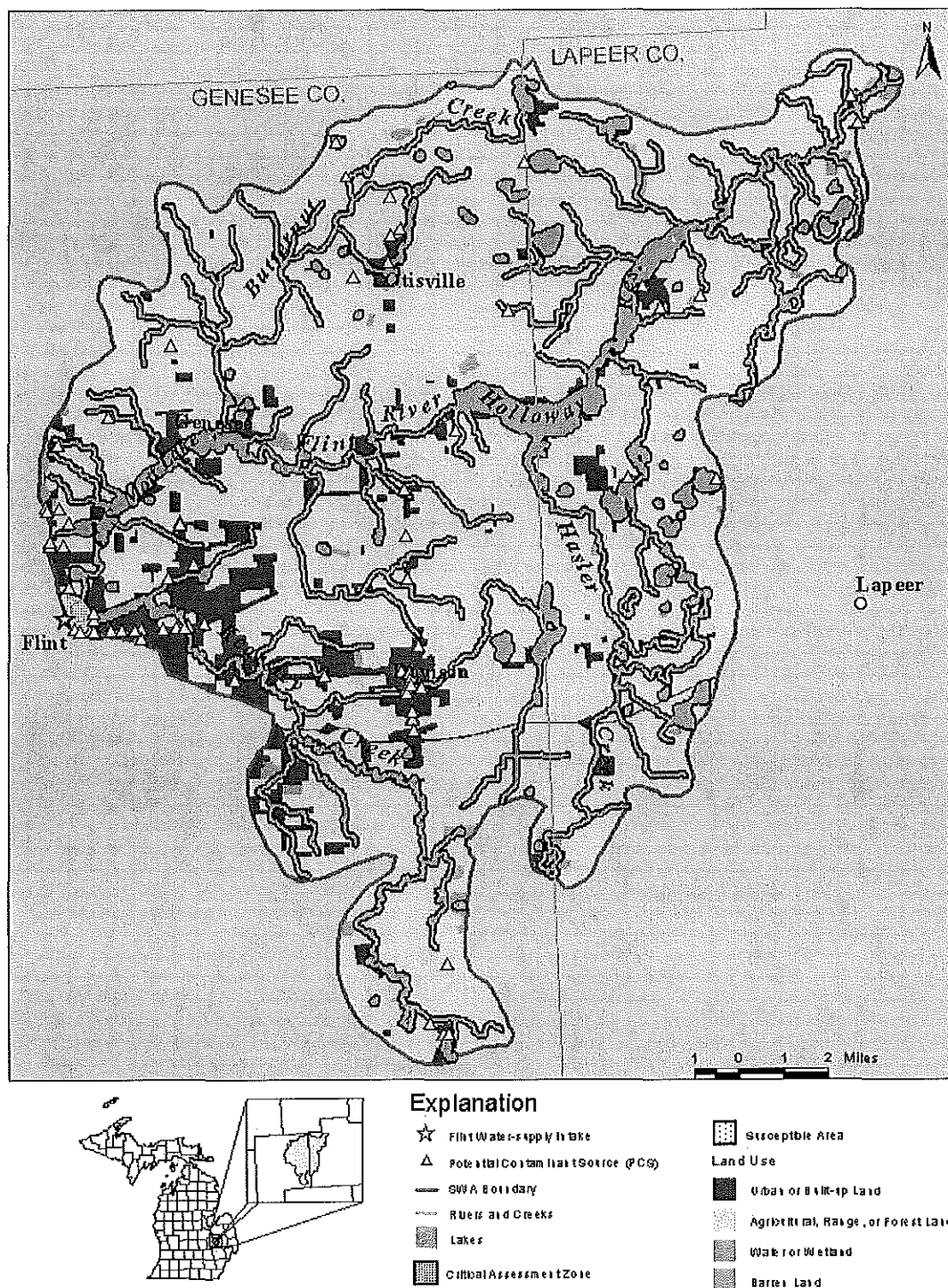


Figure 5. Potential Contaminant Sources in City of Flint Source Water Area, Flint, Michigan

cases less than a liter, can significantly affect the supply. Also of concern is the location and distribution of these sources with respect to highly permeable soils. The susceptible area consists of primarily agricultural and forested land with some urban areas. Overlaying the PCS locations and the moderately rapid to rapidly permeable soil map for the Flint SWA indicates that 21 of the located PCS are located on or very near to areas with moderately rapid to rapidly-permeable soils. All PCS within the SWA should be addressed; the susceptibility determination, however, provides the water supply with the tools to focus resources where the greatest risk occurs. The results of the PCS inventory performed for Flint water supply is shown on figure 5 and is summarized as a function of PCS locations relative to the susceptible area. The inventory results indicate that there are 7 PCS, holding 8 permits for discharge, within the susceptible area (table 2).

Table 2. Contaminant source inventory.

Site Name	Identification Number	Reason for Permit	Reason for Listing as Potential Contaminant Source
DAVISON OIL AND GAS BURTON STA 7	MI0000540310	On-Site Storage	Hazardous and Solid Waste Site
H AND M SVC	MID985612225		
KINNIES PARTY STORE	MID985597657		
ZACK CO	MID002975225		
EVERGREEN CLEANERS	MID981539711		
DORT HWY INC	MID985579945		
SUPER GO MARKETERS INC	MID985583053		
PIONEER CABINETRY INC	MID985605849		
DAVISON CITY OF	MID985625136		
MID MICHIGAN AUTO PARTS INC	MID985654789		
CLARK STORE 1849	MI0001853613	Process, Treatment, and Waste Waters	Industrial Facilities Discharge Site
FORD-NORTHVILLE PLT	MI0024643		
FOREST WASTE PRODUCTS	YCRCLA276		
OTISVILLE WWTP ^a	MI0028720	Waste Water, Dust, and Process Water	Permit Compliance System
ORCHARD COVE WWTP	MI0054755		
OTISVILLE WWTP ^a	MI0028720		

Note: Subscript denotes multiple permits

Sensitivity Analysis

Sensitivity is the natural ability of a SWA to provide protection against the contamination of the water supply intake, and includes physical attributes of lakes, rivers, and soils. The sensitivity analysis requires consideration of several different variables related to the natural environment, for example:

- Water quality history of the source.
- Distribution of moderately to highly-permeable soils.
- Amount of available water from precipitation or runoff.
- Potential for runoff to affect the intake.
- Nature of the intake, including: depth, distance from shore, age, and materials used.
- Surface water flow patterns in vicinity of intake.

To perform this analysis, USGS, MDEQ, and the operator of the Flint WTP collected, researched, and analyzed information from the WTP, monthly operator reports, sanitary surveys, soil maps, published reports, and historical plant operation and raw water quality data. The Michigan SWAP has three categories of sensitivity for surface water sources ranging from moderately sensitive to very highly sensitive. Analysis of this information, using guidelines provided in Brogren (1999) and Sweat and others (2000, in press), indicates that the Flint intake is at the high end of this range or very highly sensitive (fig. 3). This means that the natural environment offers little protection against contamination of the water supply intake.

Susceptibility Determination

Susceptibility is the relative potential for contamination to reach the public water supply intake used for drinking water purposes. Whereas the sensitivity of a water supply is the natural ability of the area to protect the intake against contamination, the susceptibility determination also takes into account other factors that will affect whether a contaminant reaches the intake. Whether or not a particular drinking water source becomes contaminated depends on three factors:

- (1) The distribution of PCS;
- (2) The source water area; and
- (3) The natural protection, or sensitivity, of the source.

In conducting a susceptibility determination, the part of the SWA that yields water to the water supply-system intake is identified by establishment of the susceptible area within the source water area. PCS within the susceptible area are then located. Based on the distribution of PCS within the susceptible area, the type of PCS, and the nature of the chemicals they use or store, PCS are analyzed for the risk they may represent to the water supply intake. Along with the presence and distribution of PCS, the sensitivity analysis is then used to determine the susceptibility of the water supply (fig. 3). This leads to a determination of whether the drinking water source is moderately susceptible, highly susceptible, or very highly susceptible to contamination (Brogren, 1999; Sweat and others, in press). It is important to understand that a system can have low sensitivity relative to some conditions (for example, intake construction and location), and high susceptibility because of other conditions (for example, the type of PCS). In Michigan, surface water sources of drinking water range from moderately-low to very-high susceptibility.

When a public water supply is determined to have a moderate, high, or very high susceptibility because of a particular condition or set of conditions, there is a significant risk of contamination of the drinking water source because of that condition or set of conditions. Although the susceptibility determination does not predict when or if contamination will actually occur, it does recognize conditions that are highly favorable for contamination of the supply. In the event of a contaminant release to soils or surface water within the susceptible area, it is very likely that contamination at the intake would occur without completion of remedial actions.

If a public water supply's drinking water source is determined to be highly susceptible, it is recommended that the system identify the condition(s) that lead to the high susceptibility. Immediate steps should be taken to protect the source, and action should be considered to remedy the condition (for example, repairing or replacing faulty intake construction, working directly with facility operators to implement sound management practices, etc.).

All water supplies, regardless of their susceptibility, should consider identified factors that could lead to higher susceptibility in the future, and should prepare a strategy to protect the water supply source. Raising public awareness through signs and other education programs, encouraging proper intake construction and the use of best management practices in existing facilities are good ways of ensuring that a surface water source maintains its moderate susceptibility rating.

Summary and Recommendations

The actual susceptibility of the drinking water source of a water supply depends on a number of contributing factors, some of which are only slightly related. Sensitivity is determined from the natural setting of the source and identifies the natural protection afforded to the source water. Susceptibility is determined by identifying those factors within the community's SWA that may pose a risk to the source water. The susceptibility determination provides information with respect to facilities within the SWA or

land areas within the SWA that should be given greater priority and oversight in the implementation of a drinking water protection program.

Sensitivity Analysis: Based on criteria adopted in the Great Lakes Protocol of the Michigan Source Water Assessment Program, the emergency intake for the Flint Water Treatment Plant has a very high degree of sensitivity to potential contaminants.

Susceptibility Determination: The SWA for the Flint intake includes 8 listed potential contaminant sources within the susceptible area, numerous storm drains discharging upstream of the intake, a railroad crossing plus urban, agricultural, and industrial runoff from the Flint River watershed. Combining these potential contaminant sources with the very highly sensitive intake yields a very highly susceptible determination for Flint source water (fig. 5).

Effective Treatment:

The results of this assessment and the recommendations based on these results are summarized as follows:

- ***Intake*** - The Flint Water WTP intake was installed in 1948 and draws water from the Flint River from a shoreline structure making the intake very highly sensitive.
- ***Soils*** - Using a mean, area-weighted, depth-integrated permeability estimation, the soil and subsoil permeability in the SWA range from 0.6 in/hr to as much as 7.7 in/hr. The mean permeability is 3.1 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998; MIRIS, 2000). About two thirds of the soils in the Flint SWA are moderately rapid or rapidly permeable. Sixteen (16) PCS are located on these soils. These factors combine to make the SWA, and thus the intake, very highly sensitive. The community should take steps to evaluate current and future land use in areas of highly permeable soils, particularly those occurring within the susceptible area. Those PCS that have been identified either on or in close proximity to these soils should be informed of the sensitive nature of the area and encouraged to adopt best management practices designed to minimize the risk of a ground release. Residential areas that have been developed on these soils should be targeted for educational programs identifying steps that residents can take to protect the water supply.
- ***Historical Contaminant Detections*** – Since the Flint WTP has not utilized the Flint River since 1967 as a source of public drinking water, extensive raw water quality data is not available. However, as is typical for river water, the periodic presence of coliform bacteria is indicative of a relationship between runoff and soil conditions, causing the presence of bacteria at detectable levels in river source water. Background turbidity has recently been reported in the range of 2.4 to 7.6 NTU. These factors indicate that the SWA, and thus the intake, is very highly susceptible.
- ***Sanitary Survey*** – Defects reported as requiring repair either have been corrected or are scheduled for repair. The Flint WTP is undergoing extensive upgrades to improve treatment and reliability. It is important that the water supply continue to follow good management practices.
- ***Potential Contaminant Sources*** - A review of the PCS inventory and the rapidly and very rapidly permeable soil distribution indicates that the Flint SWA has 21 PCS located on moderately rapid to rapidly permeable soils. Within the susceptible area, there are 7 PCS with 8 discharge permits. In addition, there are numerous storm drains within the vicinity of the intake. A railroad crossing immediately upstream of the intake also poses a potential contaminant threat. It is recommended that the community focus initially on PCS that are within the susceptible area as they pose the greatest potential threat to the water supply. These facilities should be made aware of free technical assistance that is available through MDEQ's pollution prevention programs. Through chemical inventory, waste reduction, and by increasing awareness of best management practices, the risk these facilities pose to source waters can be reduced. The PCS inventory indicates that the source is very highly susceptible.
- ***Source Water Assessment*** - The Flint source water assessment is based on these site-specific parameters:

1. Definition of a Critical Assessment Zone around both intake for a very highly sensitive source;
 2. Definition of a SWA for the Flint River, and shoreline near the intake;
 3. Flow duration and discharge in the Flint River upstream of the intake, and the effects of upstream contaminant discharges on the source water quality; and
 4. Listed and nonlisted potential contaminant sources.
- **Source Water Protection** - The City has initiated source water protection activities with an Industrial Pretreatment Program incorporating management plans, chemical containment, and spill response, spill response training, plus storm sewer and street cleaning programs.

The Flint WTP and/or the community should assemble a team to assist in the development and implementation of a source water protection program that uses this assessment to further protect the Flint source water area.

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-----, in press, Soil survey of Jackson County, Michigan:

GLOSSARY

Critical Assessment Zone (CAZ) - the area from the intake structure to the shoreline and inland, including a triangular water surface and a land area encompassed by an arc from the endpoint of the shoreline distance on either side of the on shore intake pipe location

Geographic Information System (GIS) - a system to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information

Impaired water bodies - As defined by USEPA and listed on the 303 (d) list of the federal Clean Water Act.

Intake - the point at which source (raw) water is drawn into a pipe to be delivered to a water treatment plant

Lignins - an amorphous, cellulose-like, organic substance that acts as a binder for the cellulose fibers in wood and adds strength and stiffness to cell walls

Maximum Contaminant Level (MCL) - the maximum permissible level of a contaminant in water that is delivered to any user of a public water system

Potential Contaminant Sources (PCS) - listed and non-listed agricultural sites, businesses, and industries that have the potential to cause contaminants to be introduced into source water

Sensitivity - a measure of the physical attributes of the source area and how readily they protect the intake from contaminants

Source - the water body from which a water supplier gets its water

Source Water Area (SWA) - the land and water area upstream of an intake that has the potential to directly influence the quality of the water at the intake

Source Water Assessment Program (SWAP)- in Michigan, the process defined by the state Department of Environmental Quality to complete assessments of all the state's public water supplies

Susceptibility - the Susceptibility identifies factors that may pose a risk within the community's SWA

Susceptible Area - the area defined by the critical assessment zone and a buffer on either side of any drainages that contribute water to an intake

Synthetic Organic Contaminants (SOC) - Manmade organic chemical compounds such as pesticides, etc.

Tannins - naturally occurring phenolic compounds that precipitate proteins, alkaloids, and glucosides from solution that has a yellowish appearance

Volatile Organic Contaminants (VOC) - Unnatural, volatile organic chemical compounds such as gasoline components, solvents, degreasers, etc

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 12:57 PM
To: emurphy@cityofflint.com
Subject: RE: Water Supply Sources

Elizabeth,

Yes, a source water assessment was completed for the Flint River and a report is available. I will send it to you asap (later today or on Monday).

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:01 AM
To: 'emurphy@cityofflint.com'
Subject: FW: Water Supply Sources

Elizabeth,

Below is a link to our website that lists all of surface water systems in Michigan. You will need to scroll down to the bottom of the list to see the listing of supplies using a river as their source. Also, I am not aware of any source water assessment conducted for the Flint River watershed; however, I would like to confirm that. I will let you know asap once I obtain the confirmation.

http://www.michigan.gov/deq/0,4561,7-135-3313_3675_3691-9775--,00.html

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 12:55 PM
To: Berndt, Jason (DEQ)
Subject: RE: Source Wster assessment Flint River

Jason,

I scrolled through the Flint assessment several times and did not see lat...long. Cooridinales for the intake....and only very basic mention of its construction....so I'm not sure where to edit....I couldn't see where you made edits in the St. Ig. Assessment. Call me before 2 if you get a chance...perhaps I'm missing something. Thanks

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

From: Berndt, Jason (DEQ)
Sent: Friday, February 06, 2015 11:35 AM
To: Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Busch, Stephen (DEQ)
Subject: RE: Source Wster assessment Flint River

See the attachment.

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:04 AM
To: Berndt, Jason (DEQ)
Subject: Source Wster assessment Flint River

Jason,

Has a source water assessment been performed for the Flint River watershed...spec. for the Flint WTP intake? If so, the city of Flint would like to obtain a copy of source water assessment report.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Berndt, Jason (DEQ)
Sent: Friday, February 06, 2015 11:44 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: RE: Source Wster assessment Flint River

You may want to consider the idea of providing an edited copy of the report that removes the intake location and specs. I have done this before when there is a request for a community's assessment. Are there any concerns there?

From: Busch, Stephen (DEQ)
Sent: Friday, February 06, 2015 11:39 AM
To: Berndt, Jason (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: RE: Source Wster assessment Flint River

Mike,

You may want to inquire why they don't have a copy of this record as it is a requirement. In addition, per the required CCR language they are supposed to make it available to their customers upon request.

We should also have a copy of this somewhere in the basic data files.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Berndt, Jason (DEQ)
Sent: Friday, February 06, 2015 11:35 AM
To: Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Busch, Stephen (DEQ)
Subject: RE: Source Wster assessment Flint River

See the attachment.

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:04 AM
To: Berndt, Jason (DEQ)
Subject: Source Wster assessment Flint River

Jason,

Has a source water assessment been performed for the Flint River watershed...spec. for the Flint WTP intake? If so, the city of Flint would like to obtain a copy of source water assessment report.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:37 AM
To: Benzie, Richard (DEQ)
Subject: Flint

Richard,

Just received the 15-page source water assess. of the Flint River from Jason. I will forward this to the city as requested.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:35 AM
To: Benzie, Richard (DEQ)
Subject: RE: CAZ description - Flint River

Thanks Richard,

I already left Jason a message to confirm this....I also responded to the city and provided them with the river sources (on our website)... I will get back with them on the status of the assessment and the availability of a report.

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Benzie, Richard (DEQ)
Sent: Friday, February 06, 2015 11:22 AM
To: Prysby, Mike (DEQ)
Cc: Busch, Stephen (DEQ); Berndt, Jason (DEQ)
Subject: FW: CAZ description - Flint River

Mike,

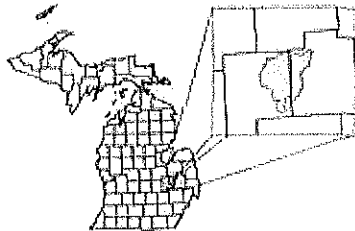
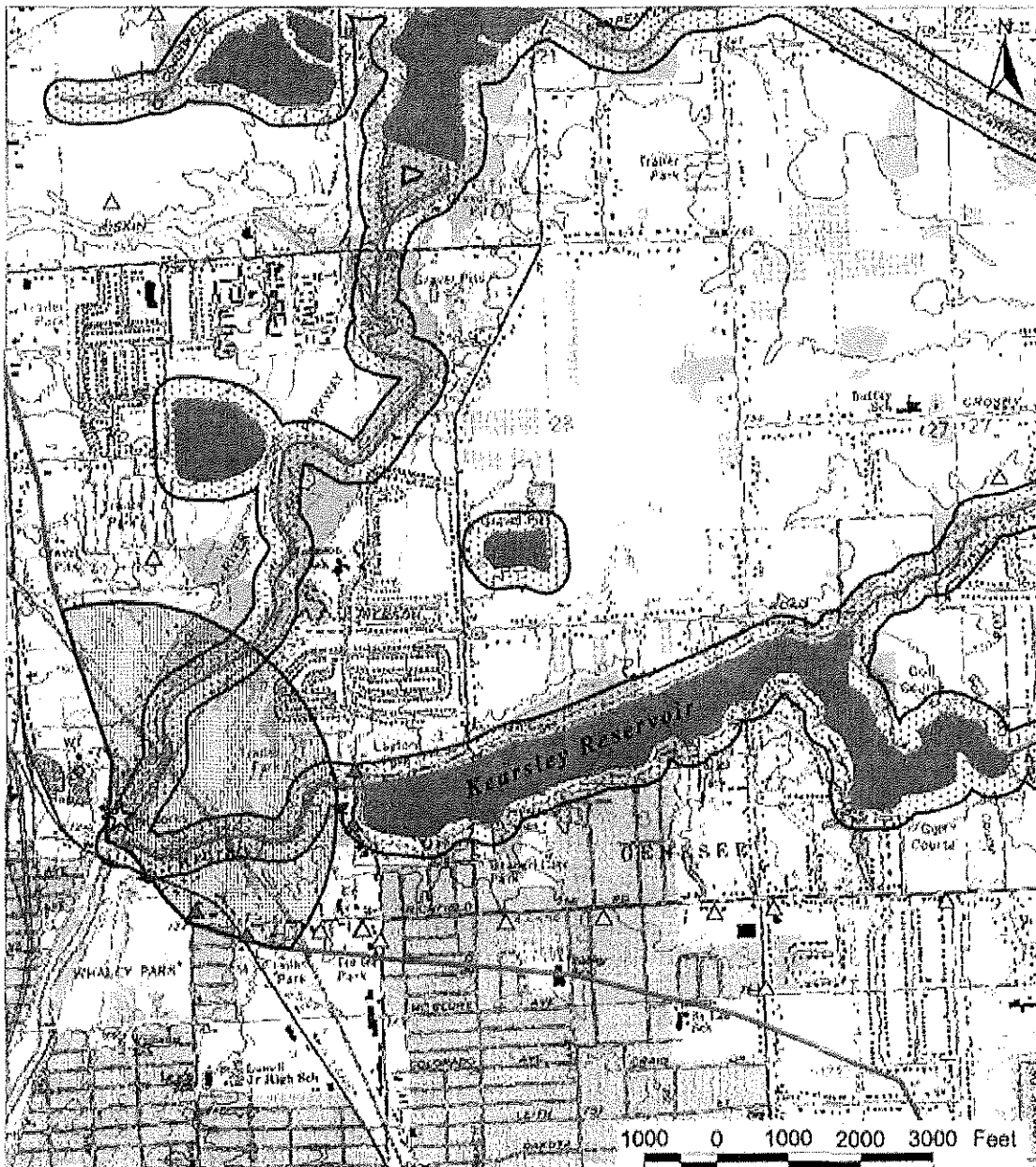
According to the recent dialogue below, there was an assessment of the Flint River. I believe they (Brad Brogren) addressed all standby intakes when they conducted the initial round of assessments. CAZ stands for Critical Assessment Zone. Contact Jason to find out more, but the file should be in our condensed files on 4 South (hopefully).

From: Berndt, Jason (DEQ)
Sent: Wednesday, January 28, 2015 10:53 AM
To: Benzie, Richard (DEQ)
Cc: Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Yes, the Sault Ste. Marie intake is in a connecting channel, but not part of the flow analysis as described below.

Yes, there was a CAZ and assessment on the Flint Intake, see below: There may not be a need, but there is some good information available in the assessment.

We should be assessing our new intakes, however, it's quite a project to complete following the protocol. Set aside \$'s??



Explanation

★ Flint Water-supply Intake	■ Lakes
△ Potential Contaminant Source (PCS)	▨ Critical Assessment Zone
--- SWA Boundary	▤ Susceptible Area
— Rivers and Creeks	

From: Benzie, Richard (DEQ)
Sent: Wednesday, January 28, 2015 10:44 AM
To: Berndt, Jason (DEQ)
Cc: Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Not that it matters for your discussion, but Sault Ste. Marie is also in a connecting channel. Maybe DeTour as well?

Did we ever develop a CAZ for the Flint River? Do we need to if it will only be a rarely used, emergency intake in another 18 months?

From: Berndt, Jason (DEQ)
Sent: Wednesday, January 28, 2015 9:28 AM
To: Goodwin, Kevin (DEQ)
Cc: Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Hi Kevin,

The assessment methodology for the intakes is slightly different based on the three surface water supply types. There are approximately 55 Great Lakes intakes, 14 Great Lakes connecting channel intakes, and 8 inland river intakes.

The Great Lakes (55) and connecting channels intakes (14) used the "Assessment Protocol for Great Lakes Sources" which was developed by a Region 5 states workgroup in August 2000. Your statement was correct on the two factors used to calculate sensitivity of each intake is length (L) of the intake pipeline and depth (D) of the intake structure. Sensitivity equals $L \times D$ as a unit less value. Sensitivity < 25k has a CAZ radius of 3000 feet, 25k – 125k with radius of 2000 feet, and >125k a radius of 1,000 feet. The other factors you mentioned contributing to the CAZ, as well potential contaminant sources, discharges, and water quality are taken into consideration with the Sensitivity analysis to determine an overall Susceptibility of the intake.

The connecting channel intakes (approx. 14) from roughly Port Huron to Wyandotte also utilized a flow model analysis of the St. Clair – Detroit River Waterway. This program included MDEQ, USGS, USACE, USEPA, and DWSD. This helped to identify concerns in contaminant tracking and develop contingency plans.

The inland river intakes (approx. 8) were watershed based assessments. In addition to the CAZ based on a Sensitivity analysis, these assessments identified buffers in the watershed upstream of the intake. These 300-foot buffers or susceptible areas were created along the shoreline of all drainages upstream of the intake. These were additional areas to identify potential risks or contaminant sources.

I attached an example of a watershed based assessment for Blissfield. More source water assessment program information is available on our website at:
http://www.michigan.gov/deq/0,4561,7-135-3313_3675_3693---,00.html

Also, we should meet to follow up on our water quality standards comparisons for our programs and proceed with the integration toolkit. I will be in Lansing tomorrow and again on February 18th.

Jason Berndt
 Environmental Quality Analyst
 Office of Drinking Water and Municipal Assistance
 Gaylord Field Office
 517-284-6513
 989-705-3420

From: Goodwin, Kevin (DEQ)
Sent: Tuesday, January 27, 2015 3:08 PM
To: Berndt, Jason (DEQ)
Subject: CAZ description

Hi Jason –

Was going to give you a call this p.m. to discuss some CAZ ‘stuff’ – but looks like you’re out of the office. Until we can talk – I wanted to see if the description below (quoted), which is currently in our Assessment Methodology of the Integrated Report, is relevant to inland surface water intakes as well (e.g. Raisin River)? This language is worded relative to Great Lakes/Connecting Channels, but based on the GIS layer we have (which I’m told came from the drinking water program originally) it looks like a similar approach is applied inland perhaps.

“For public water supply intakes that are located in the Great Lakes or connecting channels, a concept of a Critical Assessment Zone (CAZ) around each intake was developed based on a Sensitivity Factor calculated for each intake. The two attributes used to develop the Sensitivity Factor are the water depth above the intake structure and the perpendicular distance from shore or length of the intake pipeline. Other factors such as localized flow patterns, thermal effects, wind effects, lake bottom characteristics, benthic nepheloid layers, etc., may be used to complete the sensitivity analysis. A radius for the CAZ, ranging from 3,000 feet for the most sensitive intakes to 1,000 feet for the least sensitive intakes, is assigned based on the Sensitivity Factor. A shape with this radius is then drawn around the intake to illustrate the CAZ. If the CAZ intersects the shoreline, then the geographic extent of the assessment unit is determined on a case-by-case basis as the most influential 12-digit HUCs that are along the shoreline within the CAZ. For intakes that are located in open waters of the Great Lakes where the CAZ does not intersect the shoreline, the geographic extent of the assessment unit is 1.5 square miles.”

That said, I seem to remember from a Source Water Protection standpoint that anything ‘upstream’ was considered? If so, I’m just trying to wrap my head around how that differs from a CAZ...(and if not, well...I’m wrong, which is likely). It’d be helpful to chat if you have some time in the next day or so. Thanks...

Kevin Goodwin
Senior Aquatic Biologist
Water Resources Division- DEQ
517-284-5552 (ph)
517-241-9003 (fx)

Rennaker, Joanne (DEQ)

From: Berndt, Jason (DEQ)
Sent: Friday, February 06, 2015 11:35 AM
To: Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ); Busch, Stephen (DEQ)
Subject: RE: Source Wster assessment Flint River
Attachments: FlintFinal0204.doc

See the attachment.

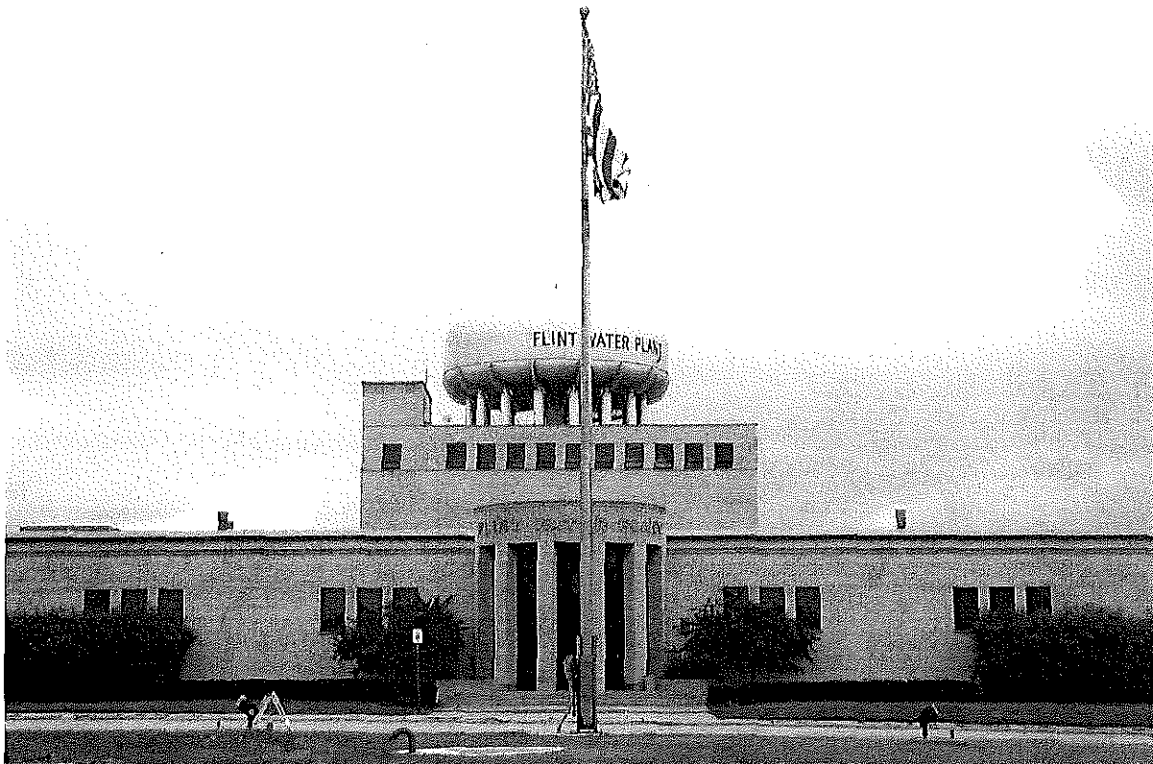
From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:04 AM
To: Berndt, Jason (DEQ)
Subject: Source Wster assessment Flint River

Jason,

Has a source water assessment been performed for the Flint River watershed...spec. for the Flint WTP intake? If so, the city of Flint would like to obtain a copy of source water assessment report.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

**Source Water Assessment Report for the
City of Flint Water Supply
Flint River Emergency Intake
February 2004**



*City of Flint Water Treatment Plant,
Flint, Michigan*

Prepared for:

City of Flint Water Supply; WSSN 2310

Prepared by:

U.S. Geological Survey, Water Resources Division, Michigan District
Michigan Department of Environmental Quality, Water Division
City of Flint Water Utilities Department

Michigan Source Water Assessment Report 54

Executive Summary

The purpose of the Source Water Assessment is to analyze the sensitivity and determine susceptibility of a community's source of drinking water to potential sources of contamination.

*Sensitivity is determined from the natural setting of the source water (raw water to the water treatment plant), and indicates natural protection afforded the source water. Using procedures established in the Great Lakes Protocol, Michigan Source Water Assessment Program, the **emergency** intake for the Flint Water Treatment Plant has a very high degree of sensitivity to potential contaminants. When the effects of agricultural and urban runoff in the Flint River watershed are considered, the Flint intake is categorized as very highly sensitive.*

*Susceptibility identifies factors within the community's source water area that may pose a risk to the water supply. The susceptibility determination provides information with respect to listed facilities and land areas within the source water area that should be given greater priority and oversight in implementing a source water protection program. The source water area for the Flint **emergency** intake includes 96 potential contaminant sources, 16 listed potential contaminant sources within the susceptible area, plus urban and agricultural runoff from the Flint River watershed into the Flint River. The potential contaminant sources, in combination with the very highly sensitive intake, indicate that the Flint **emergency** intake source water is very highly susceptible to potential contamination.*

*The Flint **emergency** intake source water is categorized as very highly susceptible, given land uses and potential contaminant sources within the source water area. However, it is noted that when operating, the City of Flint Water Treatment Plant has effectively treated this source water to meet drinking water standards. The City of Flint has instituted pollution prevention programs, but should be cognizant of additional potential threats to its source of drinking water that are identified in this report. This report explains the background and basis for these determinations.*

Using this Assessment

Clean, safe drinking water is fundamental to the viability of any community. Protecting the drinking water source is a wise and relatively inexpensive investment in your community's future. The overall intent of this assessment is to provide background information for your community to use in developing a local source water protection program. The assessment benefits your community by providing the following:

- *A basis for focusing limited resources within the community to protect the drinking water source(s).*

The assessment provides your community with information regarding activities within the **source water area (SWA)** that directly affect your water supply. It is within this SWA that a spill or improper use of **potential contaminants** may cause these contaminants to migrate toward the water **intake**. By examining where the source waters are most susceptible to contaminants, and where potential contaminants are located, the assessment clearly illustrates the potential risks that should be addressed.

- *A basis for informed decision-making regarding land use within the community.*

The assessment provides your community with a significant amount of information regarding where your drinking water comes from (the source) and what the risks are to the quality of that source. Knowing where the resource is allows your community planning authorities to

make informed decisions regarding proposed land uses within the SWA that are compatible with both your drinking water resource and the vision of growth embraced by your community.

- *A basis for dealing with future regulations.*

The assessment has been designed to functionally meet proposed requirements for surface-water supplies. Information needed to address regulatory needs and requirements has been collected and made available to your community through this report.

This source water assessment also provides the basis for a locally developed, voluntary source water protection program. Communities interested in voluntarily developing source water protection programs should contact the Michigan Department of Environmental Quality (MDEQ) or visit the Department web page at <http://www.deq.state.mi.us>.

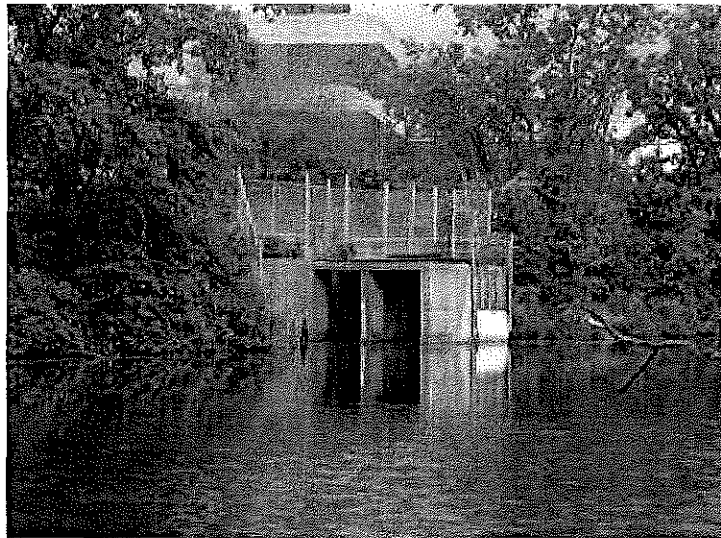
Introduction

In 1996, Congress amended the **Safe Drinking Water Act** and provided resources for state agencies to conduct source water assessments by identifying SWAs, analyzing the **sensitivity** of the source to natural conditions, conducting contaminant source inventories, and determining the **susceptibility** of the source to potential contamination. Delineations, sensitivity analyses, contaminant inventories, and susceptibility determinations comprise a "source water assessment." Assessments will be completed for every public water supply source in Michigan. To support this effort, the MDEQ Water Division established a partnership with the U.S. Geological Survey (USGS) to develop a method for conducting source water assessments for surface water supplies (Sweat and others, 2000; Sweat and others, 2001).

The requirements for public water supplies in Michigan to meet United States Environmental Protection Agency (USEPA) **maximum contaminant levels** (MCLs) provide some degree of assurance of safe drinking water; however, all systems are vulnerable to potential contamination. One of the best ways to ensure safe drinking water is to develop a local program designed to protect the source of drinking water against potential contamination. Not only does this add a margin of safety, but it also raises the awareness of consumers and/or the community of the risks of drinking water contamination. It is expected that source water assessment results will provide a basis for developing a source water protection program.

Background

Flint is located in Genesee County, about 55 miles northwest of Detroit, Michigan (fig. 1). The city of Flint water supply serves a population of 125,000. In 1967, the city connected to the Detroit Water and Sewage Department (DWSD) water supply and the Flint Water Treatment Plant (WTP) was placed on stand-by operation. The city is required by the MDEQ to maintain this treatment facility for reliability since the city obtains treated water through a single pipeline from the DWSD Lake Huron WTP which is subject to interruption of service. The present intake at the Flint WTP was constructed in 1948 and consists of a concrete box structure on the edge of the Flint River. The intake structure has a bottom elevation of 700.00 and connects through a 72-inch concrete pipe to the low service pump station. Low service pumps lift the river water through the WTP processes of conventional treatment and lime-soda softening.



*Flint WTP Emergency, Flint River Intake Structure
(Viewed from downstream)*

Treatment at the plant includes the addition ferric chloride as a coagulant, lime and soda ash for softening, chlorine for disinfection, and fluoride addition for dental health.

Water treatment plants are periodically inspected to identify construction, maintenance, operational or source defects that could make them vulnerable to contamination, particularly from contaminants that are microbial in nature, such as fecal coliforms. Water suppliers are provided a sanitary survey report that notes deficiencies in the system, and the State may direct the system to make necessary corrections. The sanitary survey is an important part of a safe drinking water program.

Climate

The Flint water supply is located in the central Lower Peninsula hydrologic province (Rheume, 1991), in the Flint River watershed (USGS, 1974, 1982). The region experiences temperate summers with moderate winters. The Flint Bishop International Airport Weather Bureau station reports that the average annual precipitation for the climatic years 1887-2001 was 30.28 inches and the average from the past 5 years is 31.42 inches (NOAA, 2001), with about 13 percent of that as snowfall between November and March. Annual average runoff for the Flint SWA, extrapolated from Miller and Twenter (1986, fig. 1) is 9 to 10 inches.

Source Water Area Geology and Hydrology

The study area for evaluating the extent of the Flint emergency intake SWA includes the upper reaches of the Flint River watershed (fig. 1). Flint is located roughly in the middle of the Flint River watershed. The



Flint River – Source Water for City of Flint WTP

SWA consists of lacustrine clays and silts; end moraines of coarse- and medium-textured till; fine-, medium-, and coarse-textured glacial tills; and postglacial alluvium. The SWA is underlain by Bayport Limestone, Marshall Sandstone and mixed shales, sandstones, and limestones of the Saginaw and Michigan Formations (Martin, 1955; Milstein, 1987). Soils underlying the Flint SWA are primarily associations of the Blount, Boyer,

Brookston, Capac, Ceresco, Celina,

Chelsea, Cohoctah, Conover, Del Ray, Kibbie, Lapeer, Lenawee, McBride, Metea, Miami, Montcalm, Sloan, Spinks series (U.S. Department of Agriculture, 1961; BASINS, 1998; MIRIS, 2000). They include loams, loamy sands, fine sandy loams, silty clay and muck.

Soil permeability is based on the calculated time of travel, in inches per hour (in/hr), for water to move vertically through a saturated soil zone. Soil thickness and permeability values are available in soil survey reports published by the National Cooperative Soil Survey and U.S. Department of Agriculture (1982, 1992, 1993, also 2 county reprints in press). Permeability ranges from less than 0.06 in/hr, rated as very slow, to more than 20 in/hr, rated as very rapid.

Source-water Area (SWA) for the City of Flint Emergency Water Supply

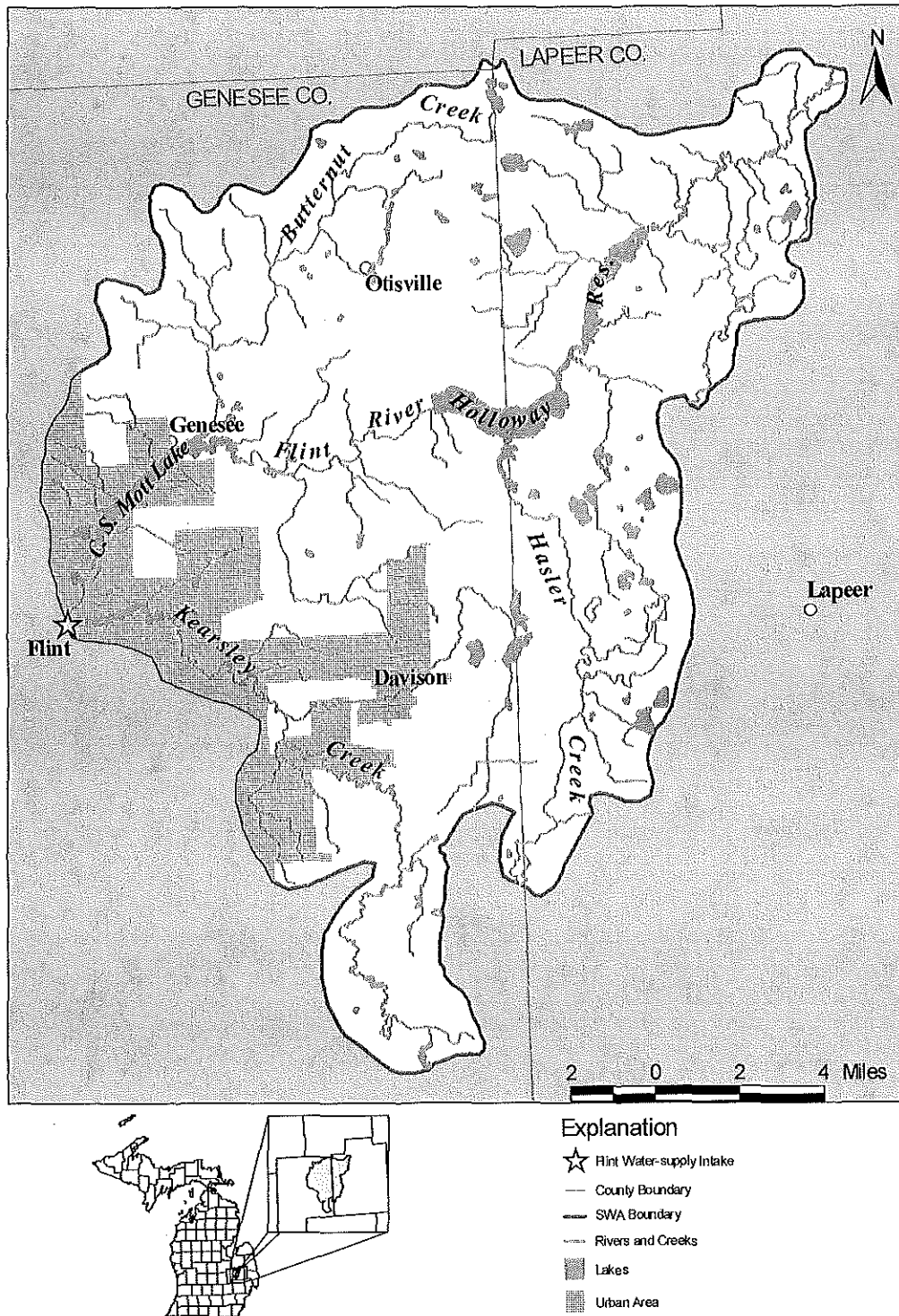


Figure 1. Source-water area (SWA) for the evaluation of the Flint emergency intake, Flint, MI.



Mott Lake and Dam on Flint River upstream of Flint WTP

3.1 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998; MIRIS, 2000). Soil permeability ranges from moderately slow in the northeastern portion of the SWA to moderate over the eastern portion of the SWA to moderately rapid throughout the central and western portions of the SWA, and rapid around the Flint River (fig. 2; U.S. Department of Agriculture, 1961; BASINS, 1998; MIRIS, 2000). Areas adjacent to the Flint River are underlain by highly sensitive drift lithologies, whereas the remainder of the SWA is underlain by least sensitive drift lithology (Lusch and others, 1992).

The Flint SWA contains an area of about 237 square miles (mi²). There are is one operable gage within the Flint SWA and a Flint River gage which operates approximately 9 miles downstream from the Flint Emergency Intake. Between 1932 and 2002 discharge has been recorded at this station by the USGS (Blumer and others, 2002). Annual mean discharge at the Flint River at Flint gauging station was 339 cubic feet per second (cfs) between 1932 and 2001, and ranged from 153 to 1258

cfs. Velocity measured at this stream gage was used to estimate the distance in which contaminants could travel within 24 hours, or the 24-hour time-of-travel (TOT) for this area on the Flint River. The distance calculated for the 24-hour TOT was approximately 27 miles.

Very slowly permeable soils significantly reduce the movement of water through the soil zone and, as a result, allow greater time for natural degradation of contaminants. However, such soils also provide for rapid overland transport of contaminants directly to receiving waters, which in turn may affect the water supply intake. Erosion and transport of soils by surface waters can cause an increase in turbidity. In contrast, very rapidly permeable soils allow for rapid infiltration and passage through the soil zone from the surface. Such soils potentially allow rapid transport of contaminants with minimal contact-time available for contaminant breakdown.

Mean, area-weighted, depth-integrated permeabilities for the Flint SWA range from 0.6 to as much as 7.8 in/hr. The mean permeability is



Kearsley Lake and Dam on Kearsley Creek Upstream of Discharge to Flint River and Flint WTP Emergency Intake

Soil Permeability for the Flint Source-water Area, Flint, MI

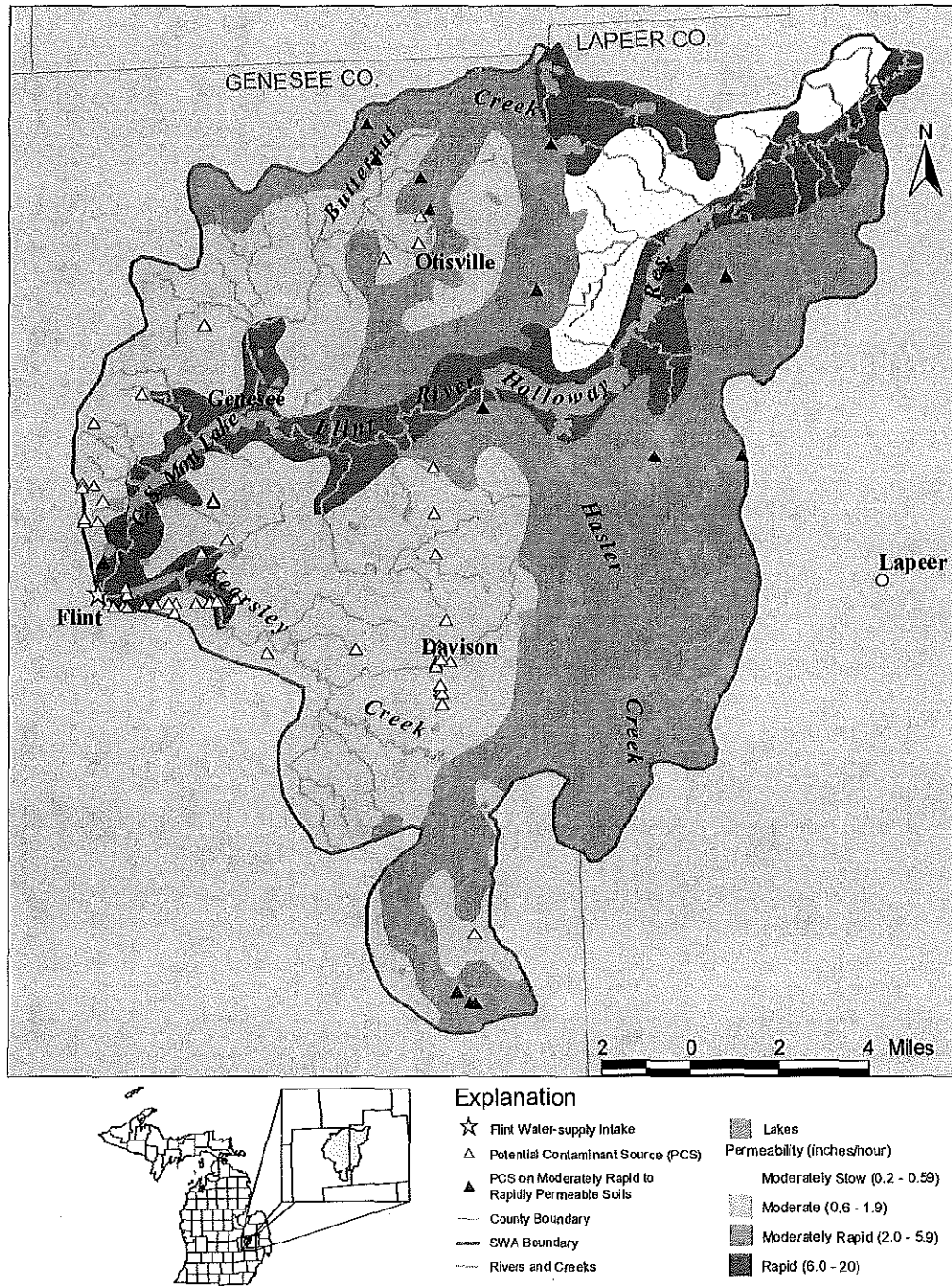


Figure 2. Soil permeability for the Flint emergency water-supply intake SWA. Flint, MI.

History of Raw Water Quality at the Source

Public water supplies are required to routinely monitor raw water quality for selected parameters to optimize treatment, and to monitor treated water quality for a list of contaminants that is determined by MDEQ and the Safe Drinking Water Act. A detection of any contaminant may indicate that a pathway exists for contaminants to reach the intake. It is important to realize that the results from a given sample only provide information regarding the water quality at the time the sample was collected. Water quality can change with time for a number of reasons. The fact that a water sample does not contain contaminants is no guarantee that contamination will not occur in the future. Conversely, the detection of a contaminant in the past does not indicate that it will occur in the future.

The Flint WTP records for the last 3 years of routine operation, 1965-1967 show that water use fluctuated between 34.4 and 46.5 million gallons per day (MGD), with an average daily use of 38.5 MGD. Raw water quality reported for these three years ranged from 5 to 183 nephelometric turbidity units (NTU) for turbidity, 203 to 375 mg/l total hardness as CaCO₃, 116 to 235 mg/l alkalinity as CaCO₃, 16 to 46 mg/l chlorides and 8.2 to 8.5 units for pH. Precipitation events were noted to increase turbidity and lower hardness. An analysis of flow duration for the Flint River and source water chemistry would probably indicate that there may be an indirect correlation between turbidity, suspended sediments, and coliforms and high flows associated with spring snowmelt and precipitation runoff events.

In recent years, the Flint WTP has undergone operational and process improvements for water treatment. Raw water quality during these testing periods when the WTP was operating but discharging to waste are noted in the table below.

Date of Tests	Turbidity (NTU)	Total Organic Carbon (mg/l)	pH (pH units)	Alkalinity (mg/l)	Hardness (mg/l)
12/5-7/2000	4.2	8.75	7.8	249	324
1/16-18/2001	2.4	8.5	7.7	275	363
3/20-21-2001	5.4	N/A	7.9	196	266
4/16-18/2001	7.6	8.6	8.2	213	284

Source Water Assessment Methodology

Technical guidelines for completing source water assessments are contained in the Michigan Source Water Assessment Program, Assessment Protocol for Great Lakes Sources (Protocol) (MDEQ, 1999, Appendix L) available at <http://www.deq.state.mi.us/dwr>. In general, an assessment is a process for evaluating a drinking water supply and the potential for its treated water to exceed an MCL due to raw water contamination. A source water assessment considers the SWA, potential sources of contamination within the SWA, conditions of the water supply intake, and susceptibility to contaminants in order to identify potential risks to drinking water quality. Although the Protocol provides the minimum requirements and instructions on how to conduct an assessment, each water supply is unique with respect to how the process is carried out, due to local conditions and information. Sweat and others (2000, 2001) have developed and documented the methodology used in the preparation of this assessment.

Delineating Source Water Areas

Delineation of the SWA is accomplished by using geographic information system (GIS) software to map the watershed(s) that have the potential to affect source water at the intake. Using information from the water supply, a critical assessment zone (CAZ) is defined for the intake (MDEQ, 1999, Appendix L). A buffer is then created along any shoreline intersected by the CAZ, and from the edge of the CAZ to the mouth of any river(s) that might influence the intake. Finally, the buffer is extended along the shoreline of any river(s) that might influence the intake, from the mouth of the river to its headwaters. The area defined by the CAZ, river and shoreline buffers is termed the susceptible area. The susceptible area within the SWA defines locations where a water supply should focus its management strategies and resources to benefit the drinking water resources.

Using the Great Lakes Protocol and the Flint water supply information:

- The CAZ for the Flint intake is assigned as 3,000 ft since the intake is located in an inland river (fig. 3).
- The susceptible area along the shoreline is determined to be: A distance of 300 ft inland along the banks of the Flint River and its tributaries (fig. 4).

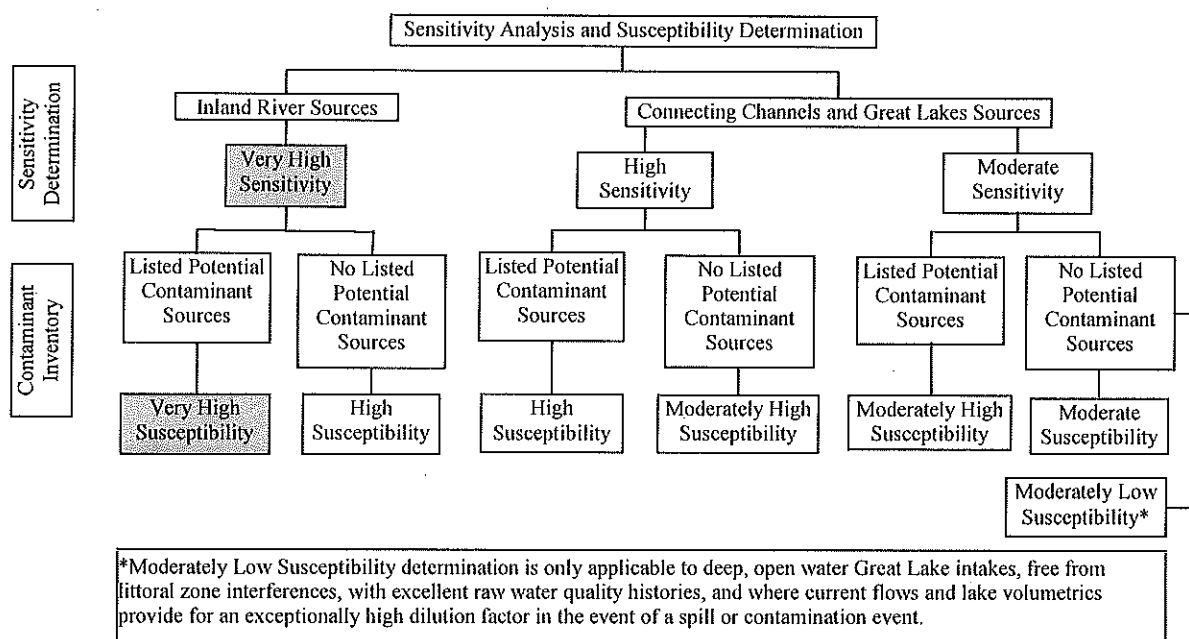


Figure 53. Surface-water source sensitivity analyses and susceptibility determination for the Ann Arbor Flint emergency water-treatment-plant source-water areas.

Contaminant Source Inventory

Past, current, and potential future sources of contaminants were inventoried to identify several categories of potential sources of contaminants including microorganisms (bacteria, oocysts, and viruses), inorganic compounds (nitrates and metals), organic compounds (solvents, petroleum compounds, pesticides), and disinfection by-product precursors (trihalomethanes, haloacetic acids).

It is important to remember that sites and areas identified by this process are only potential contaminant sources used and managed properly. In addition, assumptions were made about particular types of land uses and risks associated with those land uses. Assumptions are discussed further in the results portion of this report.

The process for completing the inventory included several steps, which are summarized as follows:

1. Reviewed readily available land use maps and historical/current aerial photographs.
2. Plotted relevant information from applicable state and federal regulatory databases including the following lists:
 - MDEQ leaking underground storage tank (LUST) sites;
 - MDEQ registered underground storage tank (UST) sites;
 - MDEQ Environmental Cleanup Site Information System (ECSI) sites;

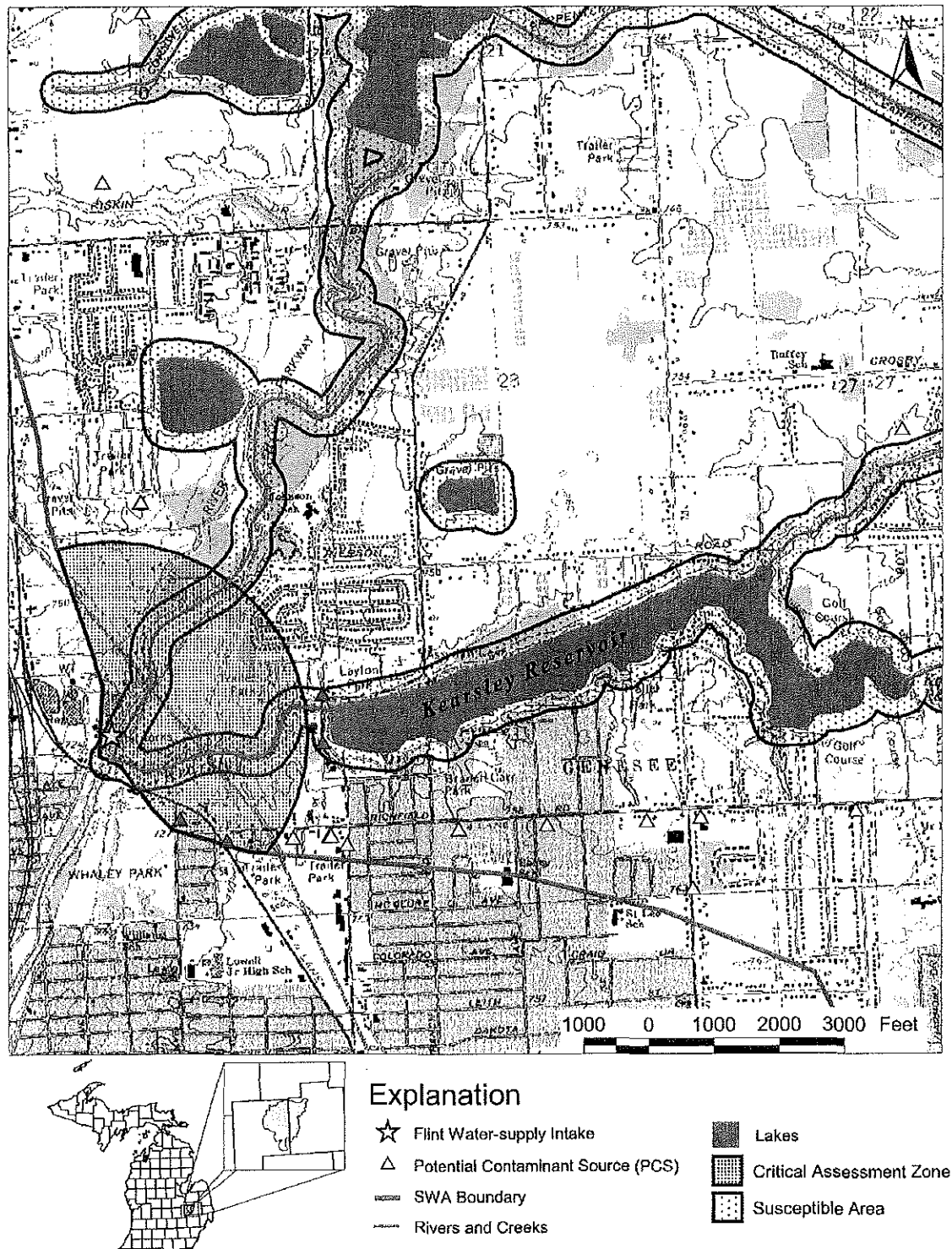


Figure 4. Critical Assessment Zone (CAZ) for the Flint emergency water-supply intake, Flint, MI.

- MDEQ Source Information System (for water discharge permit sites including National Pollutant Discharge Elimination System (NPDES) permits, Water Pollution Control Facility (WPCF) permits, storm water discharge permits, and on-site sewage (septic) system permits);
 - MDEQ Underground Injection Control (UIC) database;
 - MDEQ Active Solid Waste Disposal Permits list;
 - Michigan Department of Transportation (MDOT) - Hazardous Materials database;
 - State Fire Marshall registry of above-ground fuel storage tank sites;
 - State Fire Marshall Hazardous Material Handlers and Hazardous Material Incidents (HAZMAT) sites;
 - U.S. EPA BASINS software, version 2.1.
 - U.S. EPA Envirofacts database;
 - U.S. EPA Resource Conservation Recovery Act (RCRA) generators or notifiers list;
 - U.S. EPA RCRA Treatment, Storage, and Disposal Facility (TSDF) Permits list;
 - U.S. EPA National Priorities List (NPL);
 - U.S. EPA Comprehensive Environmental Response, Compensation and Liability Information System (CERCLA) List;
 - U.S. EPA RCRA Corrective Action Activity List (CORRACTS);
 - U.S. Department of Transportation (DOT) Hazardous Materials Information Reporting System (HMIRS);
 - U.S. EPA Toxic Chemical Release Inventory System (TRIS); and
 - U.S. EPA Oil Pollution Act of 1990 Spill Response Atlas
3. Met with public water supply and community officials on June 11, 2003 to identify potential sources not listed elsewhere in databases or on maps and completed a preliminary inventory form to be used in completing the SWA base map. Subsequent contacts by email and telephone on numerous occasions to request additional data, clarify data, and discuss results.
 4. Land use and/or ownership (for example, residential/municipal; commercial/industrial; agricultural/forest; and other land uses) was mapped and evaluated in relation to PCS, soil characteristics, and proximity to the intake(s).
 5. Conducted an informal field inventory to locate additional PCS.
 6. Completed final inventory form of PCS and plotted locations of PCS on the base map.

The purpose of the inventory is three fold: first, to provide information on the location of PCS, especially those within the susceptible area; second, to provide an effective means of educating the public about PCS; and third, to provide a reliable basis for developing a management plan to reduce potential contaminant risks to the Flint water supply.

The inventory process attempts to identify potential point-source contaminants within the SWA. It does not include an attempt to identify specific potential contamination problems at specific sites, such as facilities that do not safely store potentially hazardous materials. However, assumptions were made about particular types of land use. For example, it is assumed that rural residences associated with farming operations have specific potential contamination sources such as fuel storage, chemical storage and mixing areas, and machinery repair shops. It should also be noted that although the inventory depicts existing agricultural uses (crops grown), these are likely to undergo continual change due to normal crop rotation practices. What is irrigated farmland now may be non-irrigated farmland next year, or vice versa.

The results of the inventory were analyzed in terms of current, past, and future land uses and their relationship to the susceptible area and the supply intake. In general, land uses and PCS that are closest to the supply intake pose the greatest threat to a safe drinking water supply. Inventory results are summarized in table 1, and are shown on figure 5.

Many PCS are readily identifiable because they have a single discharge point, and often a permit is required for these discharges. However, other PCS have diffused, poorly defined discharge locations. These are known as non-point discharges because they occur over large areas and may not be quantifiable by readily accepted methods. These non-point source discharges are difficult to identify and control, and consequently to quantify, yet they are a major source of water pollution (Carpenter and others, 1998). Non-point sources also include atmospheric deposition over water and land, and include urban, rural, and

Table 1. Potential contaminant sources in the source water area

Type of Potential Contaminant Source (PCS)	Number of PCS	Number of PCS in Susceptible Area
Hazardous or solid waste site permits	71	11
Industrial facility discharge site permits	9	3
National priority list sites	1	0
Permit compliance system	12	2
Toxic release inventory permits	3	0
TOTALS	96	16

agricultural runoff from areas such as lawns, golf courses, farm fields, pastures, parking lots, and roadways. Runoff from these areas can contain many types of pollutants including sediments, metals, organic and inorganic chemicals, viral and bacterial pathogens, pharmaceuticals, and animal wastes. Transportation also represents a non-point source of contamination. Trucking and railroads transport potential contaminants through the SWA. An accident causing a spill could lead to potential contaminants entering a storm sewer, or in the case of boaters or rail transportation, directly to the Flint River. Petroleum pipeline crossing the upper reaches of the Flint River also pose contaminant threats.

Non-point sources of concern to the Flint water supply are primarily from storm sewers and from industrial, commercial, and residential sources in the SWA and communities upstream of the intake. A railroad bridge immediately upstream in the CAZ of the intake carries occasional train traffic described as hazardous. The West Boulevard storm sewer which discharges in the CAZ provides drainage to the Flint River from an industrialized area.

The Michigan Department of Agriculture is working to identify dairies and concentrated animal feedlots (greater than 1000 animal units) in the Flint River watershed upstream of the intake.



Railroad Trestle over Flint River Immediately Upstream of Flint WTP

The U.S. Environmental Protection Agency (USEPA) has identified one impaired water body in the Flint SWA on its Clean Water Act 303(d) list. The parameter of concern within the Holloway Reservoir is fish consumption advisories for PCBs. An additional impaired water body exists upstream of the SWA but not within the SWA itself. This water body is the collective of unnamed drains in Metamora, and the parameters of concern are untreated sewage discharge and pathogens (MDEQ, 2002).

In general, PCS within the susceptible area pose greater risks than those outside the susceptible area. The presence of PCS within the SWA indicates potential sources of chemicals that could, if improperly managed or released, impact the water quality at the intake. Small quantities of these chemicals, in some

Contaminant Source Inventory for the Flint Emergency Water-supply Intake, Flint, MI

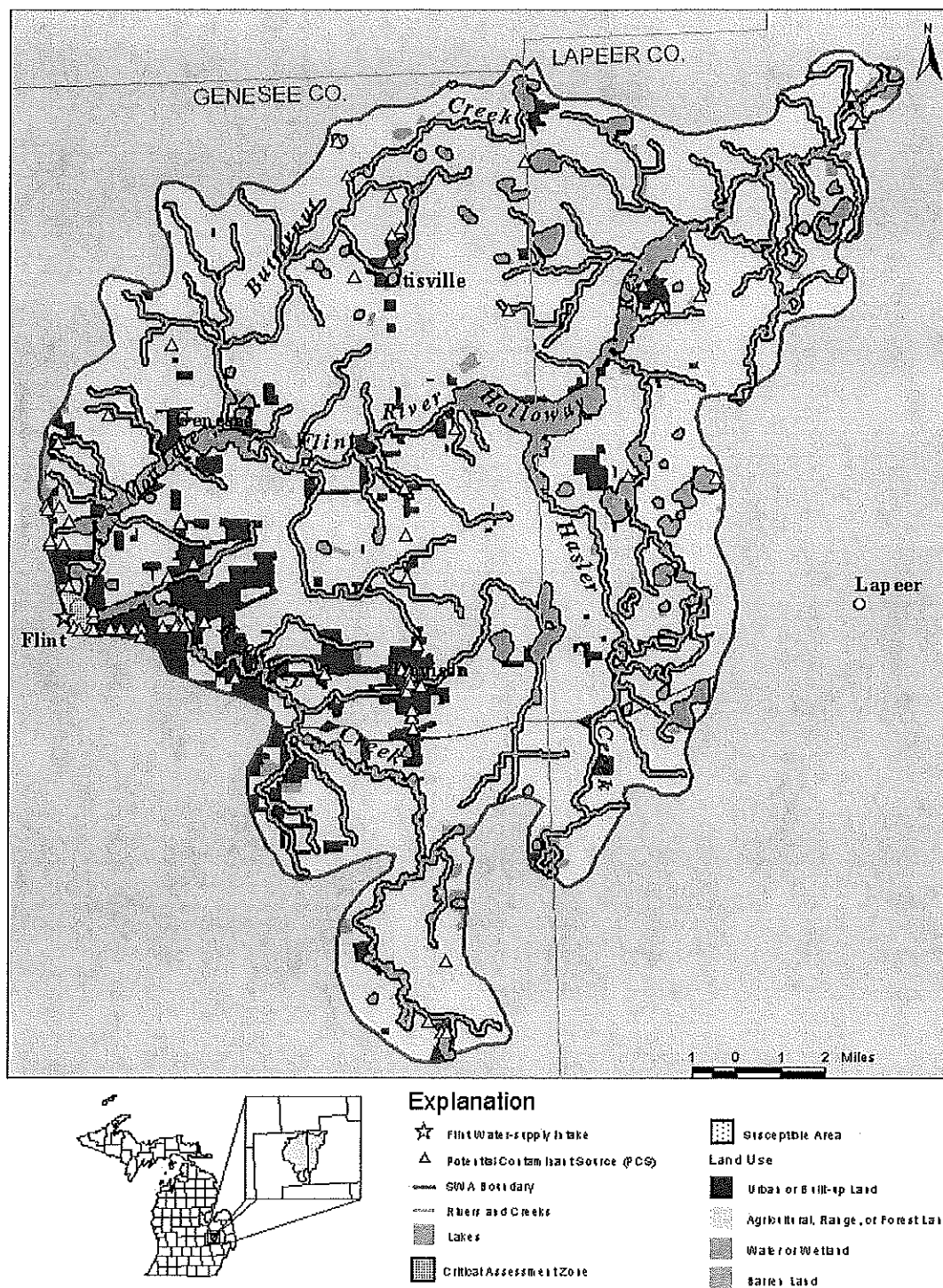


Figure 5. Potential Contaminant Sources in City of Flint Source Water Area, Flint, Michigan

cases less than a liter, can significantly affect the supply. Also of concern is the location and distribution of these sources with respect to highly permeable soils. The susceptible area consists of primarily agricultural and forested land with some urban areas. Overlaying the PCS locations and the moderately rapid to rapidly permeable soil map for the Flint SWA indicates that 21 of the located PCS are located on or very near to areas with moderately rapid to rapidly-permeable soils. All PCS within the SWA should be addressed; the susceptibility determination, however, provides the water supply with the tools to focus resources where the greatest risk occurs. The results of the PCS inventory performed for Flint water supply is shown on figure 5 and is summarized as a function of PCS locations relative to the susceptible area. The inventory results indicate that there are 7 PCS, holding 8 permits for discharge, within the susceptible area (table 2).

Table 2. Contaminant source inventory.

Site Name	Identification Number	Reason for Permit	Reason for Listing as Potential Contaminant Source
DAVISON OIL AND GAS BURTON STA 7	MI0000540310	On-Site Storage	Hazardous and Solid Waste Site
H AND M SVC	MID985612225		
KINNIES PARTY STORE	MID985597657		
ZACK CO	MID002975225		
EVERGREEN CLEANERS	MID981539711		
DORT HWY INC	MID985579945		
SUPER GO MARKETERS INC	MID985583053		
PIONEER CABINetry INC	MID985605849		
DAVISON CITY OF	MID985625136		
MID MICHIGAN AUTO PARTS INC	MID985654789		
CLARK STORE 1849	MI0001853613		
FORD-NORTHVILLE PLT	MI0024643	Process, Treatment, and Waste Waters	Industrial Facilities Discharge Site
FOREST WASTE PRODUCTS	YCRCLA276		
OTISVILLE WWTP ^a	MI0028720		
ORCHARD COVE WWTP	MI0054755	Waste Water, Dust, and Process Water	Permit Compliance System
OTISVILLE WWTP ^a	MI0028720		

Note: Subscript denotes multiple permits

Sensitivity Analysis

Sensitivity is the natural ability of a SWA to provide protection against the contamination of the water supply intake, and includes physical attributes of lakes, rivers, and soils. The sensitivity analysis requires consideration of several different variables related to the natural environment, for example:

- Water quality history of the source.
- Distribution of moderately to highly-permeable soils.
- Amount of available water from precipitation or runoff.
- Potential for runoff to affect the intake.
- Nature of the intake, including: depth, distance from shore, age, and materials used.
- Surface water flow patterns in vicinity of intake.

To perform this analysis, USGS, MDEQ, and the operator of the Flint WTP collected, researched, and analyzed information from the WTP, monthly operator reports, sanitary surveys, soil maps, published reports, and historical plant operation and raw water quality data. The Michigan SWAP has three categories of sensitivity for surface water sources ranging from moderately sensitive to very highly sensitive. Analysis of this information, using guidelines provided in Brogren (1999) and Sweat and others (2000, in press), indicates that the Flint intake is at the high end of this range or very highly sensitive (fig. 3). This means that the natural environment offers little protection against contamination of the water supply intake.

Susceptibility Determination

Susceptibility is the relative potential for contamination to reach the public water supply intake used for drinking water purposes. Whereas the sensitivity of a water supply is the natural ability of the area to protect the intake against contamination, the susceptibility determination also takes into account other factors that will affect whether a contaminant reaches the intake. Whether or not a particular drinking water source becomes contaminated depends on three factors:

- (1) The distribution of PCS;
- (2) The source water area; and
- (3) The natural protection, or sensitivity, of the source.

In conducting a susceptibility determination, the part of the SWA that yields water to the water supply-system intake is identified by establishment of the susceptible area within the source water area. PCS within the susceptible area are then located. Based on the distribution of PCS within the susceptible area, the type of PCS, and the nature of the chemicals they use or store, PCS are analyzed for the risk they may represent to the water supply intake. Along with the presence and distribution of PCS, the sensitivity analysis is then used to determine the susceptibility of the water supply (fig. 3). This leads to a determination of whether the drinking water source is moderately susceptible, highly susceptible, or very highly susceptible to contamination (Brogren, 1999; Sweat and others, in press). It is important to understand that a system can have low sensitivity relative to some conditions (for example, intake construction and location), and high susceptibility because of other conditions (for example, the type of PCS). In Michigan, surface water sources of drinking water range from moderately-low to very-high susceptibility.

When a public water supply is determined to have a moderate, high, or very high susceptibility because of a particular condition or set of conditions, there is a significant risk of contamination of the drinking water source because of that condition or set of conditions. Although the susceptibility determination does not predict when or if contamination will actually occur, it does recognize conditions that are highly favorable for contamination of the supply. In the event of a contaminant release to soils or surface water within the susceptible area, it is very likely that contamination at the intake would occur without completion of remedial actions.

If a public water supply's drinking water source is determined to be highly susceptible, it is recommended that the system identify the condition(s) that lead to the high susceptibility. Immediate steps should be taken to protect the source, and action should be considered to remedy the condition (for example, repairing or replacing faulty intake construction, working directly with facility operators to implement sound management practices, etc.).

All water supplies, regardless of their susceptibility, should consider identified factors that could lead to higher susceptibility in the future, and should prepare a strategy to protect the water supply source. Raising public awareness through signs and other education programs, encouraging proper intake construction and the use of best management practices in existing facilities are good ways of ensuring that a surface water source maintains its moderate susceptibility rating.

Summary and Recommendations

The actual susceptibility of the drinking water source of a water supply depends on a number of contributing factors, some of which are only slightly related. Sensitivity is determined from the natural setting of the source and identifies the natural protection afforded to the source water. Susceptibility is determined by identifying those factors within the community's SWA that may pose a risk to the source water. The susceptibility determination provides information with respect to facilities within the SWA or

land areas within the SWA that should be given greater priority and oversight in the implementation of a drinking water protection program.

Sensitivity Analysis: Based on criteria adopted in the Great Lakes Protocol of the Michigan Source Water Assessment Program, the emergency intake for the Flint Water Treatment Plant has a very high degree of sensitivity to potential contaminants.

Susceptibility Determination: The SWA for the Flint intake includes 8 listed potential contaminant sources within the susceptible area, numerous storm drains discharging upstream of the intake, a railroad crossing plus urban, agricultural, and industrial runoff from the Flint River watershed. Combining these potential contaminant sources with the very highly sensitive intake yields a very highly susceptible determination for Flint source water (fig. 5).

Effective Treatment:

The results of this assessment and the recommendations based on these results are summarized as follows:

- ***Intake*** - The Flint Water WTP intake was installed in 1948 and draws water from the Flint River from a shoreline structure making the intake very highly sensitive.
- ***Soils*** - Using a mean, area-weighted, depth-integrated permeability estimation, the soil and subsoil permeability in the SWA range from 0.6 in/hr to as much as 7.7 in/hr. The mean permeability is 3.1 in/hr (Schneider and Erickson, undated, series of 5 maps; BASINS, 1998; MIRIS, 2000). About two thirds of the soils in the Flint SWA are moderately rapid or rapidly permeable. Sixteen (16) PCS are located on these soils. These factors combine to make the SWA, and thus the intake, very highly sensitive. The community should take steps to evaluate current and future land use in areas of highly permeable soils, particularly those occurring within the susceptible area. Those PCS that have been identified either on or in close proximity to these soils should be informed of the sensitive nature of the area and encouraged to adopt best management practices designed to minimize the risk of a ground release. Residential areas that have been developed on these soils should be targeted for educational programs identifying steps that residents can take to protect the water supply.
- ***Historical Contaminant Detections*** – Since the Flint WTP has not utilized the Flint River since 1967 as a source of public drinking water, extensive raw water quality data is not available. However, as is typical for river water, the periodic presence of coliform bacteria is indicative of a relationship between runoff and soil conditions, causing the presence of bacteria at detectable levels in river source water. Background turbidity has recently been reported in the range of 2.4 to 7.6 NTU. These factors indicate that the SWA, and thus the intake, is very highly susceptible.
- ***Sanitary Survey*** – Defects reported as requiring repair either have been corrected or are scheduled for repair. The Flint WTP is undergoing extensive upgrades to improve treatment and reliability. It is important that the water supply continue to follow good management practices.
- ***Potential Contaminant Sources*** - A review of the PCS inventory and the rapidly and very rapidly permeable soil distribution indicates that the Flint SWA has 21 PCS located on moderately rapid to rapidly permeable soils. Within the susceptible area, there are 7 PCS with 8 discharge permits. In addition, there are numerous storm drains within the vicinity of the intake. A railroad crossing immediately upstream of the intake also poses a potential contaminant threat. It is recommended that the community focus initially on PCS that are within the susceptible area as they pose the greatest potential threat to the water supply. These facilities should be made aware of free technical assistance that is available through MDEQ's pollution prevention programs. Through chemical inventory, waste reduction, and by increasing awareness of best management practices, the risk these facilities pose to source waters can be reduced. The PCS inventory indicates that the source is very highly susceptible.
- ***Source Water Assessment*** - The Flint source water assessment is based on these site-specific parameters:

1. Definition of a Critical Assessment Zone around both intake for a very highly sensitive source;
 2. Definition of a SWA for the Flint River, and shoreline near the intake;
 3. Flow duration and discharge in the Flint River upstream of the intake, and the effects of upstream contaminant discharges on the source water quality; and
 4. Listed and nonlisted potential contaminant sources.
- **Source Water Protection** - The City has initiated source water protection activities with an Industrial Pretreatment Program incorporating management plans, chemical containment, and spill response, spill response training, plus storm sewer and street cleaning programs.

The Flint WTP and/or the community should assemble a team to assist in the development and implementation of a source water protection program that uses this assessment to further protect the Flint source water area.

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-----, in press, Soil survey of Jackson County, Michigan:

GLOSSARY

Critical Assessment Zone (CAZ) - the area from the intake structure to the shoreline and inland, including a triangular water surface and a land area encompassed by an arc from the endpoint of the shoreline distance on either side of the on shore intake pipe location

Geographic Information System (GIS) - a system to capture, store, update, manipulate, analyze, and display all forms of geographically referenced information

Impaired water bodies - As defined by USEPA and listed on the 303 (d) list of the federal Clean Water Act.

Intake - the point at which source (raw) water is drawn into a pipe to be delivered to a water treatment plant

Lignins - an amorphous, cellulose-like, organic substance that acts as a binder for the cellulose fibers in wood and adds strength and stiffness to cell walls

Maximum Contaminant Level (MCL) - the maximum permissible level of a contaminant in water that is delivered to any user of a public water system

Potential Contaminant Sources (PCS) - listed and non-listed agricultural sites, businesses, and industries that have the potential to cause contaminants to be introduced into source water

Sensitivity - a measure of the physical attributes of the source area and how readily they protect the intake from contaminants

Source - the water body from which a water supplier gets its water

Source Water Area (SWA) - the land and water area upstream of an intake that has the potential to directly influence the quality of the water at the intake

Source Water Assessment Program (SWAP)- in Michigan, the process defined by the state Department of Environmental Quality to complete assessments of all the state's public water supplies

Susceptibility - the Susceptibility identifies factors that may pose a risk within the community's SWA

Susceptible Area - the area defined by the critical assessment zone and a buffer on either side of any drainages that contribute water to an intake

Synthetic Organic Contaminants (SOC) - Manmade organic chemical compounds such as pesticides, etc.

Tannins - naturally occurring phenolic compounds that precipitate proteins, alkaloids, and glucosides from solution that has a yellowish appearance

Volatile Organic Contaminants (VOC) - Unnatural, volatile organic chemical compounds such as gasoline components, solvents, degreasers, etc

Rennaker, Joanne (DEQ)

From: Benzie, Richard (DEQ)
Sent: Friday, February 06, 2015 11:22 AM
To: Prysby, Mike (DEQ)
Cc: Busch, Stephen (DEQ); Berndt, Jason (DEQ)
Subject: FW: CAZ description - Flint River

Mike,

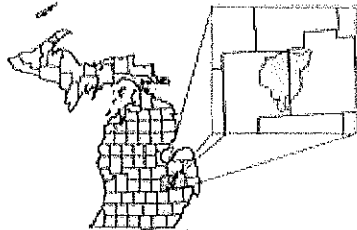
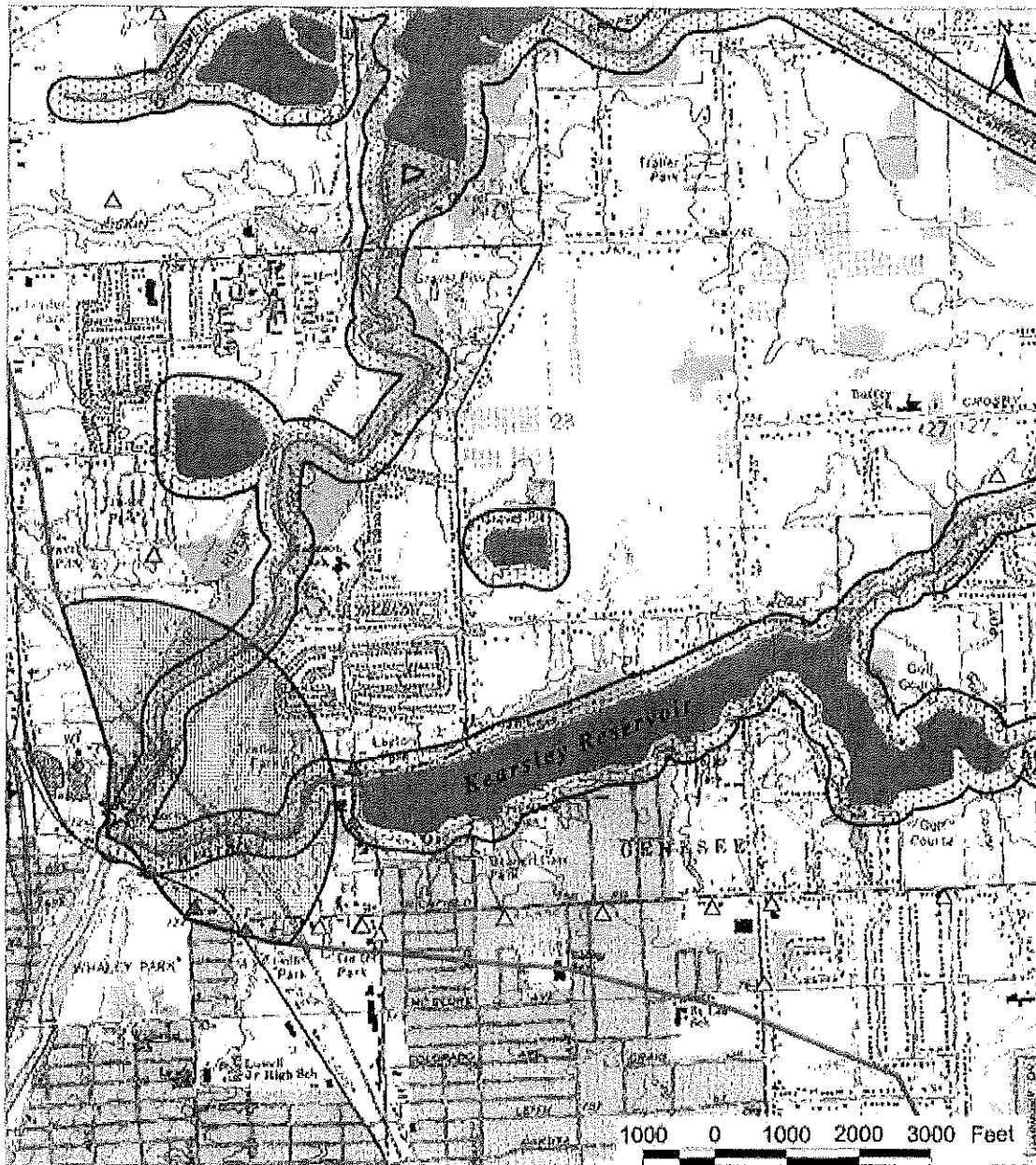
According to the recent dialogue below, there was an assessment of the Flint River. I believe they (Brad Brogren) addressed all standby intakes when they conducted the initial round of assessments. CAZ stands for Critical Assessment Zone. Contact Jason to find out more, but the file should be in our condensed files on 4 South (hopefully).

From: Berndt, Jason (DEQ)
Sent: Wednesday, January 28, 2015 10:53 AM
To: Benzie, Richard (DEQ)
Cc: Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Yes, the Sault Ste. Marie intake is in a connecting channel, but not part of the flow analysis as described below.

Yes, there was a CAZ and assessment on the Flint Intake, see below: There may not be a need, but there is some good information available in the assessment.

We should be assessing our new intakes, however, it's quite a project to complete following the protocol. Set aside \$'s??



Explanation

☆ Flint Water-supply Intake	■ Lakes
△ Potential Contaminant Source (PCS)	▨ Critical Assessment Zone
--- SWA Boundary	▤ Susceptible Area
— Rivers and Creeks	

From: Benzie, Richard (DEQ)
Sent: Wednesday, January 28, 2015 10:44 AM
To: Berndt, Jason (DEQ)
Cc: Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Not that it matters for your discussion, but Sault Ste. Marie is also in a connecting channel. Maybe DeTour as well?

Did we ever develop a CAZ for the Flint River? Do we need to if it will only be a rarely used, emergency intake in another 18 months?

From: Berndt, Jason (DEQ)
Sent: Wednesday, January 28, 2015 9:28 AM
To: Goodwin, Kevin (DEQ)
Cc: Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Fisher, Brant (DEQ)
Subject: RE: CAZ description

Hi Kevin,

The assessment methodology for the intakes is slightly different based on the three surface water supply types. There are approximately 55 Great Lakes intakes, 14 Great Lakes connecting channel intakes, and 8 inland river intakes.

The Great Lakes (55) and connecting channels intakes (14) used the "Assessment Protocol for Great Lakes Sources" which was developed by a Region 5 states workgroup in August 2000. Your statement was correct on the two factors used to calculate sensitivity of each intake is length (L) of the intake pipeline and depth (D) of the intake structure. Sensitivity equals $L \times D$ as a unit less value. Sensitivity < 25k has a CAZ radius of 3000 feet, 25k – 125k with radius of 2000 feet, and >125k a radius of 1,000 feet. The other factors you mentioned contributing to the CAZ, as well potential contaminant sources, discharges, and water quality are taken into consideration with the Sensitivity analysis to determine an overall Susceptibility of the intake.

The connecting channel intakes (approx. 14) from roughly Port Huron to Wyandotte also utilized a flow model analysis of the St. Clair – Detroit River Waterway. This program included MDEQ, USGS, USACE, USEPA, and DWSD. This helped to identify concerns in contaminant tracking and develop contingency plans.

The inland river intakes (approx. 8) were watershed based assessments. In addition to the CAZ based on a Sensitivity analysis, these assessments identified buffers in the watershed upstream of the intake. These 300-foot buffers or susceptible areas were created along the shoreline of all drainages upstream of the intake. These were additional areas to identify potential risks or contaminant sources.

I attached an example of a watershed based assessment for Blissfield. More source water assessment program information is available on our website at:

http://www.michigan.gov/deq/0,4561,7-135-3313_3675_3693---,00.html

Also, we should meet to follow up on our water quality standards comparisons for our programs and proceed with the integration toolkit. I will be in Lansing tomorrow and again on February 18th.

Jason Berndt
 Environmental Quality Analyst
 Office of Drinking Water and Municipal Assistance
 Gaylord Field Office
 517-284-6513
 989-705-3420

From: Goodwin, Kevin (DEQ)
Sent: Tuesday, January 27, 2015 3:08 PM
To: Berndt, Jason (DEQ)
Subject: CAZ description

Hi Jason –

Was going to give you a call this p.m. to discuss some CAZ 'stuff' – but looks like you're out of the office. Until we can talk – I wanted to see if the description below (quoted), which is currently in our Assessment Methodology of the Integrated Report, is relevant to inland surface water intakes as well (e.g. Raisin River)? This language is worded relative to Great Lakes/Connecting Channels, but based on the GIS layer we have (which I'm told came from the drinking water program originally) it looks like a similar approach is applied inland perhaps.

"For public water supply intakes that are located in the Great Lakes or connecting channels, a concept of a Critical Assessment Zone (CAZ) around each intake was developed based on a Sensitivity Factor calculated for each intake. The two attributes used to develop the Sensitivity Factor are the water depth above the intake structure and the perpendicular distance from shore or length of the intake pipeline. Other factors such as localized flow patterns, thermal effects, wind effects, lake bottom characteristics, benthic nepheloid layers, etc., may be used to complete the sensitivity analysis. A radius for the CAZ, ranging from 3,000 feet for the most sensitive intakes to 1,000 feet for the least sensitive intakes, is assigned based on the Sensitivity Factor. A shape with this radius is then drawn around the intake to illustrate the CAZ. If the CAZ intersects the shoreline, then the geographic extent of the assessment unit is determined on a case-by-case basis as the most influential 12-digit HUCs that are along the shoreline within the CAZ. For intakes that are located in open waters of the Great Lakes where the CAZ does not intersect the shoreline, the geographic extent of the assessment unit is 1.5 square miles."

That said, I seem to remember from a Source Water Protection standpoint that anything 'upstream' was considered? If so, I'm just trying to wrap my head around how that differs from a CAZ...(and if not, well...I'm wrong, which is likely). It'd be helpful to chat if you have some time in the next day or so. Thanks...

Kevin Goodwin
Senior Aquatic Biologist
Water Resources Division- DEQ
517-284-5552 (ph)
517-241-9003 (fx)

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:04 AM
To: Berndt, Jason (DEQ)
Subject: Source Wster assessment Flint River

Jason,

Has a source water assessment been performed for the Flint River watershed...spec. for the Flint WTP intake? If so, the city of Flint would like to obtain a copy of source water assessment report.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Friday, February 06, 2015 11:01 AM
To: emurphy@cityofflint.com
Subject: FW: Water Supply Sources

Elizabeth,

Below is a link to our website that lists all of surface water systems in Michigan. You will need to scroll down to the bottom of the list to see the listing of supplies using a river as their source. Also, I am not aware of any source water assessment conducted for the Flint River watershed; however, I would like to confirm that. I will let you know asap once I obtain the confirmation.

http://www.michigan.gov/deq/0,4561,7-135-3313_3675_3691-9775--,00.html

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Benzie, Richard (DEQ)
Sent: Friday, February 06, 2015 10:38 AM
To: Dee, Rhiannon
Cc: Ostlund, Peter (DEQ); Busch, Stephen (DEQ); Prysby, Mike (DEQ); Crooks, Jennifer; Poy, Thomas
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

I'm not sure what this complainant is alleging. Do you want Michigan to respond to the allegation that a "company or individual dumped millions of gallons of raw sewage into the city of Flint drinking water" or the allegation that "they(?) have dumped a potential cancer causing chemical into the city's drinking water" or the allegation that the city of Flint is flushing hydrants and charging customers double? The Office of Drinking Water and Municipal Assistance cannot address the issue surrounding the dumping of raw sewage and we don't interfere with water rates, but maybe an explanation of the issues that have confronted the city of Flint and their public water supply will help you understand the overall problem.

Last spring, the city of Flint decided to begin relying upon the Flint River as their source of drinking water using a treatment plant that was designed to do so. Last summer, they experienced difficulties with stagnation in some areas of the distribution system due to significantly reduced demands as a result of the loss of a significant percentage of their residential and industrial demands that accelerated over the last decade. During the summer of 2014, they also had a couple of monitoring periods where they detected total coliform at monitoring sites in these stagnant areas, and one time they detected E.coli present. The ensuing boil water advisories and public notification heightened customer concern about the quality of drinking water as a result of the switch from Detroit to the Flint River. Detroit supplied Flint with drinking water from Lake Huron, a much higher quality source than the Flint River. However, monitoring of the Flint water treatment plant tap has never indicated unacceptable water entering the distribution system. In response to these coliform detections and in an effort to prevent a recurrence, the city also increased flushing water mains in low flow areas and they have attempted to ensure the presence of a chlorine residual throughout the distribution system (is this the "potential cancer causing chemical" the complainant mentions?).

Compounding the problem of customer confidence was the initial monitoring for disinfection byproducts conducted by Flint under the Stage 2 DBR after their switch to the Flint River. The initial monitoring reported significantly elevated levels of total trihalomethane (TTHM) compounds throughout the city's distribution system. Our district office advised the city that they needed to immediately implement operational techniques at the treatment plant and in the distribution system to reduce the formation of these compounds. The steps the city of Flint has taken have been successful and have reduced TTHM concentrations to the point where the latest results are below the drinking water standard. However, the standard is calculated on a running annual average and it is likely to be another 3 to 6 months before the annual average at each monitoring station will (hopefully) meet the standard. Until then, the city has to continue to provide quarterly public notification, which will continue to concern residents despite the latest TTHM results.

The switch to the Flint River, the microbiological problems and the elevated TTHM concentrations experienced last year in Flint have caused a high level of customer dissatisfaction and distrust. The city is working diligently to restore that confidence, but it will not be accomplished easily or overnight. You should also know that the switch to the Flint River is an interim measure intended to last only until a 72-inch pipeline from Lake Huron to the Flint water treatment plant is completed. It is currently under construction and expected to be in operation in mid-2016. At that point, the city's drinking water should again be very similar in quality to what they were receiving from Detroit.

Although the subject(s) of this complaint are not clear to me, I suspect it is a result of the media coverage of the recent problems with the city's water supply. However, the information from your initial contact indicates a Grand Blanc, Michigan address, which is not in the city of Flint service area. As I mentioned, our Lansing

district office has been dealing with city representatives on this issue. If you have further questions, feel free to contact either Michael Prysby or Steve Busch. They are receiving this message so you have their contact information. You may also wish to communicate with your Region 5 counterparts in the Office of Drinking Water & Ground Water, Jennifer Crooks or Tom Poy, who have received similar complaints and with whom we have communicated regularly on these issues.

Please let us know if someone from EPA will respond to the complainant, or if you expect Michigan DEQ to do so.

Richard Benzie, P.E., Chief
Field Operations Section
Office of Drinking Water and Municipal Assistance, MDEQ
517-284-6512

From: Ostlund, Peter (DEQ)
Sent: Friday, February 06, 2015 6:55 AM
To: Dee, Rhiannon
Cc: Selden, Barry (DEQ); Benzie, Richard (DEQ); Bartley, Cheryl (DEQ)
Subject: RE: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Rhiannon, this is a drinking water complaint, not an NPDES complaint. Flint does have SSOs, and reports those. That's not the cause of this complaint.

There are public concerns with Flint's drinking water system, which switch from the city of Detroit supply to their own supply. Detroit's source water is much better, so the public may be noticing some changes.

I've copied Richard Benzie, how is the Field Operations Chief in our division that handles drinking water. If you need more follow up, he can provide it.

Thanks, Pete

Peter Ostlund
Field Operations Section Chief
Water Resources Division
Michigan Dept. of Environmental Quality
P.O. Box 30458
Lansing, Michigan 48909-7958
517-898-5128 (iPhone)
ostlundp@michigan.gov

From: Dee, Rhiannon [<mailto:dee.Rhiannon@epa.gov>]
Sent: Thursday, February 05, 2015 5:11 PM
To: Ostlund, Peter (DEQ); Selden, Barry (DEQ)
Subject: FW: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

Hi there,

Hope all is well. We received this complaint a while back. Complainant is alleging discharges into Flint River.

Let me know if you have any questions or if I should forward this on to someone else.

Best,

Rhiannon Dee
Program Analyst
U.S. Environmental Protection Agency
Water Division, WC-15J
(312) 886-4882
dee.rhiannon@epa.gov

From: howard.donna@epa.gov [mailto:howard.donna@epa.gov]
Sent: Monday, January 12, 2015 11:21 AM
To: Dee, Rhiannon
Cc: Beese, Jennifer
Subject: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan

01/12/2015

SUBJECT: FWD: (CWA - FY15-124819-3709-CV) Referred to Region - Michigan
FROM: howard.donna@epa.gov
TO: Dee.Rhiannon@epa.gov
CC: Beese.Jennifer@epa.gov

-----Original Message-----

1/11/2015 10:55 AM

HQ LEAD NUMBER: FY15-124819-3709-CV

SUBJECT: Referred to Region - Michigan

FROM: sargent

TO:

Name: marcia

Address: po box 277

City: grand blanc

State: Michigan

Zip: 48480

Phone: 8103368486

Alleged Violator's Name: city of flint michigan

Alleged Violator's Address: water department

Alleged Violator's City: flint

Alleged Violator's State: Michigan

Alleged Violator's Zip: 48503

Tip or Complaint: an individual or company dumped several million gallons of raw sewage into the city of flint Michigan drinking water and now they have dumped a potential cancer causing chemical into the water to cover up their negligent act. people are getting sick and skin rashes are becoming apparent, especially in the young and elderly. we will keep going until something is done to correct this "mistake"

Specific Directions: Flint river. runs right through the city of flint. they have been opening the hydrants and letting water pour out of them to "purge" the system, then charging consumers double for their mistake.

Violation Still Occurring? Yes

State DEP/DEQ/DEM Notified? Yes

Rennaker, Joanne (DEQ)

From: Elizabeth Murphy <emurphy@cityofflint.com>
Sent: Friday, February 06, 2015 10:35 AM
To: Prysby, Mike (DEQ)
Subject: Other Municipal River Water Testing Labs

Mike,
Could you tell me which municipal water systems in Michigan treat river water? I know Ann Arbor uses the Huron River and I believe there are cities using the Detroit River. I would like to get a contact for their labs so see if they could sample and test Flint's water production. This would be an independent source of testing, in addition to our own.

I am also wondering if MDEQ did a source water assessment of the Flint River? Could you direct me to where I might find that report?

--

Liz Murphy
Assistant to the Emergency Manager
City of Flint
810 237 2025

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Tuesday, February 03, 2015 9:34 AM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ)
Subject: FW: Flint event on Tuesday
Attachments: 2 FDCVT Grant Awards draft.docx; ATT00001.htm; Briefing Flint grant announcement.docx; ATT00002.htm; RELEASE Flint water grants.docx; ATT00003.htm

FYI.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Wurfel, Brad (DEQ)
Sent: Monday, February 02, 2015 4:35 PM
To: Wyant, Dan (DEQ); Datema, Maggie (DEQ); Tommasulo, Karen (DEQ); Thelen, Mary Beth (DEQ)
Cc: Shekter Smith, Liane (DEQ); Busch, Stephen (DEQ)
Subject: Fwd: Flint event on Tuesday

All,

Here is some early information about the event tomorrow in Flint. State leaders, including director Wyant, Will announce \$2 million in distress community grants. Based on what little I know so far, it sounds a little bit like SAW grants.

Will share more details when I get them.

b

Sent from my iPhone

Begin forwarded message:

From: "Murray, David (GOV)" <MurrayD1@michigan.gov>
Date: February 2, 2015 at 1:34:21 PM EST
To: "Agen, Jarrod (GOV)" <AgenJ@michigan.gov>, "Stanton, Terry A. (Treasury)" <StantonT@michigan.gov>, "Wurfel, Sara (GOV)" <Wurfels@michigan.gov>, "Wurfel, Brad (DEQ)" <WurfelB@michigan.gov>, "Biehl, Laura (GOV)" <BiehlL@michigan.gov>, "Hollins, Harvey (GOV)" <hollinsh@michigan.gov>, "Clayton, Stacie (GOV)" <claytons3@michigan.gov>, "Walsh, John (GOV)" <WalshJ@michigan.gov>, "Brownfield, Michael (GOV)" <BrownfieldM2@michigan.gov>, "Allard, Claire (GOV)" <allardc1@michigan.gov>, "Rexford, Tori (GOV)" <rexfordt@michigan.gov>
Subject: Flint event on Tuesday

Good afternoon team,

Just wanted to touch base on Tuesday's event in Flint. Unless told otherwise, I'm continuing to prepare for the event.

I touched base with Harvey and Stacie, who recommended we proceed. Harvey is approaching some stakeholders about appearing at the event, and will forward those names to me later today.

I left a message with Dick Posthumus to see if he has any concerns about proceeding.

The Senate Democrats said Sen. Ananich will want to appear. Katie Carey from the House said she would forward information to Rep. Neeley and Phelps. I have not heard back from her yet.

I've attached the backgrounder and the draft releases from Governor's Communications and Treasury. I've sent a message to the mayor's office about a quote, but have not heard back yet.

Brad and I spoke about Director Wyant's role and potential comments. He will point out that there are things the state can do to help monitor the situation, but also will note that the city's water infrastructure is aging, which contributes to the problems.

We need some direction on an advisory. Should this be listed on a typical advisory from the governor's office, or come from Treasury? Do we even issue an advisory in favor of just contacting media directly in the morning?

Please give the draft releases a read for potential changes, or let me know of other concerns.

Thank you!

Dave

Dave Murray

Deputy Press Secretary | Executive Office of Governor Rick Snyder

MurrayD1@michigan.gov

517-335-6397, office

517-449-8343, mobile

Twitter: @michigandmurray



STATE OF MICHIGAN
DEPARTMENT OF TREASURY
LANSING

RICK SNYDER
GOVERNOR

R. KEVIN CLINTON
STATE TREASURER

February 3, 2015

FOR IMMEDIATE RELEASE

www.michigan.gov/treasury

Contact: Terry Stanton, Treasury
(517) 335-2167

Dave Murray, Governor
(517) 335-6397

draft

Gov. Rick Snyder announces grants helping distressed municipalities with water, public safety, appraisal issues

\$8 million awarded for projects aimed at improving services, quality of life

LANSING, Mich. -- Gov. Rick Snyder today awarded \$8 million to six municipalities to fund various improvement projects, including water system and street lighting enhancements and technology upgrades through the Financially Distressed Cities, Villages, and Townships Grant Program.

Municipalities are eligible for the grants if they are experiencing one or more conditions indicative of "probable financial stress," as defined by Public Act 436 of 2012, the Local Financial Stability and Choice Act.

"Municipalities receiving this special funding are some of the areas hardest hit by the Great Recession," Snyder said. "I am pleased we can offer funding assistance to help these local governments improve various public services their taxpayers and residents expect and deserve."

Under the grant program, funding may be used to pay for specific projects, services, or strategies that move a city, village, or township toward financial stability. There was \$8 million appropriated for the program with a \$2 million cap, per local unit.

The following communities will receive funding this year, with projects and amounts noted (alphabetical order):

Local Unit	Project Description	Amount
City of Benton Harbor	Complete a property reappraisal to provide updated and accurate assessing records. Additionally, community enhancement through blight management and sidewalk replacement.	\$475,000
City of Benton Harbor	Water system enhancement through water main replacements and fire hydrant repairs.	\$434,960

City of Ecorse	Public safety enhancement through improved street lighting.	\$350,000
City of Flint	Water system enhancement through improved waste management.	\$1,100,000
City of Flint	Water system enhancement through leak detection and pipe assessments.	\$900,000
City of Hamtramck	Complete a property reappraisal to provide updated and accurate assessing records.	\$167,860
City of Hamtramck	Upgrade City Hall security.	\$50,000
City of Hamtramck	Public safety enhancement through improved street lighting.	\$404,600
City of Highland Park	Water system enhancement through meter replacement, leak detection, and system repairs.	\$2,000,000
City of Inkster	Complete a property reappraisal to provide updated and accurate assessing records.	\$73,460
City of Inkster	Water system enhancement through fire hydrant repairs.	\$150,000
City of Inkster	Provide a backup power source for public safety.	\$30,000
City of Inkster	Public safety enhancement through the creation of a multi-jurisdictional narcotic team.	\$240,000
City of Inkster	Public safety enhancement through police officer training.	\$41,970
City of Inkster	Public safety enhancement through the deployment of an additional police officer.	\$320,000
City of Lincoln Park	Public safety enhancement through updated technology.	\$143,490
City of Melvindale	Public safety enhancement through fleet replacement of police vehicles and updated technology.	\$88,000
City of Pontiac	Community enhancement through blight management.	\$125,000
City of River Rouge	Public safety enhancement through improved street lighting. Additionally, infrastructure replacements to City Hall.	\$591,508
Royal Oak Township	Public safety enhancement through improved street lighting	\$86,559
Royal Oak Township	Public safety enhancement of police services.	\$217,593

Applications for the next round of Financially Distressed Cities, Villages, and Townships Grant Program will be available on the Department of Treasury website this spring. Applications must be submitted to Treasury by the close of business on XXX, XXX 31, 2015.

Preference is generally given to applicants from local units in which:

- A financial emergency has been declared in the past five years;
- An approved deficit elimination plan for the general fund is currently in place; or,
- Two or more conditions indicating “probable financial distress” currently exist.

For more information about FDCVT grants, including an application for cities, villages, and townships, visit www.michigan.gov/revenuesharing.

###

*Conditions of “probable financial distress” relating solely to school districts are not included as conditions for FDCVT, as school districts are not eligible.

Briefing: Grant announcement in Flint

Tuesday, Feb. 3, 2015, 3-4 p.m.

Haskell Community Center, 2201 Forest Hills Ave. Flint

Governor's communications: Dave Murray, murrayd1@michigan.gov, 517-449-8343

DEQ communications: Brad Wurfel, wurfelb@michigan.gov, 517-230-8006

Treasury communications: Terry Stanton, stantont@michigan.gov, 517-830-5807

Purpose

The state government is providing support for the Flint government as it addresses issues with its water system. The state on Tuesday is announcing that Flint is receiving two grants totaling \$2 million related to water system improvements through the Financially Distressed Cities, Villages and Townships grant program. DEQ Director Dan Wyant will address ongoing efforts with his agency to test Flint water and explain why the city is facing some of its problems. Senate Minority Leader Jim Ananich, D-Flint, will discuss his appreciation for the ongoing support for the city and its residents.

Attending

- Harvey Hollins, director of the Michigan Office of Urban Initiatives
- Dan Wyant, director of the Michigan Department of Environmental Quality
- Wayne Workman, deputy treasurer, Michigan Department of Treasury
- Jerry Ambrose, Flint emergency manager
- Dayne Walling, Flint mayor
- State Sen. Jim Ananich
- State Rep. Sheldon Neeley
- State Rep. Phil Phelps

Agenda

- 3:00 PM – 3:05 PM: Harvey Hollins announces that Flint has received two grants totaling \$2 million.
- 3:05 PM – 3:10 PM: Dan Wyant discusses the state's ongoing role in monitoring Flint's water and any assistance that has been provided and will continue to be provided.
- 3:10 PM – 3:15 PM: Mayor Dayne Walling remarks about appreciation for state assistance.
- 3:15 PM – 3:20 PM: Sen. Jim Ananich remarks about appreciation for state assistance.
- 3:20 PM – 3:25 PM: Rep. Neeley remarks.
- 3:25 PM – 3:35 PM: Harvey Hollins closing remarks, opens floor to media questions.
- 3:35 PM: Event ends, though this might be optimistic.

Background

- The quality of Flint water has been a high-profile concern in recent weeks, with residents complaining about the color, taste and smell of tap water since a switch to Flint River water as a temporary source as a pipeline is built to Lake Huron as a water source starting in 2016.
 - Residents have attended meetings with jugs of brownish water.
 - U.S. Kildee has worked with labor and community groups to distribute bottled water.

- Mayor Walling has issued a letter (included below) calling for state and federal assistance for the city, including forgiveness of some \$20 million in debt through the Drinking Water Revolving Loan Fund and calling for the governor to come to Flint personally.
 - Walling also submitted a guest column to the Flint Journal with similar requests.
 - He said the loan forgiveness is needed for the city to upgrade its water treatment process.
 - Governor and Mayor Walling had a telephone conversation on Friday, and the mayor has pledged to work together on solutions.
- Rep. Sheldon Neeley also has sent the governor a letter, saying that his constituents “are on the verge of civil unrest.”
- The Department of Environmental Quality has been monitoring the water situation, with a detailed backgrounder and talking points attached below.
- The Treasury Department is announcing Tuesday that Flint is among the cities receiving a combined \$8 million the Financially Distressed Cities, Villages and Townships grant program.
 - The announcement of the other grants will follow the Flint announcement.
 - The Flint grants are \$1.1 million to allow the city to replace the functions of the old incinerator with new water pollution control facility allowing for the disposal of waste to landfills.
 - The other is \$900,000 to allow the city to hire a contractor to perform a leak detection survey, which will lead to prioritizing repairs.
 - A breakdown of the grants is included below.

Treasury breakdown of Flint grants

Flint Incinerator: The grant project entails shutting down the current Water Pollution Control Facility Incinerator (due to the incinerator not being up to new EPA standards). In order to meet EPA standards, it would cost roughly \$8.8M in upgrades to the current incinerator. The grant funding will allow them to replace the functions of the old incinerator by constructing new facilities which will allow for the disposal of waste to landfills.

Budget Breakdown

Construction Contractor	\$1,050,000
Project Management	<u>\$50,000</u>
Total	\$1,100,000

Flint Leak Detection: The grant project will allow the city to hire a contractor to perform a leak detection survey of the city water lines. The city will receive a map of leak locations and an assessment of leak severity. This data will allow the city to prioritize leak repair. The project also covers the expense of conducting a water pipe line wall thickness condition assessment on a portion of the city's pipes. The assessment will guide the city's water main replacement program.

Budget Breakdown

Project Planning	\$90,000
Mobilization of Crew to Site	\$27,000
Leak Detection < 16" diameter	\$378,000

Leak Detection 16" diameter or >	\$270,000
Pipe Condition Assessments	<u>\$135,000</u>
Total	\$900,000

DEQ backgrounder on Flint water

Following the formal approval of Flint into the KWA in 2012, DWSD sent Flint a letter saying their contract was thereby terminated (by early 2013).

Genesee County has been using DWSD water without a contract since May 2014. But Flint took the letter to imply a water cutoff, and promptly turned to DEQ with a proposal to use the Flint River (their historic backup system).

This proposed shift was pitched primarily as a money saver. But it put the city in the business of water production, where they historically had been in the business of water transmission. DEQ approved the use of the river as a source, based on the treatment plant's past performance as a standby facility and the improvements we outlined prior to a switchover.

Several municipalities around the state use surface water supplies (rivers): Blissfield near Monroe, Manistique, and Alma to name a few.

The city completed the upgrades at the water plant the facility and DEQ approved it April 2014.

There were some initial hiccups. Last summer, there were a couple of 'boil water' notices issued. One for a water test that showed e. coli, one for a break in the water main.

The challenge to using the Flint River as a source is that the condition of the water is variable and changes with season and weather. It has substantially more organic matter than deep lake sources like Lake Huron. This organic matter is mobilized by high water events, and warm weather also can account for more organic material in the water.

The treatment of the organic matter is done with chlorine. One might conclude that the continual answer is just to use more chlorine to achieve water safety. However, at some point on the continuum, the chlorine and organic matter create TTHM – total trihalomethanes – as a byproduct. When the standard for those is exceeded over several consecutive quarters of testing, the supply is required by law to issue public notice and submit an approved plan for addressing the situation.

You'll note that this regulatory approach means TTHM testing is done quarterly. That means people who use the system are exposed to TTHM for several months before the public notice is required. It's because TTHM is a chronic health threat. Over the long term (measured in decades), continued exposure can contribute to some known health problems. If this were an immediate health threat, customers would receive immediate notification to boil their water or not use it.

Put in context, the EPA (which established the standard and the rule) estimates the existence of the TTHM standard prevents an estimated 280 bladder cancer cases each year ... out of more than 330 million people who use public water supplies around the country.

It's not "nothing." State and federal law requires quarterly testing for TTHM and that the public be informed of it when the annual average of four quarters' worth of consecutive testing shows TTHM

levels exceeding 80 parts per billion. Flint's results managed to exceed the annual average in three quarters, and they must develop a plan to address it.

But it's not like an eminent threat to public health. Unlike an e. Coli or even total coliform bacteria maximum contaminant level, which require immediate public notification and response and are part of daily / hourly testing of public water supplies, TTHMs pose a public health concern with chronic, long-term exposure.

It's clear the nature of the threat was communicated poorly. It's also clear that folks in Flint are concerned about other aspects of their water – taste, smell and color being among the top complaints.

The Safe Drinking Water Act requires public water supplies be tested for more than 90 regulated contaminants, including microbial contaminants. The act, and the program here in Michigan, work to ensure that water is safe to drink. The act does not regulate aesthetic values of water. Here are some factors affecting the aesthetics of water in Flint.

1. It's the Flint River. The water supplied by DWSD historically came from Lake Huron. It's softer. With hard water, you get a different flavor and feel. It's why General Motors suspended use of Flint Water – it was rusting their parts. Also, there's the 'organics' factor (discussed previously).
2. The system is old. Flint has more than 500 miles of water pipes. More than half of those pipe miles are more than 75 years old. Much of it is cast iron. Hard water can react with cast iron and exacerbates the rusty factor, which creates that brown water that angry residents were holding up in jugs for the media cameras last week. Valve failure has also been a key challenge. The system has an estimated 7,500+ valves. When they stick open or stick shut, it affects the hydraulics of the system and increase areas of stagnation. The city has a backlog of valves that need to be addressed. They've done half a dozen or so since November.
3. Flint is old. Many of the homes served by the system are old. Brown water complaints may also be attributable to cast iron pipes in customers' service connection to the city lines. The DEQ has been encouraging people with water coloration concerns to contact the city and see whether it is the service line or the City's line causing the issue. Again, discoloration is not an indicator of water quality or water safety, but we recognize that nobody likes it.

In summary, the City of Flint has tremendous need to address its water delivery system. We are not aware that they have any capital improvement funds for preventative maintenance in place, much less line replacement project monies that will require hundreds of millions.

The City was approved for a Revolving Fund loan in 2008 or 2009. As a Distressed Community, they qualified for flexible terms and 2 percent interest rate Revolving Fund Loan. After they were notified they were approved for the loan, they declined it. Previous SRF loans from the state to Flint bear an outstanding balance of \$20.7 million today.

The DEQ continues working with the city to address the TTHM issue. They can take interim steps – from scrubbing the insides of transmission lines to carefully monitoring the hydraulic challenges in their system – to address customers' aesthetic concerns. Their TTHM numbers already are showing dramatic improvement; the November testing showed only one of seven sample points exceeding the standard.

The key now is that the standard is an average of three quarters' worth of results. It will be some time before they are officially "not in violation." However, depending on weather in 2015, it's not unforeseeable that we will be having this conversation again by next Christmas.

The key to the conversation is that TTHM is not a top health concern. That's key because residents need to understand TTHM in context, and it is key because it appears the mayor has seized on the public panic (sparked, frankly, by their poor communication of the violation notice) to ask the state for loan forgiveness and more money for their infrastructure improvement.

Another key thing to remember is that once the city connects to the new KWA system in 2016, this issue will fade in the rearview.

Key messages:

1. The DEQ Drinking Water program works with communities around the state to ensure that municipalities provide customers with clean, safe drinking water.
2. Municipal water supplies are tested rigorously and regularly for more than 90 regulated contaminants, including microbial contaminants that pose an immediate public health concern.
3. Flint's exceedance of the TTHM standard should reassure residents that the testing program is effective.
4. TTHM is not an immediate health threat. It is a chronic concern, one that can be problematic over the course of several decades of exposure. The public was notified because the law requires the city to make public notification, so that everyone can make informed decisions. This is particularly true for people with infants or those with compromised immune systems.
5. The DEQ is working with the City to address the situation. Recent tests show the TTHM numbers dropping rapidly. The department will continue working with the city in the months ahead, and residents should feel confident that their water is safe to drink unless the DEQ or City notifies them otherwise.
6. The discoloration and odor issues some Flint residents are experiencing are separate issues from the TTHM issue. TTHM is odorless, colorless and measured in parts per billion.
7. Flint water customers who have questions or concerns about their water should first contact the city to get answers and help. They also can contact the Michigan DEQ.

Mayor Walling's Facebook post

Friend,

Access to clean, safe, affordable water is a basic human right.

That's why I just sent Gov. Snyder my Flint Water Improvement Plan. It focuses on the areas of safety, quality, access, investment and education. My letter urges the governor to quickly implement these ideas so that Flint's water is 100% safe.

Please contact Gov. Snyder by calling (517) 335-6397 (or by clicking [here](#)) and ask him to take action immediately to implement my plan and ensure Flint's water is safe.

My plan offers new ideas and also builds on successful models of utility, energy and assistance programs at the state and federal levels. Here is my plan:

Safety & Quality

- 100% Safety is the standard

- City of Flint releases testing data to assure safety and expands testing to households with support from the Michigan Department of Environmental Quality
- Support alternatives for those advised not to drink the water by their doctors through the Michigan Health Endowment Fund and community partners to protect the vulnerable like seniors and infants
- Bring on experienced river water treatment operational management in the City of Flint
- Require water testing data to be released quarterly by law in all Michigan communities

Access

- Announce an amnesty program for turn-ons and reduce the turn-on cost in Flint
- Develop a revised payment plan policy to allow customers to come back on to the Flint system
- New Federal and State partnership to establish new Drinking Water Emergency Assistance Fund for customers (modeled on Federal and State energy utility programs: Low Income Home Energy Assistance Program; Michigan Energy Assistance Program; State Emergency Relief)

Investment

- Accelerate water system improvements outlined in the City of Flint Capital Improvement Plan through Federal and State Investments
- State approves City of Flint's Distressed Cities Fund applications
- Federal and State forgiveness of payment to Drinking Water Revolving Loan Fund
- Federal and State financing for future improvements
- City Water Department implements budgeted FY15 projects including leak detection, valve repairs, new pipes and meter replacements

Education

- Develop a community partnership to provide household and business customers with information on testing and conservation
- Ongoing partnership with Michigan Department of Human Services, United Way, Salvation Army and community organizations to provide information on water assistance
- Expand youth energy initiative to assist households with conservation and efficiency (piloted in summer 2014 with Northwestern High School students, EcoWorks and Consumers Energy)

The struggle with our water has gone on for too long. The state must take action and do its part. Please ask Gov. Snyder to take action immediately to implement my plan and ensure Flint's water is safe. Thank you for your ongoing support.

Links to coverage

- [Mayor, governor have 'long, productive' talk about Flint's water problems](#), Jan. 30
- [2,000 more gallons of water headed to Flint for giveaway](#), Jan. 30, 2015
- [Flint emergency manager says there are two big reasons not to reconnect Detroit water](#), Jan. 29
- [Flint Democracy Defense League plans four meetings on city's water problems](#), Jan. 29
- [Environmentalism sends out new warnings about Flint water](#), NBC, Jan. 27
- [Erin Brockovich says on Facebook she's prepared to come to Flint](#), MLive, Jan. 27
- [Mott Community College not waiting for Flint to ensure safe water](#), MLive, Jan. 26
- [Detroit water chief says she's willing to sell emergency water to Flint -- no strings attached](#), Jan. 26
- [Mayor says governor needs to visit Flint to see water crisis first hand](#), MLive, Jan. 26
- [Need water? Flint groups collect 600 cases, plan distribution this week](#), MLive, Jan. 26

- [Incoming Flint water expert would have 'continual oversight' until new pipeline connected](#), Jan. 25
- [Looking back at Flint's water problems \(photo gallery\)](#), MLive, Jan. 25
- [Flint water problems: Switch aimed to save \\$5 million -- but at what cost?](#), MLive, Jan. 23
- [State says its already 'working diligently' on Flint's water problems](#), MLive, Jan. 22
- [Officials say Flint water is getting better, but many residents unsatisfied](#), MLive, Jan. 21



STATE OF MICHIGAN
EXECUTIVE OFFICE
LANSING

RICK SNYDER
GOVERNOR

BRIAN CALLEY
LT. GOVERNOR

CONTACTS:

Sara Wurfel or Dave Murray, Governor's Office
517-335-6397
Terry Stanton, Department of Treasury
517-335-2167

FOR IMMEDIATE RELEASE

December 7, 2015

Gov. Rick Snyder awards Flint \$2 million in Distressed Cities grants for water system infrastructure improvements

Funding to be used for leak detection, waste incinerator replacement

LANSING, Mich. – Gov. Rick Snyder today awarded Flint \$2 million in grants for water system infrastructure improvements, part of an overall \$8 million plan to help cities through the Financially Distressed Cities, Villages, and Townships Grant Program.

Flint is among six municipalities receiving grants through the program. The city will use the funding to detect leaks in its water lines and replace its Water Pollution Control Facility Incinerator.

"There are opportunities for the state government to assist Flint city leaders as they address issues related to the city's water system," Snyder said. "These grants will help recovering cities improve public services and infrastructure, improving the quality of life for all residents."

The grants to Flint were announced today at the Haskell Community Center by Harvey Hollins, director of the state's Office of Urban Initiatives and Wayne Workman, the state's deputy treasurer. They were joined by Dan Wyant, director of the Michigan Department of Environmental Quality, Flint Emergency Manager Jerry Ambrose, Mayor Dayne Walling, state Senate Minority Leader Jim Ananich, state Reps. Sheldon Neeley and Phil Phelps.

Flint was awarded \$900,000 to allow the city to hire a contractor to perform a leak detection survey of the city water lines. The city will receive a map of leak locations and an assessment of leak severity, allowing the city to prioritize leak repair. The project also covers the expense of conducting a water pipe line wall thickness condition assessment on a portion of the city's pipes. The assessment will guide the city's water main replacement program.

The city also was awarded \$1.1 million to shut down its current Water Pollution Control Facility incinerator and replace it with new facilities which will allow for the disposal of waste in landfills. The existing facilities are not up to federal Environmental Protection Agency standards.

Municipalities are eligible for the grants if they are experiencing one or more conditions indicative of "probable financial stress," as defined by Public Act 436 of 2012, the Local Financial Stability and Choice Act.

Under the grant program, funding may be used to pay for specific projects, services, or strategies that move a city, village, or township toward financial stability. There was \$8 million appropriated for the program with a \$2 million cap, per local unit.

##

Rennaker, Joanne (DEQ)

From: Michael Glasgow <mglasgow@cityofflint.com>
Sent: Thursday, January 29, 2015 2:15 PM
To: Prysby, Mike (DEQ)
Subject: Flint December 2014 MOR
Attachments: Dec 2014 MOR Scan.pdf

Mike,

Good afternoon, I hope all is well there in Lansing. I just wanted to send a copy of the December MOR to you. I thought it was taken care of while I was off, sorry for the delay. A hard copy will go out tomorrow.

Mike Glasgow
City of Flint Water Plant

CITY of FLINT WATER TREATMENT PLANT MONTHLY OPERATION REPORT

SUPPLY NAME: CITY of FLINT WATER PLANTWSSN: 2310Michael Glasgow

Operator-in-Charge

December 2014

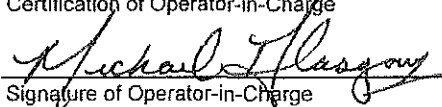
Month/Year

F-1R, F-2

Certification of Operator-in-Charge

F-1

Water Plant Classification

Signature of Operator-in-ChargeGenesee

County

Treatment Rate and Filter Data

Maximum Treatment Rate:	<u>23.8</u>	Million Gallons per Day
Rated Plant Capacity:	<u>36</u>	Million Gallons per Day
Average Filter Run:	<u>74</u>	Hours
Average Head Loss:	<u>n/a</u>	Feet *(filter head loss meters not operational)
Average Filtration Rate:	<u>2.4</u>	Gallons Per Square Feet per Minute
Maximum Filtration Rate:	<u>3.2</u>	Gallons Per Square Feet per Minute
Average Wash Water Use:	<u>2.9%</u>	Percent of Treated Water

Chemical Data

Chlorine on hand:	<u>20,000</u> lb.	Est. supply:	<u>30</u> days
Primary Coagulant (Ferric Chloride) on hand:	<u>54,000</u> lb.	Est. supply:	<u>18</u> days
Lime (CaO) on hand:	<u>296</u> tons	Est. supply:	<u>34</u> days
Fluoride on Hand:	<u>16,630</u> lb.	Est. supply:	<u>35</u> days
Cost of All Chemicals per Million Gallons:	<u>n/a</u> dollars		
Total Power Cost per Million Gallons:	<u>n/a</u> dollars		

Remarks

Confluence Point # 1 (N)

Confluence Point # 2 (S)

Number of filter confluence samples > 0.3 NTU:

00

Number of filter confluence samples collected:

226226

Percent of filter confluence samples > 0.3 NTU:

0.0%0.0%

Number of filter confluence samples > 1 NTU

00

Did any individual filter exceed:

1.0 NTU in two consecutive measurements taken 15 minutes apart?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

0.5 NTU in two consecutive measurements taken 15 minutes apart after 4 hours of operation?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

1.0 NTU in two consecutive measurements taken 15 minutes apart for 3 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

2.0 NTU in two consecutive measurements taken 15 minutes apart for 2 consecutive months?

NO

If yes, attach specific filter(s) information and indicate required follow-up status.

Was continuous (every 15 minutes) filter monitoring equipment off-line during the month?

NO

If yes, indicate date(s), duration, and individual filter grab sampling frequency on a separate sheet.

Did POE disinfectant residual fall below 0.2 ppm during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

Was minimum C*I credit achieved for the entire month?

YES

If no, indicate on a separate sheet the date(s) not achieved.

Was continuous POE chlorine residual monitoring equipment off-line during the month?

NO

If yes, indicate date(s) and duration on a separate sheet.

Filter turbidity

City of Flint Water Treatment Plant
WSSN: 2310

December 2014 Page 3

Date	Turbidity, Units												Plant Tap NTU
	Confluence Point. No.1 (N) North						Confluence Point. No.2 (S) South						Point of Entry
	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	Number of Samples	Avg.	Max	No. of 4 Hr. Compliance periods	No. of 4 Hr. Compliance periods >0.3 NTU	No. of Samples >0.3 NTU	
1	8	0.09	0.11	6	0	0	8	0.09	0.10	6	0	0	0.08
2	8	0.08	0.09	6	0	0	8	0.08	0.09	6	0	0	0.08
3	8	0.08	0.12	6	0	0	8	0.07	0.10	6	0	0	0.07
4	8	0.07	0.10	6	0	0	8	0.07	0.08	6	0	0	0.07
5	8	0.07	0.08	6	0	0	8	0.07	0.09	6	0	0	0.08
6	2	0.10	0.12	2	0	0	2	0.10	0.10	2	0	0	0.08
7	0	n/a	n/a	0	0	0	0	n/a	n/a	0	0	0	0.07
8	0	n/a	n/a	0	0	0	0	n/a	n/a	0	0	0	0.12
9	8	0.09	0.19	6	0	0	8	0.07	0.11	6	0	0	0.08
10	8	0.08	0.14	6	0	0	8	0.06	0.07	6	0	0	0.05
11	8	0.08	0.10	6	0	0	8	0.07	0.10	6	0	0	0.07
12	8	0.09	0.13	6	0	0	8	0.09	0.14	6	0	0	0.07
13	8	0.07	0.10	6	0	0	8	0.07	0.08	6	0	0	0.08
14	8	0.06	0.07	6	0	0	8	0.06	0.07	6	0	0	0.05
15	8	0.06	0.06	6	0	0	8	0.06	0.07	6	0	0	0.06
16	8	0.07	0.08	6	0	0	8	0.06	0.06	6	0	0	0.06
17	8	0.07	0.08	6	0	0	8	0.07	0.08	6	0	0	0.08
18	8	0.07	0.11	6	0	0	8	0.06	0.07	6	0	0	0.07
19	8	0.08	0.13	6	0	0	8	0.06	0.09	6	0	0	0.07
20	8	0.07	0.10	6	0	0	8	0.07	0.09	6	0	0	0.06
21	8	0.06	0.07	6	0	0	8	0.06	0.09	6	0	0	0.07
22	8	0.06	0.07	6	0	0	8	0.07	0.16	6	0	0	0.06
23	8	0.07	0.09	6	0	0	8	0.07	0.12	6	0	0	0.07
24	8	0.06	0.10	6	0	0	8	0.06	0.10	6	0	0	0.06
25	8	0.06	0.09	6	0	0	8	0.06	0.10	6	0	0	0.06
26	8	0.08	0.16	6	0	0	8	0.07	0.15	6	0	0	0.08
27	8	0.08	0.12	6	0	0	8	0.07	0.11	6	0	0	0.07
28	8	0.07	0.11	6	0	0	8	0.05	0.07	6	0	0	0.07
29	8	0.07	0.09	6	0	0	8	0.06	0.07	6	0	0	0.08
30	8	0.06	0.08	6	0	0	8	0.05	0.06	6	0	0	0.06
31	8	0.07	0.09	6	0	0	8	0.06	0.08	6	0	0	0.08
Avg.	7	0.07	0.10	5	0	0	7	0.07	0.09	5	0	0	
Max.	8	0.10	0.19	6	0	0	8	0.10	0.16	6	0	0	0.12
Min.	0	0.06	0.06	0	0	0	0	0.05	0.06	0	0	0	

Fluoridation &
ChlorinationCity of Flint Water Treatment Plant
WSSN: 2310

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Date	Fluoride Applied as F- mg/L	Fluoride Analysis (mg/L)			Chlorine Application (mg/L)			Chlorine Residual (mg/L)					
					Intermediate Chlorine	Post Chlorine	Total Chlorine	Filtered		3 MG Well		Tap	
		Raw	Tap	Dist.				Free	Total	Free	Total	Free	Total
1	0.5	0.22	0.71		2.0	3.8	5.8	0.5	0.8	3.0	3.5	3.0	3.5
2	0.5	0.21	0.72		2.0	3.6	5.6	0.7	1.0	3.0	3.5	2.7	3.2
3	0.5	0.23	0.72		2.1	3.0	5.1	0.7	1.0	2.7	3.2	2.5	2.9
4	0.5	0.21	0.73	0.64	2.0	3.0	5.0	0.6	0.8	3.0	3.5	2.4	2.8
5	0.4	0.21	0.68		1.9	3.0	4.9	0.6	0.8	2.7	3.2	2.2	2.5
6	0.5	0.22	0.77		1.9	3.0	4.9	0.4	0.6	3.1	3.5	2.1	2.5
7	0.0	0.22	0.70		0.0	0.0	0.0	n/a	n/a	3.0	3.5	2.4	2.8
8	0.0	0.22	0.71		0.0	0.0	0.0	n/a	n/a	2.9	3.2	2.6	2.9
9	0.4	0.24	0.67	0.65	2.0	2.3	4.3	0.6	0.8	2.2	2.9	2.7	3.1
10	0.4	0.22	0.71		1.8	2.7	4.5	0.5	0.8	2.6	2.9	2.4	2.7
11	0.4	0.24	0.69		1.8	2.8	4.6	0.5	0.7	2.5	3.1	2.4	2.8
12	0.4	0.21	0.64		1.8	2.7	4.5	0.6	0.8	2.4	2.9	2.0	2.3
13	0.4	0.21	0.63		2.0	2.6	4.6	0.6	0.8	3.0	3.5	2.6	2.9
14	0.4	0.20	0.64		2.0	2.6	4.6	0.7	1.0	2.9	3.2	2.9	3.1
15	0.4	0.24	0.64		2.0	2.6	4.6	0.7	0.9	2.8	3.0	2.6	2.9
16	0.4	0.24	0.63	0.60	2.0	2.6	4.6	0.7	0.9	2.8	3.0	2.3	2.5
17	0.4	0.22	0.63		2.0	2.6	4.6	0.7	0.9	2.7	3.0	2.4	3.0
18	0.4	0.21	0.59		2.0	2.7	4.7	0.6	0.8	2.6	3.0	2.1	2.4
19	0.4	0.21	0.58		2.1	2.6	4.7	0.7	0.9	3.0	3.3	2.6	3.1
20	0.4	0.20	0.61		1.9	2.6	4.5	0.6	0.8	2.6	3.1	2.0	2.5
21	0.4	0.22	0.62		1.3	2.4	3.7	0.6	0.8	2.8	3.0	2.6	2.8
22	0.4	0.22	0.63		2.0	2.6	4.6	0.9	1.1	2.7	3.1	2.6	3.0
23	0.4	0.23	0.63	0.64	1.9	3.1	5.0	0.6	0.9	2.9	3.2	2.5	2.9
24	0.4	0.20	0.63		1.9	3.0	4.9	0.9	1.1	2.8	3.0	2.3	2.7
25	0.4	0.21	0.63		1.9	3.1	5.0	0.5	0.7	2.6	3.0	1.7	2.2
26	0.4	0.23	0.69		2.0	2.8	4.8	0.6	0.7	2.8	3.1	2.3	2.6
27	0.4	0.19	0.60		2.1	2.8	4.9	0.7	0.9	2.9	3.5	1.9	2.5
28	0.4	0.20	0.67		1.9	3.0	4.9	0.6	0.9	2.7	3.0	2.4	2.7
29	0.4	0.21	0.62		1.9	3.0	4.9	0.6	0.9	2.7	3.0	2.7	3.0
30	0.4	0.20	0.60	0.54	1.9	3.1	5.0	0.6	0.9	2.7	2.9	1.9	2.5
31	0.4	0.22	0.63		1.9	3.3	5.2	0.8	1.1	2.7	3.1	2.8	3.1
Avg.	0.39	0.22	0.66	0.61	1.8	2.7	4.5	0.6	0.9	2.8	3.2	2.4	2.8
Max.	0.50	0.24	0.77	0.65	2.1	3.8	5.8	0.9	1.1	3.1	3.5	3.0	3.5
Min.	0.00	0.19	0.58	0.54	0.0	0.0	0.0	0.4	0.6	2.2	2.9	1.7	2.2

Chemical Analyses

City of Flint Water Treatment Plant

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Date	pH (S.U.)		Total Hardness as CaCO ₃ (mg/L)		Total Alkalinity as CaCO ₃ (mg/L)		Non-Carbonate Hardness as CaCO ₃ (mg/L)		Calcium as Ca ²⁺ (mg/L)		Magnesium as Mg ²⁺ (mg/L)		Chloride as Cl ⁻ (mg/L)	
	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap	Raw	Tap
1	8.26	7.82	303	204	248	109	55	95	97.8	63.3	14.6	11.7	47	77
2	8.12	8.27	303	193	248	97	55	96	98.6	54.5	14.1	13.6	47	77
3	8.21	8.26	307	192	243	96	64	96	113.8	64.1	5.8	7.8	47	75
4	8.42	7.84	312	193	257	97	55	96	103.4	55.3	13.6	13.6	48	76
5	8.21	8.23	314	197	257	98	57	99	109.0	65.7	9.7	7.8	45	74
6	8.27	8.34	314	210	254	115	60	95	109.8	69.7	9.7	8.3	47	74
7	8.43	8.08	326	203	265	102	61	101	103.4	58.5	16.5	13.6	47	78
8	8.35	8.00	326	197	268	93	58	104	107.4	56.9	14.1	13.1	48	77
9	8.33	7.95	324	200	263	97	61	103	121.0	71.3	6.3	5.8	48	77
10	8.23	7.95	329	190	269	81	60	109	106.6	53.7	15.1	12.6	48	82
11	8.17	7.95	321	190	261	88	60	102	111.4	68.1	10.2	4.9	48	79
12	8.13	8.33	324	197	260	95	64	102	116.2	70.5	8.3	2.9	49	81
13	8.13	7.41	322	208	261	100	61	108	119.4	75.4	6.3	4.9	48	83
14	8.18	8.16	334	206	270	97	64	109	101.0	55.3	20.4	16.5	48	81
15	8.24	8.18	328	207	269	102	59	105	97.0	59.3	19.9	14.1	50	83
16	8.29	8.37	324	200	269	95	55	105	103.4	55.3	16.0	14.6	48	82
17	8.22	8.18	321	201	261	89	60	112	107.4	65.7	12.2	9.2	44	85
18	8.24	8.15	325	203	264	91	61	112	108.2	60.9	13.6	12.2	48	82
19	7.99	8.03	319	199	258	91	61	108	117.0	69.7	6.8	5.8	48	84
20	8.23	7.90	318	196	252	90	66	106	116.2	70.5	7.3	4.9	48	83
21	8.31	8.20	317	173	260	77	57	96	99.4	51.3	17.0	9.7	45	78
22	8.31	8.35	319	177	266	72	53	105	102.6	48.1	15.1	14.1	47	80
23	8.25	8.22	322	168	263	71	59	97	121.0	52.9	15.1	7.8	49	79
24	8.27	8.49	323	179	264	72	59	107	108.2	54.5	12.6	10.2	46	79
25	8.28	8.12	312	183	255	72	57	111	109.0	63.3	10.2	6.3	49	82
26	8.25	8.18	307	182	248	79	59	103	109.0	65.7	9.7	3.9	46	81
27	8.21	8.07	289	173	232	76	57	97	102.6	64.1	8.3	4.9	44	80
28	8.26	8.03	290	174	235	67	55	107	95.4	52.1	13.1	10.7	42	82
29	8.29	7.62	313	184	251	75	62	109	101.0	53.7	15.1	11.7	43	83
30	8.17	7.77	319	197	257	84	62	113	107.4	60.9	12.2	10.7	46	84
31	8.17	7.67	320	181	260	60	60	121	117.8	69.7	7.3	1.9	48	87
Avg.	8.24	8.07	317	192	258	88	59	104	107.8	61.3	12.1	9.3	47	80
Max.	8.43	8.49	334	210	270	115	66	121	121.0	75.4	20.4	16.5	50	87
Min.	7.99	7.41	289	168	232	60	53	95	95.4	48.1	5.8	1.9	42	74

Bacteriological &
Physical ParametersCity of Flint Water Treatment Plant
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Date	Total Coliform						Standard Plate Count (Simplate MPN)		Conductivity (mS)	Temp. C	Color		Odor	
	Raw (Colilert MPN)		Filter Confluence (N&S)		Plant Tap									
	# Samples	Count	# Samples	# pos	# Samples	# pos	Raw	Tap			Tap	Raw	Raw	Tap
1	1	24066	12	0	1	0	> 14760	4	0.38	5.1				
2	1	18416	12	0	1	0	2320	2	0.38	6.4				
3	1	6152	12	0	1	0	1360	4	0.37	5.6				
4	1	2324	12	0	1	0	1020	< 2	0.38	5.4				
5	1	852	12	0	1	0	340	< 2	0.38	6.1				
6	1	518	4	0	1	0	40	2	0.40	7.2				
7	1	194	0	0	1	0	80	< 2	0.38	1.4				
8	1	350	0	0	1	0	240	< 2	0.38	3.3				
9	1	342	12	0	1	0	120	< 2	0.40	4.8				
10	1	346	12	0	1	0	240	< 2	0.38	6.5				
11	1	62	12	0	1	0	120	< 2	0.38	4.9				
12	1	40	12	0	1	0	< 2	< 2	0.39	6.0				
13	1	82	12	0	1	0	160	< 2	0.32	6.4				
14	1	40	12	0	1	0	80	2	0.39	5.6				
15	1	20	12	0	1	0	40	< 2	0.40	5.9				
16	1	219	12	0	1	0	> 14760	< 2	0.40	6.0				
17	1	83	12	0	1	0	166	< 2	0.39	6.3				
18	1	88	12	0	1	0	161	< 2	0.40	5.8				
19	1	56	12	0	1	0	116	2	0.39	6.4				
20	1	68	12	0	1	0	156	< 2	0.35	7.0				
21	1	248	12	0	1	0	137	< 2	0.38	3.9				
22	1	308	12	0	1	0	216	< 2	0.36	3.4				
23	1	1300	12	0	1	0	324	< 2	0.35	4.5				
24	1	1300	12	0	1	0	324	< 2	0.36	6.4				
25	1	687	12	0	1	0	470	< 2	0.37	7.4				
26	1	1986	12	0	1	0	392	< 2	0.36	5.1				
27	1	> 2419	12	0	1	0	> 738	< 2	0.37	5.6				
28	1	> 48392	12	0	1	0	9400	2	0.36	4.5				
29	1	39732	12	0	1	0	2640	< 2	0.37	4.0				
30	1	4286	12	0	1	0	560	< 2	0.37	2.2				
31	1	1976	12	0	1	0	300	< 2	0.37	2.6				

Avg.									0.38	5.2				
Max.							9400	4	0.40	7.4				
Min.									0.32	1.4				

Date	Free Chlorine Residual at Bacteriological Monitoring Stations mg/l										Number of Samples
	1	2	3	4	5	6	7	8	CS	WS	
1									2.8	0.7	2
2	0.2	2.0	1.9	1.8	1.2	0.1	1.2	2.1	1.6	1.8	10
3	0.9	1.7	1.9	1.6	1.0	0.1	1.5	1.8	1.8	2.0	10
4	0.6	1.1	1.6	1.7	0.9	0.1	1.4	1.8	1.3	1.7	10
5											0
6											0
7											0
8									0.4	0.4	2
9	0.9	0.1	1.4	0.2	0.1	0.2	1.7	2.5	0.3	1.2	10
10	0.7	0.2	1.8	1.7	0.2	0.2	1.5	1.9	1.6	0.8	10
11	0.6	0.5		1.4	0.8	0.1	1.5	1.8	1.5	0.9	9
12											0
13											0
14											0
15									0.8	1.6	2
16	0.7	1.7	1.5	1.6	0.7	0.2	0.8	1.8	1.3	2.1	10
17	0.6	0.8	1.4	1.5	0.7	0.1	0.8	1.8	1.1	1.4	10
18	0.8	1.5	1.5	1.5	0.5	0.2	1.5	1.8	1.2	1.3	10
19	0.5	1.7	1.7	1.3	0.8	0.1			0.9	1.0	8
20											0
21											0
22											0
23	0.7	1.5	1.3	1.5	0.8	0.3	1.5	1.8	1.8	0.3	10
24	0.6	1.1	2.1	0.6	0.5	0.5	1.0	2.0	0.7	1.2	10
25											0
26											0
27											0
28											0
29											0
30	0.6	0.4	1.7	1.5	0.8	0.3	1.2	2.0		1.4	9
31											0

Distribution Sample Summary

Total # of routine distribution samples analyzed	132
Total # of routine distribution samples required	100

Distribution Bacteriological Summary

Total # of positive routine distribution samples	0
Percent of routine distribution samples positive	0%

See page 9 for positive sample information.

Distribution Disinfectant Total Residual Summary

Percentage of samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.1

Distribution
System Monitoring

City of Flint Water Treatment Plant
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Date	Total Chlorine Residual at Bacteriological Monitoring Stations mg/l										
	1	2	3	4	5	6	7	8	CS	WS	Number of Samples
1									3.2	1.0	2
2	0.4	2.6	2.5	2.1	1.5	0.2	1.5	2.5	2.1	2.0	10
3	1.2	2.0	2.1	1.9	1.3	0.4	1.8	2.1	2.1	2.3	10
4	1.0	1.4	1.9	2.0	1.3	0.2	1.7	2.1	1.5	1.9	10
5											0
6											0
7											0
8									0.5	0.6	2
9	1.3	0.2	1.6	0.4	0.3	0.4	1.9	2.7	0.5	1.5	10
10	1.1	0.3	2.1	2.0	0.3	0.3	1.7	2.2	1.9	1.1	10
11	1.0	0.5	1.5	2.0	0.8	0.3	2.1	1.9	2.0	2.0	10
12	0.9	0.8		1.6	1.0	0.3	1.7	2.0	1.8	1.2	9
13											0
14											0
15									1.1	1.9	2
16	0.9	2.1	1.8	1.8	1.0	0.3	1.0	2.3	1.5	2.4	10
17	0.8	1.1	1.7	1.8	1.0	0.3	1.0	2.1	1.4	1.8	10
18	1.0	1.7	1.7	1.8	0.8	0.2	1.7	2.0	1.4	1.6	10
19	0.8	1.9	1.9	1.5	1.1	0.3			1.2	1.3	8
20											0
21											0
22											0
23	1.0	1.7	1.6	1.7	1.1	0.5	1.7	2.1	2.0	0.6	10
24	0.8	1.2	2.3	0.8	0.7	0.8	1.2	2.3	0.9	1.4	10
25											0
26											0
27											0
28											0
29											0
30	0.8	0.5	1.9	1.7	1.1	0.5	1.4	2.4		1.6	9
31											0

Distribution Disinfectant Total Residual Summary	
Percent samples with a detectable disinfectant residual	100%
Average disinfectant residual this month	1.4

Positive Distribution Samples

[illegible]

Rennaker, Joanne (DEQ)

From: Wurfel, Brad (DEQ)
Sent: Wednesday, January 28, 2015 3:06 PM
To: Prysby, Mike (DEQ)
Subject: RE: Flint issue DEQ points. Please check me for message accuracy?

Terry, all good and thanks for working these up. Been rebriefed by our staff, so let me throw in some things that are pertinent from that point.

Following the formal approval of Flint into the KWA, DWSD sent Flint a letter saying their contract was thereby terminated (at some certain date). According to our folks, Genesee County has been using DWSD water without a contract for years. But Flint took the letter to imply a water cutoff, and promptly turned to DEQ with a proposal to use the Flint River (their historic backup system).

This proposed shift put the city in the business of water production, where they historically had been in the business of water transmission. DEQ approved the use of the river as a source, believing that with the proper conditions it could be managed. Several municipalities around the state use surface water supplies (rivers): Blissfield near Monroe, Manistique, and Alma to name a few.

The city constructed the facility and DEQ approved it April / May 2014.

There were some initial hiccups. Last summer, there were a couple of 'boil water' notices issued. One for a water test that showed e. coli, one for a break in the water main.

The challenge to using the Flint River as a source is that the condition of the water is variable and changes with season and weather. It has substantially more organic matter than deep lake sources like Lake Huron. This organic matter is mobilized by high water events, and warm weather also can account for more organic material in the water.

The treatment of the organic matter is done with chlorine. One might conclude that the perennial answer is just to use more chlorine to achieve water safety. However, at some point on the continuum, the chlorine and organic matter create TTHM – total trihalomethanes – as a byproduct. When the standard for those is exceeded over several consecutive quarters of testing, the operator of the system is required by law to issue public notice and submit an approved plan for addressing the situation.

You'll note that this regulatory approach means TTHM testing is done quarterly. That means people who use the system are exposed to TTHM for several months before

the public notice is required. It's because TTHM is a chronic health threat. Over the long term (measured in decades), continued exposure can contribute to some known health problems. Put in context, the EPA (who established the standard and the rule) estimates this rule prevents an estimated 280 bladder cancer cases each year ... out of more than 330 million people who use public water supplies around the country.

It's not nothing. State and federal law requires quarterly testing for TTHM and that the public be informed of it when three quarters' worth of consecutive testing shows elevated TTHM levels, and they must develop a plan to address it. But it's not like an eminent threat to public health like e. Coli or even coliform bacteria, which require immediate public notification and response and are part of daily / hourly testing of public water supplies.

It's clear the nature of the threat was communicated poorly. It's also clear that folks in Flint are concerned about other aspects of their water – taste, smell and color being among the top complaints.

The Safe Drinking Water Act requires public water supplies be tested for more than 90 toxins and pathogens. The act, and the program here in Michigan, work to ensure that water is safe to drink. The act does not cover aesthetic values of water. Here are some factors affecting the aesthetics of water in Flint.

1. It's the Flint River. The water supplied by DWSD historically came from Lake Huron. It's softer. With hard water, you get a different flavor and feel. It's why General Motors suspended use of Flint Water – it was rusting their parts. Also, there's the 'organics' factor (discussed previously).
2. The system is old. Flint has more than 500 miles of water pipes. More than half of those pipe miles are more than 75 years old. Much of it is cast iron. Hard water hits cast iron and exacerbates the rusty factor, which creates that brown water that angry residents were holding up in jugs for the media cameras last week. Valve failure has also been a key challenge. The system has an estimated 7,500+ valves. When they stick open or stick shut, it affects the hydrology of the system. Water can stagnate in pipes. The city has a backlog of valves that need to be addressed. They've done half a dozen or so since November.
3. Flint is old. Many of the homes served by the system are old. Residents who are getting brown water may have aged, cast iron pipes in their service connection to the city lines. The DEQ has been encouraging people with water coloration concerns to contact the city and see whether it is the service line or the City's line causing the issue. Again, discoloration is not an indicator of water quality or water safety, but we recognize that nobody likes it.

In summary, the City of Flint has tremendous need to address its water delivery system. We are not aware that they have any Capital Improvement account in place to set aside maintenance funds, much less line replacement project monies that will require hundreds of millions. The City was approved for a Revolving Fund loan in 2008 or 2009. As a Distressed Community, they qualified for flexible terms and 2 percent increase. After they were notified they were approved for the loan, they declined it. Previous SRF loans from the state to Flint bear an outstanding balance of \$20.7 million today.

The DEQ continues working with the city to address the TTHM issue. They can take interim steps – from scrubbing the insides of transmission lines to carefully monitoring the hydrological challenges in their system – to address customers' aesthetic concerns. Their TTHM numbers already are showing dramatic improvement; the November testing showed only one of seven sample points exceeding the standard. The key now is that the standard is an average of three quarters' worth of results. It will be some time before they are officially "not in violation." However, depending on weather in 2015, it's not unforeseeable that we will be having this conversation again by next Christmas.

The key to the conversation is that TTHM is not a top health concern. That's key because residents need to understand TTHM in context, and it is key because it appears the mayor has seized on the public panic (sparked, frankly, by their poor communication of the violation notice) to ask the state for loan forgiveness and more money for their infrastructure improvement.

Another key thing to remember is that once the city connects to the new KWA system in 2016, this issue will fade in the rearview.

Until then, our top messages:

1. The DEQ Drinking Water program works with communities around the state to ensure that municipalities provide customers with clean, safe drinking water.
2. Municipal water supplies are tested rigorously and regularly for more than 90 toxins and pathogens.
3. Flint's exceedance of the TTHM standard should reassure residents that the testing program is effective.
4. TTHM is not an immediate health threat. It is a chronic concern, one that can be problematic over the course of many years. The public was notified because the law requires the city to make public notification, so that everyone can make informed decisions. This is particularly true for people with infants or those with compromised immune systems.
5. The DEQ is working with the City to address the situation. Recent tests show the TTHM numbers dropping rapidly. The department will continue working with the

city in the months ahead, and residents should feel confident that their water is safe to drink unless the DEQ or City notifies them otherwise.

6. The discoloration and odor issues some Flint residents are experiencing are separate issues from the TTHM issue. TTHM is odorless, colorless and measured in parts per billion.
7. Flint water customers who have questions or concerns about their water should first contact the city to get answers and help. They also can contact the Michigan DEQ at ***** (web or phone address?)

From: Stanton, Terry A. (Treasury)
Sent: Tuesday, January 27, 2015 5:52 PM
To: Wurfel, Brad (DEQ); Wurfel, Sara (GOV); Murray, David (GOV)
Cc: Brown, Jessica (GOV); Stanton, Terry A. (Treasury); Sampson, Jeremy (TREASURY)
Subject: Flint issue
Importance: High

All,

Please see the attached TPs. I have also attached a couple pdfs noted in the TPs. They include the Treasurer's conditional approval of the eventual move to KWA and the EM's response to DWSD's "last, best offer."

Additionally, during my most recent interaction with Jerry Ambrose, he indicated that the water issue is critically important and that he and staff are working on it every day. They have posted a host of information for residents on the City's website (<http://cityofflint.com/?p=6251>). They have extended the deadline for the Water Quality Consultant RFP to this Thursday, to ensure interested and qualified firms can submit comprehensive proposals and assist the city.

I have also attached the earlier talking points I had shared with Dave.

Let me know if you need anything else in the meantime...or before we speak again...

Terry

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, January 27, 2015 10:00 AM
To: Elliott, Larry F.
Cc: Busch, Stephen (DEQ); Benzie, Richard (DEQ); Wurfel, Brad (DEQ); Shekter Smith, Liane (DEQ); Rosenthal, Adam (DEQ)
Subject: RE: ABC12 News Flint water test results comment?

Larry,

We are willing to review the TTHM results of all samples collected within the Flint water system for a limited assessment of the data. Please include the following information with the sample results:

1. Sampling location /time – was Flint's Stage 2 DDBP monitoring plan sites used?
2. Who collected the samples? Did city certified operators collect the samples or oversee the sample collection?
3. Sampling protocol (method)
4. Certified lab used
5. Lab method used & proper sampling unit

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Elliott, Larry F. [<mailto:larry.f.elliott@abc12.com>]
Sent: Tuesday, January 27, 2015 7:48 AM
To: Prysby, Mike (DEQ)
Subject: ABC12 News Flint water test results comment?

Mike,
 We have just completed our own independent testing of multiple sites within the Flint water system and wonder if you'd be willing to look them over and give us your professional opinion.
 I could email you the reports from the testing lab we used.
 Larry Elliott
 ABC12 News
 (810)257-2805 office
 (810)877-5378 cell

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, January 27, 2015 9:20 AM
To: Busch, Stephen (DEQ)
Subject: Re: ABC12 News Flint water test results comment?

Absolutely and ...is the city aware of the sampling and/or have they had an opportunity to look at the results?

Sent from my iPhone

On Jan 27, 2015, at 9:17 AM, "Busch, Stephen (DEQ)" <BUSCHS@michigan.gov> wrote:

I would be sure to look into:
 Who collected the samples
 What sampling protocols were used
 Is the lab certified to run this analysis
 What lab method was used

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Prysby, Mike (DEQ)
Sent: Tuesday, January 27, 2015 8:55 AM
To: Busch, Stephen (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ)
Subject: FW: ABC12 News Flint water test results comment?

I am in the position to look at these results; however, the validity of the samples may be questionable given they were most likely not collected by Flint operators or in accordance to Flint's Stage 2 DDBP plan. Any professional opinion may need to be carefully worded....

Michael Prysby, P.E.
 District Engineer
 Office of Drinking Water and Municipal Assistance
 517 290-8817

From: Elliott, Larry F. [<mailto:larry.f.elliott@abc12.com>]
Sent: Tuesday, January 27, 2015 7:48 AM
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Larry Elliott

ABC12 News

(810)257-2805 office

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Rennaker, Joanne (DEQ)

From: Elliott, Larry F. <larry.f.elliott@abc12.com>
Sent: Tuesday, January 27, 2015 7:48 AM
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We have just completed our own independent testing of multiple sites within the Flint water system and wonder if you'd be willing to look them over and give us your professional opinion.

I could email you the reports from the testing lab we used.

Larry Elliott

ABC12 News

(810)257-2805 office

(810)877-5378 cell

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Monday, January 26, 2015 1:09 PM
To: Wurfel, Brad (DEQ); Shekter Smith, Liane (DEQ); Benzie, Richard (DEQ); Prysby, Mike (DEQ); Datema, Maggie (DEQ); Tommasulo, Karen (DEQ)
Subject: FW: interview for article on Flint drinking water

FYI. Bridge Magazine request for information. See below. Note Letter to Governor office deferred to Governor's Office at this time.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Busch, Stephen (DEQ)
Sent: Monday, January 26, 2015 1:07 PM
To: 'Chastity Pratt'
Subject: RE: interview for article on Flint drinking water

Ms. Pratt Please see responses to your questions below.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Chastity Pratt [<mailto:cpratt@bridgemi.com>]
Sent: Monday, January 26, 2015 11:35 AM
To: Busch, Stephen (DEQ)
Subject: interview for article on Flint drinking water

Hi,

I am a reporter for Bridge Magazine working on a deadline story about Flint's drinking water. My story will focus on state involvement and state policy.

My major questions:

1. Several agencies and officials are involved - can you clarify DEQ's role in the Flint water situation?

The City of Flint water system is one of over 1400 Community Water Systems in Michigan regulated under the Michigan Safe Drinking Water Act (1976 Public Act 399, as amended), which incorporates requirements of the federal Safe Drinking Water Act. The DEQ Office of Drinking Water and Municipal Assistance has been given authority for oversight of these regulations. DEQ regulatory oversight is mainly conducted through inspections, review of monitoring information (this includes sample results and operations data), issuance of construction permits for water systems, and planning (reliability, emergency response, capital improvement, operation and maintenance, etc.) As both community water systems and the DEQ desire the mutual goal of safe water, the DEQ works proactively in partnership with water systems to provide compliance assistance. This also includes activities such as source water protection and infrastructure funding.

2. What is the DEQ's response to the mayor's request for assistance?

As indicated by phone this letter was directed to the Governor's Office and should be followed up with that office for response at this point in time.

3. What on-going testing is DEQ doing with Flint water and how often?

The City is required to follow all state and federal monitoring requirements under Act 399. This includes sample analysis of over 90 contaminants with health based drinking water standards along with monitoring of its source, treatment, and distribution operations. Sample analysis frequency is based on the specific contaminant type, its level of detection if any, and its potential variability.

In regards to total coliform and e.coli bacteria compliance monitoring, the City is required to analyze at least 100 samples each monthly compliance period from its distribution system.

In regards to Total Trihalomethane (TTHM) compliance monitoring, the City is required to collect quarterly samples from 8 locations in its distribution system. The TTHM standard is based on a Running Annual Average for each of the 8 locations, rather than individual sample results. The location and timing of these samples is based on worst case conditions in the water system to identify the highest level of long term exposure.

4. So far, how many drinking water violations have occurred in Flint since the switch to Flint River water and what sanctions - if any - does the city face?

The City has had the following Maximum Contaminant Level (MCL) standard violations:

E.Coli Acute bacteria MCL violation, August 2014

Total Coliform bacteria MCL violation, September 2014

TTHM locational running annual average MCL violation, October-December quarter (2 of 8 sites)

There are generally two requirements in regards to the violations: Public Notification and corrective action

Public Notice for acute health threats like the e.coli MCL must be made within 24 hours of the violation.

Public Notice for non-acute health threats such as total coliform bacteria and TTHM must be made within 30 days of the violation.

Corrective action regarding bacteria detections generally involves taking steps to disinfect and repair the affected areas and sampling to obtain confirmation the bacteria source is has been addressed.

The City has remained in compliance with this standard for each of the monthly monitoring periods since September, including thus far in January

Corrective action for TTHM involves taking steps to reduce the amount of TTHM so that they are below the standard. The City is required to complete an Operational Evaluation report within 90 days of the violation. This report includes examination of treatment and distribution operational practices (source water quality, treatment changes, storage tank operations, excess storage capacity, distribution system flushing, treatment problems that contribute to TTHM formation. The City proactively completed an Operational Evaluation following sample results from August 2014, and is now completing another operational evaluation further evaluated based on information from the November monitoring. November monitoring showed individual sample results now below the standard at 7 of 8 locations. However, as noted compliance is determined based on a running annual average at each location.

5. What does DEQ tell Flint residents who call DEQ with concerns about discolored water?

Callers indicating discoloration or other aesthetic water quality issues are directed to contact the Flint DPW to allow the DPW staff to investigate the situation. Generally color, odor and taste are aesthetic water quality issues not related to any health based standards including total coliform bacteria, e.coli bacteria, and TTHM.

Treated water is monitored for color at the Water Treatment Plant as part of its operation, and has not been abnormal. The City of Flint has over 500 miles of distribution piping and conditions in some isolated sections of water main piping or private premise plumbing may cause changes to aesthetic conditions such as color, taste, or odor.

Those are my major questions. Could you please give me a call today?

--

Chastity Pratt Dawsey

Reporter

Bridge Magazine/The Center for Michigan

28 W. Adams Suite 330, Detroit, MI 48226

www.bridgemi.com

C: 313-310-7867

Rennaker, Joanne (DEQ)

From: Erb, Robin <rerb@freepress.com>
Sent: Thursday, January 22, 2015 4:01 PM
To: Prysby, Mike (DEQ)
Subject: RE: Flint TTHM Results

Thanks much, I really appreciate your help today.

From: Prysby, Mike (DEQ) [mailto:PRYSBYM@michigan.gov]
Sent: Thursday, January 22, 2015 3:04 PM
To: Erb, Robin
Subject: Flint TTHM Results

Robin,

Attached is the summary of Flint's TTHM sample results beginning with the May 2014 quarter.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Thursday, January 22, 2015 3:04 PM
To: rerb@freepress.com
Subject: Flint TTHM Results
Attachments: Flint 2014 DBP results.pdf

Robin,

Attached is the summary of Flint's TTHM sample results beginning with the May 2014 quarter.

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Flint 2014 TTHM & HAA5 results and Locational Running Annual Average (LRAA)

1/16/15

TTHM Results (mg/L)				
	5/21/14	8/21/14	11/20/14	LRAA
DBP1 McDonalds 3719 Davison	0.162	0.145	0.059	0.092
DBP2 Liquor Palace 3302 S. Dort Highway	0.112	0.127	0.033	0.068
DBP3 North Flint Auto 6204 N. Saginaw St.	0.097	0.118	0.041	0.064
DBP4 University Market 2501 Flushing Road	0.106	0.196	0.094	0.099
DBP5 Taco Bell 3606 Corunna Road	0.079	0.181	0.034	0.074
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.088	0.144	0.054	0.072
DBP7 Salem Housing 3216 MLK Boulevard	0.082	0.112	0.050	0.061
DBP8 BP Gas Station 822 S. Dort Highway	0.075	0.112	0.036	0.056

HAA5 Results (mg/L)				
	5/21/14	8/21/14	11/20/14	LRAA
DBP1 McDonalds 3719 Davison	0.064	0.043	0.016	0.031
DBP2 Liquor Palace 3302 S. Dort Highway	0.052	0.031	0.015	0.025
DBP3 North Flint Auto 6204 N. Saginaw St.	0.048	0.037	0.018	0.026
DBP4 University Market 2501 Flushing Road	0.055	0.017	0.024	0.024
DBP5 Taco Bell 3606 Corunna Road	0.050	0.024	0.015	0.022
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.049	0.030	0.017	0.024
DBP7 Salem Housing 3216 MLK Boulevard	0.041	0.025	0.005	0.018
DBP8 BP Gas Station 822 S. Dort Highway	0.038	0.040	0.021	0.025

Locational running annual average (LRAA): the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

Maximum contaminant level (MCL): the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

The Stage 2 Disinfection By-Products Rule (DBPR) requires systems to meet an LRAA of 0.080 mg/L for TTHM and 0.060 mg/L for HAA5 at each compliance monitoring location.

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Thursday, January 22, 2015 12:05 PM
To: Looney, Carolyn (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: RE: Voicemail from Ms. Ann Newell, 810-262-9459

I called and left a voicemail for her to call me back.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

From: Looney, Carolyn (DEQ)
Sent: Thursday, January 22, 2015 11:14 AM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: Voicemail from Ms. Ann Newell, 810-262-9459

I received a voicemail yesterday at 1:17 pm from Ms. Ann Newell, 810-262-9459. She is the Infection Control Manager at Hurley Medical Center in Flint. She would like a call back to let you know about the issues and concerns they are dealing with at the hospital regarding the bad water in Flint. Please give her a call. Thanks!!

Carolyn Looney
Secretary for the Environmental Health Section
Office of Drinking Water and Municipal Assistance
Michigan Department of Environmental Quality
Phone: 517-284-6535
Fax: 517-241-1328
Email: looneyc@mi.gov

Rennaker, Joanne (DEQ)

From: Wurfel, Brad (DEQ)
Sent: Wednesday, January 21, 2015 4:37 PM
To: Fonger, Ronald
Cc: Prysby, Mike (DEQ); Busch, Stephen (DEQ)
Subject: RE: a question about flint

The water is still pre-treated. I think you mean when the water was coming from DWSD, and the city was just in the water transmission business instead of the water treatment business. I believe the answer is no, they didn't have many violations, but I'd encourage you to put the question to Mike Prysby, who will be at the meeting. Understand that dozens and dozens of 'boil water' advisories are issued by municipalities around the state every year for various reasons – anything from an abnormal coliform count to broken water mains that expose water to outside influence ... and the advisory is not by itself a warning that folks drinking the water will become ill. It's representative of a comprehensive, conservative protection standard with ample public notification measures to ensure that water customers can make informed decisions.

All of that said, the two guys most likely to know the answer to your specific question will be in the room tonight. And I've copied them here to make them aware you've got questions.

b

From: Fonger, Ronald [<mailto:RFONGER1@mlive.com>]
Sent: Wednesday, January 21, 2015 4:08 PM
To: Wurfel, Brad (DEQ)
Subject: a question about flint

Brad:
 One thing I'd like to know is whether Flint has ever been in violation of the Safe Drinking Water Act previously – at least as far back as your records go.
 I'm guessing we didn't have too many when the water was pre-treated.
 Thanks,

Ron Fonger
 MLive Media Group
 Reporter

mobile 810.347.9963
 email rfonger1@mlive.com
 address 540 S. Saginaw St. #101, Flint MI 48502

Rennaker, Joanne (DEQ)

From: Wurfel, Brad (DEQ)
Sent: Wednesday, January 21, 2015 10:30 AM
To: Shekter Smith, Liane (DEQ); Busch, Stephen (DEQ); Prysby, Mike (DEQ); Benzie, Richard (DEQ)
Cc: Datema, Maggie (DEQ); Howes, Sarah (DEQ); Sygo, Jim (DEQ)
Subject: RE: Flint Mayor request to Governor regarding Flint Water

PERFECT message, Liane. Has anyone got a copy of the letter?

b

From: Shekter Smith, Liane (DEQ)
Sent: Wednesday, January 21, 2015 10:26 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ); Benzie, Richard (DEQ)
Cc: Datema, Maggie (DEQ); Howes, Sarah (DEQ); Wurfel, Brad (DEQ); Sygo, Jim (DEQ)
Subject: RE: Flint Mayor request to Governor regarding Flint Water

In light of the Mayor's letter, this could be quite uncomfortable for us tonight.

Our position has always been that we do not dictate which acceptable option(s) a water supply may choose. Our responsibility is to see that operations are managed properly, regulations are met, and safe water is delivered. For example, when Flint decided to leave Detroit and operate using the River, our role wasn't to tell them our opinion; only what steps would be necessary to make the switch.

Now that there is a violation of a drinking water standard, we have been treating Flint as we would any other supply. It is up to them to propose a solution/corrective action. Our role is to determine the reasonableness of that proposal. One option available to them is to continue to use the river until the KWA source is available as long as they implement operational changes to mitigate the formation of DBPs. Another acceptable option is to return to Detroit (GLWA) until the KWA source is available. And third option could certainly be returning to GLWA permanently.

The Mayor is saying that since there is an EM, the state (Governor) has responsibility for decisions being made (not our position). It will be very important for DEQ staff to limit our discussion to our role under the Safe Drinking Water Act. Hopefully, the EM will be prepared to respond if and when the conversation veers off into this other arena.

Liane J. Shekter Smith, P.E., Chief
 Office of Drinking Water and Municipal Assistance
 Michigan Department of Environmental Quality
 517-284-6543

From: Busch, Stephen (DEQ)
Sent: Wednesday, January 21, 2015 8:41 AM
To: Shekter Smith, Liane (DEQ); Prysby, Mike (DEQ); Benzie, Richard (DEQ)
Cc: Datema, Maggie (DEQ); Howes, Sarah (DEQ)
Subject: Flint Mayor request to Governor regarding Flint Water

FYI. Please see the link below. The mayor of Flint has requested the state provide assistance through a number of specific initiatives.

http://www.mlive.com/news/flint/index.ssf/2015/01/flint_mayor_asks_governor_for.html

As we are scheduled to participate in the meeting in Flint this evening please let me know if we need to further discuss these requests.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Wednesday, January 21, 2015 9:48 AM
To: Wurfel, Brad (DEQ)
Cc: Shekter Smith, Liane (DEQ); Prysby, Mike (DEQ)
Subject: RE: Flint Public Meeting Carpool

Brad,

Mike and I are available most of the day. I have a conference call 11-12 and an offsite meeting 2:30-4:30. Just come down to the first floor whenever you have time.

The issue has further escalated this morning with a letter from the Flint Mayor to the Governor requesting additional assistance.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Wurfel, Brad (DEQ)
Sent: Wednesday, January 21, 2015 9:45 AM
To: Busch, Stephen (DEQ)
Subject: RE: Flint Public Meeting Carpool

Steve, thanks and my apologies for missing our confab yesterday afternoon. SOS stuff made for a crazy day. Not sure I'm going to make it to Flint tonight, but wanted to spend a few minutes today if you've got time. Bluntly, I have tremendous confidence in you and Mike to handle yourselves admirably with the public and press. My only concern is that the City has communicated so poorly that we could end up in position to serve as their defacto spokespeople. Let me know if you've got a few today.
 b

From: Busch, Stephen (DEQ)
Sent: Tuesday, January 20, 2015 3:45 PM
To: Wurfel, Brad (DEQ)
Subject: Flint Public Meeting Carpool

Brad,

Mike and I were planning to carpool up to Flint tomorrow night. Did you want to carpool as well? Just let us know. Thanks.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Wednesday, January 21, 2015 8:41 AM
To: Shekter Smith, Liane (DEQ); Prysby, Mike (DEQ); Benzie, Richard (DEQ)
Cc: Datema, Maggie (DEQ); Howes, Sarah (DEQ)
Subject: Flint Mayor request to Governor regarding Flint Water

FYI. Please see the link below. The mayor of Flint has requested the state provide assistance through a number of specific initiatives.

http://www.mlive.com/news/flint/index.ssf/2015/01/flint_mayor_asks_governor_for.html

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Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Tuesday, January 20, 2015 5:08 PM
To: Busch, Stephen (DEQ)
Cc: Prysby, Mike (DEQ); Elizabeth Murphy; Gerald Ambrose; Flint Mayor; Shekter Smith, Liane (DEQ)
Subject: Re: Water Forum

Steve,

Thanks for the input, I have made the changes and will address the rates as well.

On Tue, Jan 20, 2015 at 3:33 PM, Busch, Stephen (DEQ) <BUSCHS@michigan.gov> wrote:

Howard,

Please revise the DEQ bullet points to as follows:

- Role of the DEQ
- Explanation of TTHM violation

Delete all others. Thanks.

Based on the calls we have been getting from your water customers, our Office strongly recommends someone from the City discuss the City's water rate structure and what the City's water rates are being used to support.

Stephen Busch, P.E.

Lansing and Jackson District Supervisor

Office of Drinking Water and Municipal Assistance

MDEQ

517-643-2314

From: Howard Croft [mailto:hcroft@cityofflint.com]
Sent: Tuesday, January 20, 2015 3:13 PM

To: Prysby, Mike (DEQ); Busch, Stephen (DEQ); Green, Warren; John O'Brien; djansen@gcdcwws.com; rosejo@msu.edu
Cc: Elizabeth Murphy; Gerald Ambrose; Flint Mayor
Subject: Water Forum

Here is the current agenda that I have assembled for our Wednesday night forum. I am looking for everyone to speak for about 10 minutes at the opening and then we will move to written questions.

I have attempted to highlight each persons area of expertise as it relates to initial comments and I will moderate through the questions. We do not plan to have an open microphone.

Starting time is 7:00 in the Dome, I will be available in City Hall for those that arrive early.

Thank you all for participating,

--

Howard Croft

Public Works Director

City of Flint

1101 S. Saginaw Street

Flint, MI 48502

PH# 810.766.7346 Ext.2043

hcroft@cityofflint.com

--

Howard Croft

Public Works Director

City of Flint

1101 S. Saginaw Street

Flint, MI 48502

PH# 810.766.7346 Ext.2043

hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Tuesday, January 20, 2015 3:33 PM
To: Howard Croft; Prysby, Mike (DEQ)
Cc: Elizabeth Murphy; Gerald Ambrose; Flint Mayor; Shekter Smith, Liane (DEQ)
Subject: RE: Water Forum
Attachments: City of Flint_Public Forum (1).pdf

Howard,

Please revise the DEQ bullet points to as follows:

- Role of the DEQ
- Explanation of TTHM violation

Delete all others. Thanks.

Based on the calls we have been getting from your water customers, our Office strongly recommends someone from the City discuss the City's water rate structure and what the City's water rates are being used to support.

Stephen Busch, P.E.
 Lansing and Jackson District Supervisor
 Office of Drinking Water and Municipal Assistance
 MDEQ
 517-643-2314

From: Howard Croft [<mailto:hcroft@cityofflint.com>]
Sent: Tuesday, January 20, 2015 3:13 PM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ); Green, Warren; John O'Brien; djansen@gcdcwws.com; rosejo@msu.edu
Cc: Elizabeth Murphy; Gerald Ambrose; Flint Mayor
Subject: Water Forum

Here is the current agenda that I have assembled for our Wednesday night forum. I am looking for everyone to speak for about 10 minutes at the opening and then we will move to written questions. I have attempted to highlight each persons area of expertise as it relates to initial comments and I will moderate through the questions. We do not plan to have an open microphone.

Starting time is 7:00 in the Dome, I will be available in City Hall for those that arrive early.

Thank you all for participating,

--

Howard Croft
 Public Works Director
 City of Flint
 1101 S. Saginaw Street
 Flint, MI 48502
 PH# 810.766.7346 Ext.2043
hcroft@cityofflint.com



City of Flint Public Forum

Wednesday January 21, 2015

7:00 pm City Hall Dome

AGENDA

Opening COF – DPW Director - Howard Croft

- Forum Ground Rules
- Overview of Format (each guest to speak for ~10 minutes, written questions afterward)
- Introduction of Guests

1st Speaker DEQ – Local Representative - Mike Prysby, Steve Busch

- Water safety
- Explanation of violations (impact of being over MCL)
- Another violation coming in March due to the calculation method (what that means)
- Role of DEQ
- Other places in Michigan with violations?

2nd Speaker LAN – Lead Engineer - Warren Green

- Discuss Engineering role
- Discuss evaluation of Treatment Plant and Distribution system (as reflected in report)
- They are working with KWA and coordinate with DEQ regularly

3rd Speaker Health Expert – MSU Microbiologist – Dr. Joan Rose Ph.D.

- Risk Assessment (what do the numbers mean?)
- What to do if someone suspects they are at risk
- What about the elderly and those with a weak immune system
- What will the next violation mean (water is still safe)

4th Speaker GCDC – Jeff Wright

- What to expect from KWA raw water as source
- Update on KWA timeline

Final COF – DPW Director – Howard Croft

- Summary (Next Steps – Action Plans)
 - Hiring a consultant
 - Increasing communication
 - Strategic goals in Utility Dept. (importance of community supported CIP as it relates to infrastructure)
 - Funding (state funding through the DWRF, Federal opportunities)
- Questions (Expected to have an hour of panel response time)
- Conclusion - Thank the panel, (Additional follow up at next Public Works Committee meeting)

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Tuesday, January 20, 2015 3:13 PM
To: Prysby, Mike (DEQ); Busch, Stephen (DEQ); Green, Warren; John O'Brien;
djansen@gcdcwws.com; rosejo@msu.edu
Cc: Elizabeth Murphy; Gerald Ambrose; Flint Mayor
Subject: Water Forum
Attachments: City of Flint_Public Forum (1).pdf

Here is the current agenda that I have assembled for our Wednesday night forum. I am looking for everyone to speak for about 10 minutes at the opening and then we will move to written questions. I have attempted to highlight each persons area of expertise as it relates to initial comments and I will moderate through the questions. We do not plan to have an open microphone.

Starting time is 7:00 in the Dome, I will be available in City Hall for those that arrive early.

Thank you all for participating,

--

Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7346 Ext.2043
hcroft@cityofflint.com



City of Flint Public Forum

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 - Funding (state funding through the DWRF, Federal opportunities)
- Questions (Expected to have an hour of panel response time)
- Conclusion - Thank the panel, (Additional follow up at next Public Works Committee meeting)

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Tuesday, January 20, 2015 1:15 PM
To: Busch, Stephen (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ); Rosenthal, Adam (DEQ); Rennaker, Joanne (DEQ)
Subject: tally of Flint calls
Attachments: Calls from Public list.doc

See revised list....

Michael Prysby, P.E.
District Engineer
Office of Drinking Water and Municipal Assistance
517 290-8817

Flint TTHM Violation Completed Calls from the Public MFP

- 1/5: Mike P.-Ron Fonger – Flint Journal – Media inquiry
 1/5: Mike P. - Lawrence Reynolds – Mott Children's Health
 1/5: Mike P. - Walter Smith-Randolph – NBC 25 Flint News – Recorded interview
 1/5: Adam R. – Denise – Flint Resident
- 1/6: Mike P. - Arthur Woodston – resident – general questions, invite to res. Mtg
 1/6: Mike P. - Bradley - resident – ok to boil water for baby formula bottle?
 1/6: Mike P. - Raimy Elley – resident – gen info., most upset on city's delay to notify
 1/6: Mike P. - Reps. Sheldon Neeley and Phil Phelps – update State Reps for Flint Districts on TTHM issue. Richard Benzie and Sarah Howes participated.
 1/6: Steve B. – Cheryl Wormsman – friend of Flint resident- general questions/concerns
- 1/8: Mike P. – Sandra Wilkes – resident – excessive cost for poor quality, who can force Flint to re-connect to Detroit...
 1/8: Mike P – Arthur Woodston (2nd call). Recc. Not to drink water from doc...where do I go?
- 1/9: Mike P – Patricia Warner – Gen. info...excessive cost/poor WQ, better comm. from city needed
 1/9: Mike P – Jeanette Doll (DTMB) – left message to call me back concerning alt. water for state Bldg.. in Flint. Answer ? pertaining to future TTHM results and PN. Call most likely to ensue on Monday 1/12. **** Completed call w. Jeanette on 1/12 and answered her question pertaining to future TTHM monitoring and how it will pertain to compliance.**
- 1/14: Mike P – Mindy Blasdeed – resident – daughter with skin rash since being on DWSD water, On-going bladder infection – Mindy was at physician office and call was cut short. I will contact Mindy tomorrow to finish our call.
- 1/20: Mike P- Paris Glazer (Assoc. Attorney – LaRose Bosco law firm) – determining validity for Case claim (Fed. Statute claim) for Flint residents. Are there any way(s) to remediate high TTHM levels before KWA? Possible FOIA.....

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Friday, January 16, 2015 5:03 PM
To: jimananich@house.mi.gov; repphelps@house.mi.gov; Sheldon Neeley; Hovey, Amy
Cc: Tom Lenard; Bryanna McGarry; Sean Walser; Dickinson, Jordan; Flint Mayor; Prysby, Mike (DEQ); Busch, Stephen (DEQ); John O'Brien; djansen@gcdcwws.com; Green, Warren; Matta, Samir; Elizabeth Murphy; Gerald Ambrose; Brian Larkin
Subject: Public Forum
Attachments: Public Water Presentation 1.21.2015.pdf; Adressing Flint's Water Concerns.pdf

All,

The City of Flint is hosting a public forum next Wednesday January 21st in the dome at City Hall at 7:00 pm. The focus will be a presentation followed by a question and answer session about water. The panel will consist of two of our DEQ representatives, the lead engineer from LAN, the Genesee County Drain Commissioner Jeff Wright, and myself.

Please feel free to attend or recommend your constituency to attend, I am forwarding a copy of the press release along with our most recent communication's about the City of Flint water system.

I am looking to build a better communication network for sending out information from the City of Flint DPW Department to interested parties on a more frequent basis. I will inform everyone when that is formally established.

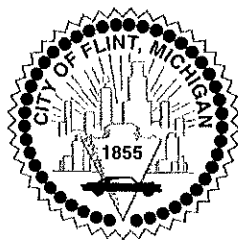
Please call me if you have any questions,

Thank you,

--

Howard Croft
Public Works Director
City of Flint
1101 S. Saginaw Street
Flint, MI 48502
PH# 810.766.7346 Ext.2043
hcroft@cityofflint.com

Gerald Ambrose
Emergency Manager



Dayne Walling
Mayor

Jason Lorenz
Public Information Officer
(810) 237-2039
jlorenz@cityofflint.com

For Immediate Release

City of Flint Will Hold Public Water Presentation Wednesday, January 21, 2015 at 7:00pm in the City Hall Dome

Flint, Michigan – January 16, 2015 — The City of Flint will be hosting a water presentation on Wednesday, January 21, 2015 at 7pm. That presentation will be held in the City Hall Dome and will feature information detailing water treatment, water distribution and the steps being taken to ensure that citizens get water that meets all regulatory safety and quality standards. "We want the residents, businesses and visitors of Flint to know that the water in Flint is safe and that we are working every day to make improvements to our system to ensure that," said City DPW Director Howard Croft. "Our goal is make sure we get people the information on our efforts and assure them that we are on the right track with them."

DPW Director Croft and Utilities Administrator Daugherty Johnson will be joined on a panel by representatives from the Genesee County Drain Commissioner's office, the Michigan Department of Environmental Quality and LAN engineering. Written questions from the audience will be collected during the presentation and answered by the panel after the presentation.

—END—

Addressing Flint's Water Concerns

Recent events have raised concerns among many as to the safety and quality of the water provided by the City's utility system. The City is and continues to be committed to assuring that residents and visitors know that the water is safe and that those responsible for providing water are working every day to improve the quality of the water. The quality of the water does need improvement, but that is not to be confused with safety of the water. The recent notice by MDEQ clearly stated that the water provided by the utility system is safe to drink, but cautioned that some vulnerable groups may want to consult with their health care provider if they have concerns. The City remains committed to their efforts to assure that the water is safe for everyone and that quality is both improved and improving.

To date, the City has taken the following actions:

- As an integral part of the transition to the Flint River on a temporary basis, the MDEQ was consulted about the City's plans, and ultimately issued necessary permits to proceed. The City also engaged the services of the LAN engineering firm to guide the city in installing the necessary equipment to treat the water on an ongoing basis. This resulted in the development of a comprehensive drinking water plan.
- The City monitors its water quality on a daily basis to assure that water quality remains within established guidelines. With the variances in water temperature and the leakage and infiltration problems arising as the result of failure of parts of the distribution system, water quality did exceed, for a time, some of the established guidelines. This resulted in the issuance of the recent notices to the public. Upon receipt of information that some guidelines were exceeded, the City's priority focus was to bring water quality back within guidelines. Efforts taken to address non-compliance included increasing water flow through valve replacements and hydrant flushing and optimizing treatment processes.
- The City has committed to increasing communication with the public in order to inform water users factually of the issues which have arisen, to alleviate unnecessary concern and to identify the steps being taken to address the issues. This is being implemented through detailed and easy to understand educational materials being made available both online and at City Hall, as well as through ongoing public informational meetings.
- Most recently, in light of recent concerns raised by resident groups over the quality and safety of water, Department of Public Works Director Howard Croft and his staff collected questions from citizens during a recent public meeting. After reviewing these questions, DPW Director Croft and his staff set out to answer them in concise detail; the result of that work is a full Water System Questions and Answers document is available online. Along with the detailed information within, the document also contains links to other source documents and regulatory statutes found online which were used as reference. **"We want the residents, businesses and visitors of Flint to know that the water in Flint is safe**

and that we are working every day to make improvements to our system to ensure that," said Croft. "Our goal is make sure we get people the information on our efforts and assure them that we are on the right track with them." More documentation, including regular water quality monitoring reports, will be made available.

- Additionally, a number of public meetings have and will continue to take place. Two of the most recent of these took place at the Antioch Baptist Church and the Mott Community College Regional Technology Center. These meetings were held by concerned neighborhood groups and were attended by Mayor Walling and DPW Director Croft. At both meetings, citizens voiced their concerns and asked questions about water quality and the recent violation notice. Director Croft offered detailed answers to common questions, but also offered to investigate specific water issues raised by residents in which the City could offer assistance. Those in attendance came away with a better understanding of the issues surrounding the drinking water in their community.
- The City of Flint will be hosting a water presentation on **Wednesday, January 21, 2015 at 7pm. That presentation will be held in the City Hall Dome** and will feature information detailing water treatment, water distribution and the steps being taken to ensure that citizens get water that meets all regulatory safety and quality standards. City DPW Director Howard Croft and Daugherty Johnson, Utilities Administrator, will be joined on a panel by representatives from the Genesee County Drain Commissioner's office, the Michigan Department of Environmental Quality and LAN engineering. Written questions from the audience will be collected during the presentation and answered by the panel after the presentation.
- The City of Flint has also determined that in light of the serious concerns raised, it will secure the services of an external firm with expertise in managing drinking water quality to assess the steps that the city has taken, to make recommendations as to other steps to be taken, to oversee their implementation, and to monitor operations until the City's water source becomes the KWA. A Request for Proposal was issued on January 15, 2015, with proposals due back on January 26.

The DWSD Question:

As a result of the concerns raised, several community members have suggested that the City reconnect to the Detroit Water and Sewer Department (DWSD). DWSD has advised that they would be willing to allow such a reconnection without a hook-up fee. However, the City would be obligated to pay a fixed monthly charge of \$846,700 plus the \$14.92/Mcf cost of water itself and agree to a long term arrangement. The City's analysis of the DWSD proposal concludes that the City's cost would increase by more than \$12 million per year at the proposed rates, and could increase even more as proposed rates are subject to change after July 1, 2015. This increase in costs would not be in the best interests of the City or its water users, as the City is committed to assuring safety and improving water quality by following its current plan, and reconnecting to DWSD would likely require deferment of existing capital improvements or an additional increase in rates.

Rennaker, Joanne (DEQ)

From: Rosenthal, Adam (DEQ)
Sent: Friday, January 16, 2015 1:31 PM
To: larry.f.elliott@abc12.com
Cc: Prysby, Mike (DEQ); Busch, Stephen (DEQ); Wurfel, Brad (DEQ); Benzie, Richard (DEQ); Shekter Smith, Liane (DEQ)
Subject: Flint Disinfection By-Product data
Attachments: Flint 2014 DBP results.PDF

Dear Mr. Elliott at ABC 12 Flint.

Attached are results and definitions for Disinfection By-Products samples collected during 2014 for the City of Flint. The Locational Running Annual Average (LRAA) is the number used for compliance with the Maximum Contaminant Levels (MCLs).

Sincerely,

Adam Rosenthal, EQA
MDEQ – Office of Drinking Water and Municipal Assistance
Lansing District – Constitution Hall 1SW
PO Box 30242
Lansing, MI 48909
517-284-6644
fax: 517-241-3571

Flint 2014 TTHM & HAA5 results and Locational Running Annual Average (LRAA)

1/16/15

TTHM Results (mg/L)				
	5/21/14	8/21/14	11/20/14	LRAA
DBP1 McDonalds 3719 Davison	0.162	0.145	0.059	0.092
DBP2 Liquor Palace 3302 S. Dort Highway	0.112	0.127	0.033	0.068
DBP3 North Flint Auto 6204 N. Saginaw St.	0.097	0.118	0.041	0.064
DBP4 University Market 2501 Flushing Road	0.106	0.196	0.094	0.099
DBP5 Taco Bell 3606 Corunna Road	0.079	0.181	0.034	0.074
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.088	0.144	0.054	0.072
DBP7 Salem Housing 3216 MLK Boulevard	0.082	0.112	0.050	0.061
DBP8 BP Gas Station 822 S. Dort Highway	0.075	0.112	0.036	0.056

HAA5 Results (mg/L)				
	5/21/14	8/21/14	11/20/14	LRAA
DBP1 McDonalds 3719 Davison	0.064	0.043	0.016	0.031
DBP2 Liquor Palace 3302 S. Dort Highway	0.052	0.031	0.015	0.025
DBP3 North Flint Auto 6204 N. Saginaw St.	0.048	0.037	0.018	0.026
DBP4 University Market 2501 Flushing Road	0.055	0.017	0.024	0.024
DBP5 Taco Bell 3606 Corunna Road	0.050	0.024	0.015	0.022
DBP6 Rite-Aid Pharmacy 5018 Clio Road	0.049	0.030	0.017	0.024
DBP7 Salem Housing 3216 MLK Boulevard	0.041	0.025	0.005	0.018
DBP8 BP Gas Station 822 S. Dort Highway	0.038	0.040	0.021	0.025

Locational running annual average (LRAA): the average of sample analytical results for samples taken at a particular monitoring location during the previous four calendar quarters.

Maximum contaminant level (MCL): the maximum permissible level of a contaminant in water which is delivered to any user of a public water system.

The Stage 2 Disinfection By-Products Rule (DBPR) requires systems to meet an LRAA of 0.080 mg/L for TTHM and 0.060 mg/L for HAA5 at each compliance monitoring location.

Rennaker, Joanne (DEQ)

From: Busch, Stephen (DEQ)
Sent: Friday, January 16, 2015 10:33 AM
To: Looney, Carolyn (DEQ)
Cc: Benzie, Richard (DEQ); Prysby, Mike (DEQ)
Subject: RE: Voicemail from Ms. Jacklyn Pemberton (sp?), 810-252-3732

I have spoken with Ms. Pemberton.

Stephen Busch, P.E.
Lansing and Jackson District Supervisor
Office of Drinking Water and Municipal Assistance
MDEQ
517-643-2314

From: Looney, Carolyn (DEQ)
Sent: Thursday, January 15, 2015 7:59 AM
To: Busch, Stephen (DEQ); Prysby, Mike (DEQ)
Cc: Benzie, Richard (DEQ)
Subject: Voicemail from Ms. Jacklyn Pemberton (sp?), 810-252-3732

Yesterday, I received a voicemail from Ms. Jacklyn Pemberton (sp?), 810-252-3732 regarding the water in Flint. Please give her a call.

Carolyn Looney
Secretary for the Environmental Health Section
Office of Drinking Water and Municipal Assistance
Michigan Department of Environmental Quality
Phone: 517-284-6535
Fax: 517-241-1328
Email: looneyc@mi.gov

Rennaker, Joanne (DEQ)

From: Howard Croft <hcroft@cityofflint.com>
Sent: Thursday, January 15, 2015 4:35 PM
To: Green, Warren
Cc: Jason Lorenz; Prysby, Mike (DEQ); Busch, Stephen (DEQ); djansen@gcdcwws.com; John O'Brien
Subject: Re: Water Forum

All,

We will confirm the time and details on next Wednesday's meeting internally tomorrow morning and I will relay information to everyone.

Thank you,

On Wed, Jan 14, 2015 at 5:04 PM, Howard Croft <hcroft@cityofflint.com> wrote:
 All,

In looking ahead to next weeks forum on water I am planning to host a conference call this Friday morning with the participants to get everyone on the same page and discuss details of how the forum should be structured. We have participation commitments from LAN engineering, Genesee County Drain Commissioners office, and MDEQ but we are leaving the door open for others.

The meeting is scheduled for Wednesday January 21st and we are contemplating what time it should be held. Currently we think 7:00 pm is the best time slot.

Please forward me your best availability for Friday morning, and I will establish the call. We would like to begin informing the public of the time, place, and participants of the forum on Friday afternoon.

Thank you,

--

Howard Croft
 Public Works Director
 City of Flint
 1101 S. Saginaw Street
 Flint, MI 48502
 PH# 810.766.7346 Ext.2043
hcroft@cityofflint.com

--

Howard Croft
 Public Works Director
 City of Flint
 1101 S. Saginaw Street

Flint, MI 48502
PH# 810.766.7346 Ext.2043
hcroft@cityofflint.com

Rennaker, Joanne (DEQ)

From: Howes, Sarah (DEQ)
Sent: Thursday, January 15, 2015 1:47 PM
To: Rennaker, Joanne (DEQ)
Cc: Busch, Stephen (DEQ); Prysby, Mike (DEQ); Shekter Smith, Liane (DEQ)
Subject: RE: Formal correspondence sent to City of Flint in 2014

Thank you, Joanne, for your quick return on this.

I sent this over yesterday.
 It's much appreciated.
 Sarah

Sarah M. Howes | Legislative Liaison
 Department of Environmental Quality
 517.284.6707 O | C 517.282.9204

From: Rennaker, Joanne (DEQ)
Sent: Wednesday, January 14, 2015 10:35 AM
To: Howes, Sarah (DEQ)
Cc: Busch, Stephen (DEQ); Prysby, Mike (DEQ); Shekter Smith, Liane (DEQ)
Subject: Formal correspondence sent to City of Flint in 2014

Dear Ms. Howes,

Per your request to Steve Busch, I have attached scanned copies of the formal correspondence (correspondence sent on letterhead) sent to the City of Flint in 2014.

Please let us know if you require anything else.

Jo Anne Rennaker
 Secretary
 Department of Environmental Quality - Lansing District Office
 Office of Drinking Water & Municipal Assistance
 Office of Waste Management & Radiological Protection
 517-284-6643

Rennaker, Joanne (DEQ)

From: Drullinger, Dave (DEQ)
Sent: Thursday, January 15, 2015 1:03 PM
To: Benzie, Richard (DEQ); Prysby, Mike (DEQ)
Subject: RE: Flint Drinking Water

Thanks Richard. How about if we give out two numbers to callers until Tuesday, Mike's and Steve's, in that order.

These are generally callers just looking for information.

=== Dave

From: Benzie, Richard (DEQ)
Sent: Thursday, January 15, 2015 12:44 PM
To: Prysby, Mike (DEQ)
Cc: Drullinger, Dave (DEQ)
Subject: RE: Flint Drinking Water

Thanks Mike. I would still recommend to OEA that they forward calls to you and let the caller decide whether to leave a message or attempt to reach someone else in the Lansing District.

From: Prysby, Mike (DEQ)
Sent: Thursday, January 15, 2015 12:31 PM
To: Benzie, Richard (DEQ)
Subject: Re: Flint Drinking Water

Richard,

I am out in the field today, flexing tomorrow, and out on Monday...I will respond to emergency calls but not sure if I should be taking Flint calls while out. I plan to participate in tomorrow's conference call from home with the City of Flint, DEQ, Gen Co. Concerning the upcoming public meeting on Jan 21st

Sent from my iPhone

On Jan 15, 2015, at 12:22 PM, "Benzie, Richard (DEQ)" <BENZIER@michigan.gov> wrote:

Mike Prysby first, then Steve Busch, then Adam Rosenthal, all in the Lansing District. Oh, then me or Liane.

From: Drullinger, Dave (DEQ)
Sent: Thursday, January 15, 2015 11:12 AM
To: Benzie, Richard (DEQ)
Subject: Flint Drinking Water

Hi Richard, OEA is getting calls and emails on the Flint drinking water issues. Do you have a contact person on that? Steve Busch?

Thanks.

=== Dave

Rennaker, Joanne (DEQ)

From: Prysby, Mike (DEQ)
Sent: Thursday, January 15, 2015 12:49 PM
To: Fonger, Ronald
Cc: Busch, Stephen (DEQ); Benzle, Richard (DEQ)
Subject: Re: qualifications

Ron,

I am out of the office till next Tues; however, I am taking the opportunity to answer your question concerning qualification (certification requirements) for the Flint WTP. The city of Flint (WTP) is required to designate an Operator In Charge (OIC) holding an F-1 drinking water license. The F designation stands for Complete Treatment and the 1 designation stands for the level (based on pop served, greater than 20,000). Flint meets this requirement. Flint must also have a shift operator available having at least an F-4 license to cover shifts when the OIC is not present. The city employs numerous operators holding F-4, F-3, and F-2 licenses; thus, the city meets MDEQ's operator certification requirements.

Sent from my iPhone

On Jan 15, 2015, at 9:33 AM, "Fonger, Ronald" <RFONGER1@mlive.com> wrote:

Hi Mike:

There's some reader conversation about the qualifications of those who operate the Flint Water Plant. I know there are requirements that some on staff have achieved a certain certification. I've heard city officials talk about that.

What are the certifications required and how many employees have to have achieved it?

Thanks,

Ron Fonger
MLive Media Group
Reporter

mobile 810.347.9963
email rfonger1@mlive.com
address 540 S. Saginaw St. #101, Flint MI 48502