Flint Rash Investigation

A Report on Findings from Case Interviews, Water Testing, and Dermatologic Screenings for Rashes that Developed or Worsened after October 16, 2015

August 2016

Unified Coordination Group—Flint, Michigan

Michigan Department of Health and Human Services
U.S. Department of Health and Human Services
- Centers for Disease Control and Prevention
- Agency for Toxic Substances and Disease Registry
- Office of the Assistant Secretary for Preparedness and Response

U.S. Environmental Protection Agency
Genesee County Health Department
Michigan Department of Environmental Quality

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Background

On April 25, 2014 the City of Flint, Michigan switched its drinking water source from Lake Huron to the Flint River. While the primary focus of public health response to the ensuing Flint Water Crisis has been on the elevated lead levels resulting from the lack of corrosion control, general concerns about overall water quality and whether the water was responsible for skin rashes have been major health concerns of Flint residents.

As part of the federal response to the Flint Water Crisis, the Unified Coordination Group (UCG), a collaboration between local, state and federal health and environmental agencies lead by the US Department of Health and Human Services (HHS), supported an investigation to assess whether Flint water might be associated with the rashes experienced by some community residents.

Dermatitis and rash are general terms referring to inflammation of the top layer of the skin. Skin affected by dermatitis may be red, itchy, scaly and dry. Sometimes fissures or cracks and rarely tiny blisters are present. Dermatitis usually causes some degree of itching, which can be very intense at times and even cause burning and stinging symptoms. Rashes are a common occurrence across the United States. While the incidence of many rashes varies by countries and climates, the prevalence of the most common types of rash, atopic dermatitis is estimated to be up to 20% in school aged children.

Correctly diagnosing rashes is complicated. The cause of most rashes is often multifactorial with many contributing and exacerbating factors, including but not limited to environmental factors (e.g. ambient humidity and temperature), exposure to irritants (e.g. soaps, chemicals) and dryness of skin. Many conditions have a strong seasonal component, with most worsening in the winter (when the heat is turned on and windows are closed) and improving in the summer. Almost all inflammatory skin conditions are exacerbated by stress, both physical (e.g. contact with irritating chemicals) and psychological. Direct contact with water that is hard and/or has high alkalinity, pH and chlorine has been associated in some scientific studies with skin and eye irritation.

The objectives of the rash investigation were to better understand and characterize rash cases; explore possible causes of the rashes and possible associations with the current Flint water supply; and make recommendations for interventions.

Methods

The three investigative efforts undertaken by the UCG included:

1. A questionnaire/telephone survey of Flint residents reporting rashes and water quality concerns.
2. Clinical dermatologic evaluations for residents who agreed to be seen by one of four volunteer dermatologists living in Flint or providing care for Flint-area residents.
3. Current water-quality testing for some survey respondents' homes.

Investigating residence- specific past water quality was not possible as the investigation began after the city returned to using Lake Huron water. To compensate for this, a review of historical water quality data reported by the Flint water treatment plant was also conducted.

Results

Highlights of Questionnaire Results

Residents with rash concerns were identified through a variety of mechanisms, including physician referrals and self-nomination.

- Of the 429 individuals who met case identification criteria, 390 were interviewed (90.9%).
- More respondents reported rash onset dates before October 2015 (56%; n=189 of 339) compared with after October 2015 (44%; n=149 of 339).
- Among those who reported rash onset dates of October 2015 and later, a majority (57%; n=85) reported onsets in January and February of 2016. Over 77% (n=296 of 383) of respondents reported that they noticed changes (e.g., color, odor, taste) in the tap water at the time their symptoms began.
- Nearly 80% (n=296 of 371) of respondents reported changing their showering or bathing habits.

Case Identification

The investigation focused on rash-related concerns associated with current water quality. The case definition was a person with Flint municipal water exposure reporting a current or obviously worsening rash with onset on or after October 16, 2015.

Highlights of Water Testing Results

- Water samples from 170 homes were collected and analyzed for a wide range of water-quality issues, including metals and other parameters (e.g. hardness, pH), but the investigation focused on metals and parameters associated with skin effects. (Note: results from one home were excluded from the analysis due to their reported use of a private well and/or use of water treatment, thus results presented in the report represent 169 homes).
- The water in some homes were found to have higher levels of metals (e.g. iron, aluminum, manganese) that are known to have an adverse effect on the taste and coloration of the water. The higher levels of these and some other metals in the water are likely the result of corrosion of water service lines and/or internal plumbing due to inadequate corrosion control when the Flint River served as the water source.
- The other metals and minerals that were detected in the water can generally be found in any water system that uses surface water as a drinking water source, at levels that are generally similar to levels reported from the City of Detroit system which uses Lake Huron as their source.
- Water samples were analyzed for metals that have been associated in some studies with either allergic or irritant contact dermatitis. Arsenic, total chromium and silver levels were below the lowest levels specified by drinking water regulations for all samples from all homes.
- Less than one percent of the samples exceeded the lowest drinking water regulations for copper and nickel.
- A review of historic system water quality data from the period of time when Flint River water was used as the source (April 2014–October 2015) demonstrated significant variability in water hardness, pH/acidity, and free chlorine levels that could have played a role in skin and other irritant health effects. During that time, pH, chlorine, and water hardness levels were all higher than they were when measured for this study.
- Since a majority of rashes began while residents were using the Flint River water source, the fluctuations in water quality during that time provide one possible explanation for a majority of the eczema-related diagnoses made by the dermatologists. However, because water samples from the

homes of participants are not available for the Flint water source time period, confirmation of this is not possible.

Highlights of Dermatologic Assessments Results

- Clinical dermatological assessments were provided for 122 residents.
- No presumptive or confirmed bacterial or viral infectious etiologies for rash were identified among participants by the dermatologists.
- About 80% (n=97) of participants were classified as having current or resolved skin conditions possibly related to water exposure. (See Appendix D for classification details.)
- Month or year of symptom onset was available for 89% of those clinically screened. Rashes with onset after 2015 were more likely acute, less clinically severe and of limited duration. These rashes were also more likely to be considered unrelated to water by the dermatologists (e.g. seborrheic dermatitis). Respondents with rashes with onset before October 2015 tended to have chronic diagnoses, such as eczema. The majority of respondents with those rashes stated their rash began when the Flint River was being used as the water source.
- A subset of dermatology screening participants also had water quality testing results specific to their residences. Current water quality data for those in the "definitely unrelated to water category" were compared to the "possibly related". Although a few metals were higher in homes of the possibly related skin conditions, no levels were sufficiently high enough to be considered clinically significant.

Conclusions

This investigation documented 390 rash and 175 hair loss complaints, with the majority of participants reporting changes in water quality when symptoms began. The proportion of participants evaluated by dermatologists with clinically severe presentation of rash was higher among those with onset before October 2015. The types of metals and minerals detected in participant's homes can generally be found in any water systems that use surface water as their drinking water source. No specific contaminant or group of contaminants in the water samples collected suggest a primary causal factor associated with rashes. However, during the time when corrosion control was inadequate (before October 2015), and for a period of time afterwards, some metals concentrations may have been higher. However, historic data on such a wide spectrum of metals is not available from either individual homes or the water treatment plant for that time period. Limited historic water sampling data for that period from the Flint water treatment plant suggests very different water quality parameters (e.g., higher levels of chlorine, pH, and water hardness) compared with treatment plant data after October 2015. These factors could have played a role in the development of skin irritation or rashes among some participants.

Access to drinkable and useable water is an important quality of life consideration. Survey results and dermatological histories demonstrated the direct (e.g., rash related symptoms) and indirect (e.g., changes in the use of water for bathing, showering, or drinking) impact.

While we were unable to find a consistent pattern relative to the rashes and current water quality, our findings were limited by the lack of historical data. One plausible hypothesis, however, is that conditions present during the period when water was sourced from the Flint River (e.g. variable pH, hardness, and chlorine levels) could have triggered skin irritation, dryness and rashes for a subset of susceptible individuals. Further, these conditions could have been exacerbated by a variety of factors, including seasonal household

conditions (e.g. the heat being on with windows closed in the winter), self-care practices (e.g. use of some lotions and creams), and fear and anxiety associated with the water crisis overall. Unfortunately, the lack of historical data on either rash patterns in the community or residence- specific water samples from that time period make drawing definitive conclusions impossible.

The findings have several limitations, including lack of residence specific historic water-sampling data; exclusion of rash cases that did not worsen after October 16, 2015; of the 429 individuals that participated in the interview survey and offered a dermatological screening, 122 were seen by dermatologists for confirmatory diagnosis versus self-reported symptoms; and the complex relationship between the interaction of genetic and environmental factors that can cause rashes, irrespective of water concerns. Participation in the investigation was voluntary and is not generalizable to the larger Flint population. A comparison population from a similar sized city that did not experience corrosion of municipal water plumbing infrastructure was not available to establish a baseline of information on occurrence of rash.

Recommendations and Next Steps

Recommendations

Certain types of dermatitis can be difficult to resolve. However, most rashes are readily treatable. Residents who have persistent rashes are urged to seek medical care, either from their primary care provider or from a dermatologist. Fortunately, almost all Flint residents are covered by, or have access to, health insurance. In addition, there are two federally qualified health centers that can provide care to all Flint residents, regardless of background or ability to pay for care. Medicaid eligibility has been expanded, and additional resources have been made available to the federally qualified health centers to ensure that all Flint residents have access to care, including for investigation of rashes. Behavioral health services are also available for residents with symptoms related to stress and anxiety, which, as noted in this report, are quite common.

In light of the results of this investigation, the following recommendations are provided for individuals:

1. If you have a rash or are concerned that you may have a metal allergy, schedule an appointment with your primary care provider for evaluation, treatment, or referral to a specialists such as a dermatologist or allergist.

2. Take care of your skin, particularly if it is sensitive. Follow the tips from local dermatologists: http://www.michigan.gov/documents/flintwateDos_and_Donts_of_Rashes_Dr_Barkey_Final_530621_7.pdf
3. If water in your home is discolored or has an unusual odor, flush water until the discoloration disappears. If you want your water tested, contact the City of Flint or the MDEQ.

4. Flint residents are encouraged to discuss any adaptive strategies with their healthcare providers, , such as changes in showering frequency or source of water, changes in showering products, and general skin care changes.

Next Steps

1. MDHHS will conduct follow up interviews of study participants who received dermatologic screening assessments to determine whether participants received treatments recommended by dermatologists, the status of rash complaints, and the effect of re-exposure to municipal water following resolution of rash.

2. MDHHS will work with the Genesee County Medical Society volunteer dermatologists to provide guidance to primary care physicians on diagnosis and effective management strategies for the types of rashes most commonly diagnosed among study participants. This will build upon general guidance on the role of primary care physicians in the treatment of eczema that was provided by the dermatologists to the primary care physicians of study participants who were diagnosed with eczematous dermatitis. MDHHS and the dermatologists will continue working with the Genesee County Medical Society and expanding outreach to include the Greater Flint Health Coalition and the Genesee County Osteopathic Society.

3. Complete results of this investigation will be posted by MDHHS online at http://www.michigan.gov/flintwater. It will also be posted online by the Agency for Toxic Substances and Disease Registry.

4. MDHHS will continue ongoing surveillance of rash and other related health complaints in Flint by monitoring trends in patient-reported data from Genesee County emergency departments via the Michigan Syndromic Surveillance System (MSSS). Further review of Flint municipal water data from periods before, during, and after the Flint River served as the municipal water source, in comparison to data from MSSS and the Michigan Medicaid program will help provide further insight into potential water quality changes temporally associated with rash.

5. EPA will continue to monitor the status of the Flint Water system.

6. The Department of Health and Human Services, including CDC/ATSDR, will continue to work with the MDHHS to monitor health issues of Flint residents that may be related to the water system.

Section 1: Introduction

Background

On April 25, 2014, the City of Flint switched water sources from the Detroit Water and Sewerage Department (DWSD) to the Flint River. Ultimately, the lack of corrosion control resulted in elevated lead levels in drinking water, and these elevated levels and their health consequences have been the primary focus of the public health response. However, soon after the switch in water sources, Flint-area residents began reporting broader concerns about water quality and skin rashes. Over time, the skin rash concerns became a major concern to the community. The study reported here was conducted in response to those concerns.

Timeline of Events

This short synopsis of events following the water switch outlines key events related to the water system that may be relevant to the community concerns about rashes. As mentioned above, on April 25, 2014, the City of Flint switched water sources from the Detroit Water and Sewerage Department to the Flint River. In August and September of 2014, the City of Flint issued boil-water advisories due to violations of total coliform and *Escherichia coli (E. coli*) levels in the water distribution system. Subsequently, the city increased the chlorine added at the water treatment plant and flushed the water distribution system; however, corrosion controls were not implemented. In December 2014, the city was found to be in violation of a U.S. Environmental Protection Agency (EPA) regulation regarding the disinfection byproduct, total trihalomethanes (TTHM). Blood lead levels (BLL) in Flint were found to be elevated, particularly in children (Hanna-Attisha 2016; CDC 2016), and an analysis of water samples detected elevated lead in the residential tap water (EPA 2016a, State of Michigan 2016).

In an effort to mitigate the corrosion and consequent adverse health effects, the City of Flint returned to buying water from DWSD on October 16, 2015. However, residents continued to report new or worsening rashes as well as hair loss even after the switch back to DWSD water, raising significant concern among Flint residents.

During the time that Flint municipal water was fed by the Flint River, the system experienced substantial variations in water quality parameters (e.g., pH, hardness, alkalinity, and chlorine). There is some evidence from the scientific literature of an association with skin and eye irritation and these parameters (Perkin, 2016; McNally, 1998; Miyake, 2004; Arnedo-Penn, 2007).

Since the transition back to the supply by DWSD on October 16, 2015, the water has continued to be closely monitored and has shown substantial reductions in variability in water quality parameters, and now has a water-quality composition comparable to other municipalities in the State of Michigan.

While the initial public health response was focused on lead, rash and other dermatological conditions such as hair loss have been identified by Flint residents as one of most concerning health problem associated with the Flint water crisis. A recent household survey demonstrated that 51% of households reported feeling that the physical health of at least one member has worsened due to the Flint water crisis. Of those, 23.5%

reported skin rashes or irritation as the health condition (DHHS/CDC, 2016). Flint residents remain distrustful of the water supply, with a majority of residents reporting being fearful of the water supply and feeling that the problems will not be fixed, and the general public continues to report anxiety and mistrust regarding the Flint water situation and its impact on their daily lives. In that same survey, participants reported that they considered bottled water a much safer source for drinking and cooking compared with filtered tap water (DHHS/CDC, 2016).

Introduction to Rash Illness

Dermatitis and rash are general terms referring to inflammation of the top layer of skin. Skin affected by dermatitis may be red, scaly, and dry. Sometimes fissures or cracks and rarely tiny blisters are present. If these features are present for weeks, the skin may become hyper pigmented (darker) and acquire a leathery feel. Dermatitis usually causes some degree of itching, which can be very intense at times and can even cause burning and stinging symptoms. Because rash (or dermatitis) is not a reportable condition in the State of Michigan unless it is a manifestation of a reportable disease, the baseline prevalence of rash in Michigan and in Flint is unknown. Chief complaint data from emergency departments across Michigan show that the 5-year weekly average of rash-related visits is 19.4 and 19.2 visits per 1,000 visits for Flint and the State of Michigan, respectively (MSSS, 2016).

Rashes are common. According to the National Institutes of Health, atopic dermatitis affects up to 30% of people in the United States (NIH, 2013). Correctly diagnosing and classifying rashes is complicated. The etiology of most rashes is often multifactorial with many contributing and exacerbating factors, including but not limited to environmental factors (e.g., ambient humidity and temperature), exposure to irritants (e.g., soaps, chemicals), allergic predisposition, and dryness of skin. Many conditions such as atopic dermatitis, eczematous dermatitis, and even psoriasis have a strong seasonal component, with most worsening in the winter (when the heat is turned on and the windows are closed) and improving in the summer (Dr. Walter Barkey, personal communication, 2016).

While the incidence of many rashes varies by countries and climates, the prevalence of one of the most common types of rash, atopic dermatitis, is estimated to be up to 20% in school aged children. (Nutten, 2015). Atopic dermatitis is among the most common of all chronic childhood diseases (Laughter 2000), and it has been described as having the greatest health-related quality of life impact of all chronic childhood diseases (Mozaffari, 2007). Fourteen percent of children in Michigan are reported to suffer from skin allergies with the highest rates among black non-Hispanic children (Villarroel, 2016). The prevalence of atopic dermatitis and related conditions (e.g., eczematous dermatitis) is high in the adult population as well, and this group makes up a significant percentage of office visits to dermatologists and primary care providers. Recent estimates from the US Center for Health statistics indicates that 13% of adults in Michigan have dermatitis, eczema or any other red, inflamed skin rash (Villarroel, 2016).

Some people have itching in their skin but have no visible rash. Sometimes this is attributed to dry skin, especially if it is worse in winter and improves with use of moisturizers. The etiology of localized intermittent itching with no visible rash is sometimes impossible to determine.

Almost all inflammatory skin conditions are exacerbated by stress, both physical (e.g., contact with irritating chemicals) and psychological. For atopic dermatitis, psychologic stress is associated with both a gradual worsening of existing rash as well as acute flares (Arndt, 2008). These effects are mediated through a combination of biological and psychological stress factors, including changes in immune response and further loss of skin-barrier function beyond that which is a hallmark feature of atopic dermatitis (Arndt, 2008). Strategies to reduce stress and anxiety have been shown to be effective in reducing negative quality of life impacts from atopic dermatitis (Arndt, 2008), and are an important part of effective comprehensive management strategies (Tollefson, 2014).

Genetic and environmental factors have been shown to have a significant role in sensitivity and risk for dermatitis. However, the interplay between genetic and environmental factors in dermatitis is complicated. Atopic dermatitis, for example, has a well-known genetic predisposition, running in families often in conjunction with asthma and hay fever. People with atopic dermatitis also have dry skin that is known to be exacerbated by even minor exposure to irritants (especially soap and hot water). Atopic dermatitis is often worse in the winter and is aggravated by mental, physical, and emotional stress. The rash in atopic dermatitis is driven by itching, and the resultant scratching produces further damage to the skin barrier. This leads to more exacerbation by irritants.

Another very common class of dermatitis is contact dermatitis, which is further divided into allergic contact dermatitis and irritant contact dermatitis. External irritants can cause direct injury to the skin surface through chemical effects or physical and mechanical effects resulting in irritant contact dermatitis. Common causes of irritant contact dermatitis include chemicals (e.g., detergents, solvents, acids or alkaline solutions, or prolonged hand exposure to wet work environments) and physical irritants (e.g., metal tools/instruments, wood, fiberglass, plants such as poison ivy, and soil). Because repeated exposures over time can lead to chronic eczematous dermatitis, a critical element in making the diagnosis of irritant contact dermatitis and distinguishing it from atopic dermatitis, is a history of symptom onset within minutes to hours of exposure, often with more pain or burning than itching (in contrast to atopic dermatitis) (Rietschel, 2004).

Allergic contact dermatitis is the result of a delayed hypersensitivity immune response to external agents that a person is exposed to primarily through direct skin contact. Dermal sensitization involves a delayed allergic response to a substance that is applied to the skin, which results in skin irritation such as redness and swelling. Sensitization is also known to play a role in the onset or worsening of symptoms in some patients with atopic dermatitis. Importantly, multiple exposures to an allergen are typically necessary for sensitization to occur and symptoms of dermatitis to develop. Common allergens that can trigger such a response over time include certain metals (e.g., nickel, cobalt, gold, and chromium), preservatives, cosmetics, fragrances, hair care products, propylene glycol, antibiotic ointments, adhesives, and fabric dyes (Mowad, 2016).

Hair Loss

Hair loss has many possible causes that present in different but often very distinct patterns. Hair loss that results in breakage of hair shafts often has extrinsic causes related to hair care techniques and external exposures. Hair loss that results in loss of hair by the roots or hair loss that results in permanent scarring is much less likely to be related to extrinsic factors and more likely to be related to internal factors (e.g., drugs, thyroid disorders, internal disease like lupus). Too much ingestion of arsenic and thallium have been

reported to result in hair loss; however, lead and other metals have not been associated with hair loss even in people with occupational exposures to high levels of lead and other metals.

Skin Conditions and Tap Water

Everything that comes into contact with skin, including water, can potentially be an irritant under the right conditions, if applied for sufficient time and at a high enough concentration. Various chemical and physical properties of water (e.g., pH, hardness, temperature) and some contaminants have been linked to skin conditions (Tsai, 2013).

Tap water has been previously implicated as a cause of skin disease and irritation. However, studies of the association between tap water quality and skin irritation are generally lacking. A recent review of possible associations between skin irritation and tap water quality in the United Kingdom concluded that a lack of data prevents any definitive conclusions (WRc Group, 2011). In their report, the WRc Group suggested the need for studies evaluating the effect of different tap water parameters (e.g., water hardness, alkalinity, and magnesium and calcium concentrations) on the physical and biological properties of human skin.

Additionally, research by the U.S. Environmental Protection Agency (EPA) on potential links between chloramine (a chlorine based-disinfectant) and dermal, respiratory, and gastrointestinal irritation found no evidence for causal link. EPA did create a Disinfectants and Disinfection Byproducts Rule to reduce exposure to such products (EPA, 2016b) but this rule was not specific to potential for these particular health effects. A study specifically examining the relationship between water hardness and eczema did not support switching to soft water to improve eczema (Thomas, 2011). However, a recent British study found a link between domestic water hardness, chlorine, and atopic dermatitis risk in over 1300 3-month-old infants (Perkin, 2016), consistent with findings from three previous ecological surveys (McNally, 1998; Miyake, 2004; Arnedo-Penn, 2007). CDC/ATSDR has also conducted several rash investigations since 1954, the majority of which were for rashes likely to be infectious in nature. A review of these investigations can be found in Appendix A.

Objectives of this Investigation

In response to continued rash reports from Flint community members and healthcare providers following the switch back to DWSD water, on February 3, 2016, the Michigan Department of Health and Human Services (MDHHS) launched an investigation into rash complaints from residents using the Flint municipal water supply. The objectives of the rash investigation were to:

- better understand and characterize rash cases,
- explore causes of the rashes and possible associations with the current Flint water supply, and
- make recommendations for public health interventions.

On February 25, 2016, MDHHS requested assistance from the Centers for Disease Control/Agency for Toxic Substances and Disease Registries (CDC/ATSDR) to support this investigation. Through the Unified Coordination Group, convened by federal and state government responders, the CDC/ATSDR Assessment of Chemical Exposures (ACE) program and EPA agreed to assist.

The study design is consistent with a case series study, with a focus on case characterization. The investigation did not include a control population without rashes and did not follow participants over time.

The primary questions explored by this investigation are:

- Is the water provided to Flint residents from DWSD as of October 16, 2015 associated with initiating or worsening rashes?
- Is there evidence of rash medical history and historical water sampling (from the Flint Water Treatment Plant) that implicates water from the Flint River in initiating or worsening rashes?

Because the study team did not have access to reliable information about individuals' rashes over time, it relied on patient questionnaires and assessments by dermatologists both to obtain a clinical rash history and to characterize the rashes. The study team also evaluated historical data on water quality during the time water was sourced from the Flint River, and water samples collected from residents of individuals with rash complaints. Retrospective, home-based water samples from residences of individuals with rash-related complaints prior to this investigation were not available. As a result, it was not feasible to conduct a retrospective investigation of skin conditions that existed during the time the water was sourced from the Flint River.

Section 2: Methods

Identification of Individuals with Current and/or Worsening Rashes

Individuals with rashes were identified between January 29 and May 11, 2016, using several methods:

- MDHHS issued three press releases, encouraging affected individuals to call an existing hotline to access local resources. Rash callers were referred to MDHHS.
- MDHHS released health alerts to the medical community in Genesee and surrounding counties, instructing them to refer patients with rashes to MDHHS (i.e., with patient consent).
- MDHHS and CDC/ATSDR personnel accompanying the Michigan Department of Environmental Quality (MDEQ) and EPA staff on visits to homes identified people with rashes and reported their contact information to MDHHS for follow up (i.e., if people agreed to participate in the study).
- The Genesee County Health Department forwarded names and contact information of anyone who called with a rash, with consent from the person calling.

After participants were identified, an MDHHS epidemiologist or CDC/ATSDR team member called the individuals with reported rashes to determine if they met the case definition. Cases were defined as individuals with Flint municipal water exposure reporting a current or obviously worsening rash with onset on or after October 16, 2015. A flow chart of the rash response protocol is provided in Appendix A.

Questionnaire

A questionnaire adapted from a prior assessment conducted by the ATSDR Assessment of Chemical Exposure team related to potential health effects thought to be caused by chloramine-treated tap water in Vermont (Appendix B) was used to assess the characteristics of the rashes and tap water use. At least four attempts were made to contact all individuals meeting the case definition to administer the questionnaire.

Interviews were conducted by phone whenever possible. If an individual requested an in-person interview or required a translator, the interview was performed in person. Parents or legal guardians were interviewed to collect information for children under 18 years of age. With parental permission, one older teenage child was interviewed directly.

All interviewees gave verbal consent before the questionnaire was administered. All participants were instructed that their participation was strictly voluntary and that they could decline to answer any question and could stop the interview at any point.

After the interview was conducted, participants were asked to participate in a free dermatology screening with a local dermatologist. MDHHS or a member of the CDC/ATSDR team helped schedule these appointments. If transportation was needed, the interviewer or MDHHS staff helped make these

arrangements through the Mass Transportation Authority. Participants were also asked if they wanted EPA to test their water.

Survey data were managed in an Epi Info™ 7 v.7.1.5.2 database. Data were proofread to ensure accuracy in data entry. Descriptive statistics were generated from clinical and questionnaire data using Epi Info™ 7 and Excel 2013.

Collection and Analysis of Water Samples

Water samples from 170 homes of individuals who completed the rash questionnaire and agreed to participate in the water quality testing were collected, labeled, preserved, stored and shipped to either the EPA Certified Regional Laboratory (CRL) or a designated contract laboratory for analysis of a range of metals and water-quality parameters. One of these homes were excluded from the analyses due to their reported use of a private well and/or water treatment, thus 169 homes are represented in the analyses). The collection and analysis of the water samples were performed in accordance with the EPA Drinking Water Lead and Water Quality Sampling Quality Assurance Project Plan (QAPP) (www.epa.gov/sites/production/files/2016-06/documents/epa_flint_qapp-revision_2.pdf). EPA sampling of residential tap water was conducted between January and early May 2016, several months after the switch back to the DWSD water supply (i.e., on October 16, 2015). Only the existing (current) source of water (from DWSD) was available for testing in homes of Flint rash investigation participants. Samples collected from residences with a rash complaint during the period that the Flint River served as the municipal water source do not exist. However, limited historical water-quality data (based on sampling at the water treatment plant when water was sourced from the Flint River) were reviewed.

Microbiological quality was not routinely assessed as part of this investigation. Samples for bacterial testing would require more complicated sampling protocols, and there were no indications from the dermatologists' assessments that bacterial or viral infectious causes were a likely cause of any of the rashes. Proper water disinfection levels reduces the risk of growth and spread of these organisms. Thus, residual chlorine levels were measured to ensure the levels were high enough to prevent microbial contamination, but not too high as to cause irritation. When cold water chlorine levels were found to be below 0.05 ppm, a water sample was sent to the Genesee County Health Department Laboratory for analysis of total coliforms and *E. coli*.

Cold water samples were collected at the kitchen sink faucet, a bathroom sink faucet, bathtub faucet, and shower head with one or more hot samples collected from the shower head and/or bath tub. A range of elements and chemical compounds, including those that are known to be skin irritants or associated with hair loss, were measured (Table 4-1).

Pilot Study to Evaluate Organic Compounds

During the course of the investigation, a pilot study was initiated to evaluate the levels of organic compounds that may be present in residential water. The focus of the pilot study of 11 homes was to evaluate the levels of disinfection byproducts and many other organic compounds in cold and hot water samples taken where residents would shower or bathe. See Appendix C for methodology and results of the pilot project.

Contaminant levels from home-based water samples were compared to:

- federal drinking water standards or health advisories,
- levels measured at the Detroit Water Treatment Plant, the current water source for the City of Flint,
- levels detected in other water systems using chlorine for disinfection, and
- health-based screening values from ATSDR and EPA.

Additional analyses were conducted to examine the differences in hot and cold water taken from the shower head. Statistical analysis of the data was performed using SAS® software.

Dermatological Assessment

Four board-certified dermatologists associated with the Genesee County Medical Society volunteered to spend one half day per week screening investigation participants in their individual clinics. Dermatologists were blinded to the water-quality data collected from the homes of study participants. The dermatologists worked together to develop and implement the protocol for the dermatologic assessment. The objectives of the dermatologic assessments were:

- identifying the clinical characteristics of rash and other dermatologic conditions in individuals with rash complaints who were exposed to Flint municipal water,
- assessing the relationship between clinical presentation and exposure history,
- making a clinical diagnosis when appropriate, and
- providing recommendations to primary care providers of study participants regarding management and follow up of those individuals being screened.

After the screening evaluations, a copy of the assessment with any recommendations for rash management was sent to each participant and their primary care physician. The dermatologists obtained written informed consent for the screening evaluations and release of information to primary care providers and MDHHS. CDC/ATSDR team members abstracted clinical information from assessment forms and entered it into a database. All results were coded to protect subject confidentiality. A copy of the assessment form is provided in Appendix D.

Once the dermatologic examinations were completed, the lead dermatologist worked with study investigators to classify all the diagnoses according to the likelihood that they could be related to exposure to Flint water. The goal of the classification was to first divide all diagnoses into those that were “definitely not” water related and those “possibly” related to the water based on known causes of diagnoses made and any temporal relationship with Flint water exposure. Conditions for which there was uncertainty among health care providers as to their cause were categorized as possibly water related. Conditions that were possibly water related were further divided, based on whether they were a dermatitis or not and whether they had resolved or not.

- **Category 1** – conditions and diagnoses that were **definitely unrelated** to the water
- **Category 2** – dermatitis diagnoses that were considered **possibly related** to water exposure
- **Category 3** – non-dermatitis diagnoses that were considered **possibly related** to water exposure
- **Category 4** – resolved or inactive rashes **possibly related** to water exposure

Active rash conditions possibly related to water exposure (i.e. categories 2 and 3) were assessed in terms of clinical severity: mild, mild-moderate and severe based upon physical characteristics (i.e. redness, swelling, skin thickening, excoriations from scratching), distribution (generalized versus localized), relative potency of recommended treatments and reported frequency and intensity of symptoms and their impact on daily living. See Appendix D for a complete list of diagnoses in each category.

Diagnoses were also categorized by whether or not they were eczematous dermatitis or not. This determination included both active (most of Category 2) and resolved or inactive (some of Category 4) diagnoses. Descriptive frequencies of the clinical data were generated using Excel 2013 and Epi Info 7 v. 7.1.5.2.

Data Analysis - Relationship between Water Quality and Rashes

The analysis focused on determining whether there were consistent patterns in the rash history and categorization, and on correlating relevant rash characteristics to the water sampling data. Microsoft Excel and SAS software was used to transfer, clean, and combine datasets containing rash categorization and household water testing measurements. SAS was used as the primary tool to conduct the statistical analyses, and Excel was used as the primary tool for conducting quality assurance of the results and ensuring reproducibility. A detailed description of the statistical analyses used on this data can be found in Appendix E.

Ethics Review

The Michigan Department of Health and Human Services Institutional Board Review (IRB) for the Protection of Human Subjects approved this investigation with non-research determination (MDHHS IRB Log #201602-01-NR).

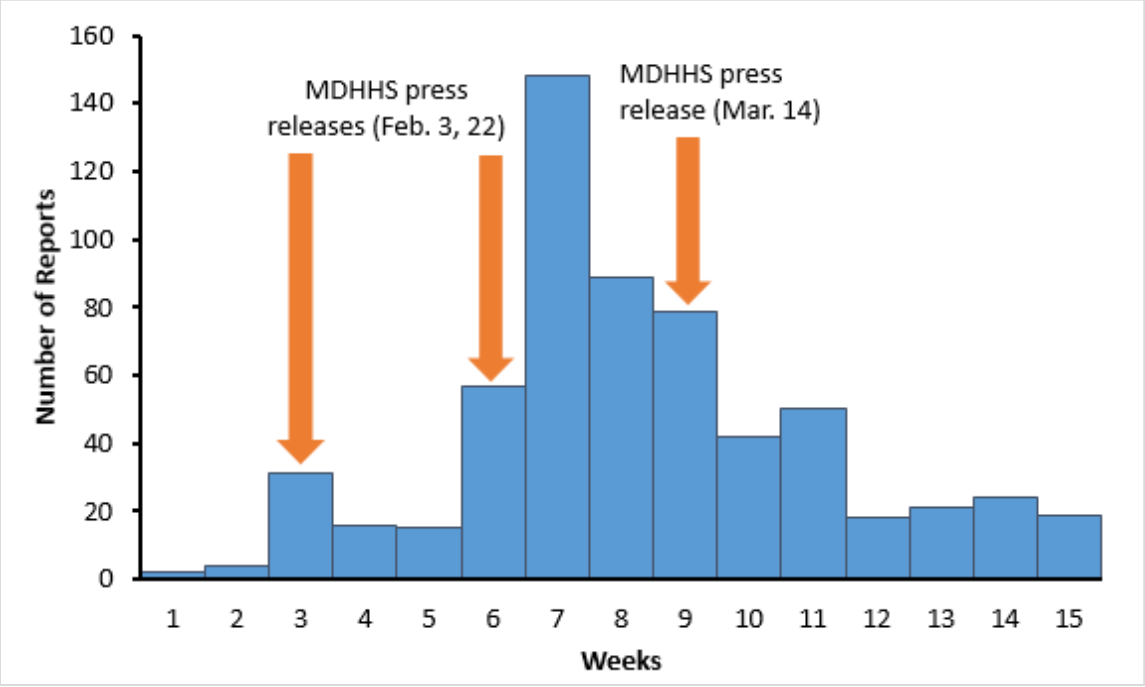
Section 3: Questionnaire Results

A flowchart showing the distribution off individuals involved in each part of the investigation is included in Appendix B. A total of 614 individuals were referred to or contacted MDHHS from January 21, 2016 to April 29, 2016. Referral sources are displayed in Table 3-1. Figure 3-1 shows the distribution of referrals over the 15-week referral period. Of these 614 referrals, 429 (69.9%) met the case definition (new or worsening of pre-existing or chronic rashes after the switch back to DWSD water on October 16, 2015), 104 (16.9%) did not meet the case definition, 78 (12.7%) could not be reached, and 3 (0.5%) elected not to participate in the investigation.

Table 3-1. Source of rash referrals

Referral Source	N	%
Public calls to 211	291	47.4
US EPA home visit/CDC-ATSDR consultation	155	25.2
MDHHS/MDEQ home visit	81	13.2
Doctors' offices	33	5.4
Genesee County Health Department	26	4.2
MDHHS Division of Environmental Health's MITOXIC hotline	22	3.6
Governor's Constituency Services Office	6	1.0
TOTAL	614	100.0

Figure 3-1. Distribution of referrals by week (N=614)



Of the 429 individuals classified as cases, 390 (90.9%) were interviewed, 32 (7.5%) were unable to be reached after four or more follow up calls, and 7 (1.6%) declined further participation. Data from the 390 interviewees comprise this portion of the analysis.

Participants ranged in age from <1 to 93 years. The median age was 51 years, and the mean was 43 years. The majority of the interviewed cases were female (254, 65.1%). Of the 296 adults over the age of 18 with occupational data available, 83 (28.0%) reported working at the time of interview. Two participants under the age of 18 were employed.

The frequencies of reported chronic diseases, skin conditions, and allergies are displayed in Table 3-2. Frequencies of reported metal allergies are displayed in Table 3-3.

Table 3-2. (N=390)
Reported pre-existing medical conditions

Pre-existing Condition	N	%
Chronic diseases	158	40.5
Asthma	75	19.2
Diabetes	54	13.8
Other chronic lung disease	48	12.3
Heart disease	37	9.5
Skin conditions	71	18.2
Eczema	42	10.8
Psoriasis	9	2.3
Other dermatitis	7	1.8
Allergies	110	28.2
Seasonal allergies	70	17.9
Food allergies	36	9.2
Metal allergies	15	3.8
Current smoker	94	24.1

Table 3-3. (N=390)
Reported metal allergies

Metal	n	%
Nickel*	8	2.4
Metal, not specified*	7	1.7
Gold	1	0.3
Copper/brass	1	0.3

*Two reported allergy to nickel and other metals.

Self-Reported Rash Characteristics

The questionnaire asked about the history of each participant's rashes, including date of initial onset and date(s) of any exacerbations. Questions elicited a comprehensive history of participants' rash histories, both current and prior. Of the rashes reported, 149 (38.2%) had onset dates October 2015 and later, 189 (48.5%) had rashes with onset prior to October 15 that worsened after the switch back to DWSD water, and 52 (13.3%) of respondents did not provide an onset. For rashes that had onset dates after October 2015, over

half (57%, n=85) had onsets in January or February 2016. Data specific to rashes that existed before the switch to Flint River water are not available.

Frequencies of rash symptoms are listed in Table 3-4.

At the time of interview, 348 (90.2%) of 386 participants that provided a response to this question reported their rash was still present, 35 (9.1%) said that it had resolved, and 3 (0.8%) did not know if their rash had resolved. In addition, 175 (45.7%) respondents reported hair loss.

The most frequently reported aggravating factors were contact with water/bathing/showering (193), nothing (50), and any contact with the rash (e.g., by clothing, fingers) (30).

Table 3-4. Frequency of current rash symptoms

Description	n	%*
Itchy skin	356	92.0
Raised bumps	266	69.6
Dry or flakey skin	257	69.1
Painful skin	191	50.7
Hives	134	36.0
Other**	239	

*Number of responses varies from 372–387

**Includes redness, burning, bumps, blisters, welts, and irritation

Reported Changes in Water Quality and Use

Over 77% of respondents (296/383) reported changes in their tap water quality at the time their symptoms began. Reported changes included: smelled bad (n=87); had a bleach/chlorine/chemical odor (n=64); and smelled like sewage (n=29), swamp or fish (n=11), or rotten eggs/sulfur (n=10). Other commonly reported changes were in appearance: brown (n=108) or yellow (n=32) color or being cloudy/foggy (n=44). Individuals often reported multiple water quality changes.

When asked if they noticed changes in the water pressure at the time of symptom onset, 152/374 (40.6%) individuals responded that they had. These included 123/152 (80.9%) reporting a decrease in water pressure, 8 (5.3%) reporting an increase in water pressure, and 11 (7.2%) reporting both an increase and a decrease. Several individuals not reporting a change in water pressure noted that the water pressure fluctuated.

Participants were also asked whether they changed the source of water they used for household activities including that used for feeding pets. The results are presented in Table 3-5.

Table 3-5. Report changes in water source for personal care and household activities following onset of rash symptoms (N=390)

Activity	N	%
Drinking water*	350	89.7
Bottled water	311	
Filtered water	9	
Cooking*	299	76.7
Bottled water	246	
Filtered water	20	
Brushing teeth*	250	64.1
Bottled water	216	
Filtered water	11	
Washing dishes	80	20.5
Showering	53	13.6
Other	43	11.0
Pets/animals	14	
Taking a bath	37	9.5
Doing laundry	18	4.6
Using a hot tub	9	2.3

*Alternative water source was collected using an open text field; only the most common sources are shown.

Other survey questions focused specifically on behavior changes relative to bathing habits. Nearly 80% (296/371) of respondents reported changing their bathing or showering

habits. Of these, 223 (75.3%) were showering less frequently, and 209 (70.6%) were taking shorter showers. There were 185 individuals (49.9%) who reported changing their bathing method. These changes included 59/185 (31.9%) bathing with bottled water, 25 (13.5%) showering at a location that does not use Flint municipal water, 20 (10.8%) taking sponge baths, 17 (9.2%) taking showers with cooler water, and 7 (3.8%) using baby wipes.

The primary factors motivating changes in tap-water use included symptoms (184), health concerns (156), and media reports (119). Twenty-two individuals indicated that they changed their tap water use primarily based on a doctor's advice.

Medical Care

Around two-thirds of the interviewees reported seeking medical care for their symptoms. Just over a third of these individuals were aware of receiving a diagnosis, and two-thirds received treatment. Many individuals (222/358, 62.0%) treated their rashes with over the counter products. The most commonly used products listed were lotions (56), hydrocortisone cream (37), other creams (37), diphenhydramine (Benadryl) (33), and oils (26).

Summary of Questionnaire Data

The interview results provide a better understanding of the characteristics of Flint residents who reported (or were reported as having) rash concerns.

- Many individuals were unable to identify when the rashes started or worsened, limiting the ability to draw inferences about the relationship of rash onset and the water switch. However, over half of those who identified a date of symptom onset reported that it was prior to October 2015.
- Most of the respondents were adults (median age 51), and itchy skin was the most common skin-related complaint.
- A majority of study participants reported other non-skin symptoms experienced along with their rash. The most common of these included diarrhea and eye irritation. These collective symptoms were the primary factor leading a majority of study participants to change their routine bathing or showering practices (e.g., decreasing the frequency and/or duration of showers, avoiding Flint municipal water for bathing purposes by using bottled water or using facilities supplied by an alternate source of water).
- Few study participants reported using filtered water for any purpose. Changes in color, odor, and reduced water pressure were among the subjective water quality changes noted by study participants.

It is clear from the interview data that a number of survey participants experienced rashes and other irritant effects thought to be associated with water. The data also demonstrate significant behavioral changes associated with bathing and showering due to health concerns associated with perceived water quality. There was no consistent pattern associated with timing of rashes, however our ability to draw specific conclusions was limited based upon the fact that many participants were unable to identify a specific time when their rashes started or worsened.

Section 4: Water Testing Results

Metals

Table 4-1 presents data on levels of several metals (i.e., arsenic, chromium, copper, nickel, and silver) and water quality indicators (i.e., chlorine, pH, and hardness) that could be reactive with the skin. The table also compares levels of contaminants found in household water with those found at the Detroit Water plant, which is the source of the water before it travels through Flint pipes. The table shows the water composition of the household samples and the Detroit water to be comparable, and provides a comparison to regulatory standards and health based guidance levels for reference. It is noteworthy that the types of metals and minerals detected in the residential water are generally found in any water systems that use surface water as a drinking water source. The results are also generally similar to the analysis reported in the annual water quality reports for finished water from the City of Detroit water system, which uses Lake Huron as its source water and is the current water supplier to the City of Flint (DWSD, 2016).

The levels of metals and minerals are also generally similar to those reported in water for the City of Chicago, a large, older urban municipality that draws source water from Lake Michigan. However, some homes in Flint have higher levels of several metals (cadmium, copper, iron, lead, manganese, and zinc) than water from Detroit or Chicago. The sources of these elevated metals are likely to be related to releases from water service lines, internal plumbing, and fixtures resulting from inadequate corrosion control during the period of the use of the Flint River as a water source (see Appendix C for a detailed description of the statistical analysis of metals data and water quality measurements for the analysis of residential water of individuals who participated in the rash investigation). Comparisons in this report are restricted to the current municipal water supply for Flint residents (i.e., the DWSD/Lake Huron supply). Sampling data for residential tap water during the period of time that the Flint River served as the drinking water source is limited to testing for lead and copper levels and did not include testing at homes for other metals or water-quality indicators.

Of those metals that can be reactive with skin, arsenic, chromium, and silver do not exceed the EPA drinking water standards. The other metals exceed their standard/regulatory guidance levels with a relatively low frequency: copper (0.9%) and nickel (0.1%). Further, although there were higher levels of some metals in the water of some residences, there were not generally high levels across all homes with reported rashes. It is likely that these exceedances are related to specific conditions in individual homes related to the impacts of the previous corrosive condition of the water in pipes and fixtures.

Other Water Characteristics

Other water characteristics known to have potential association with skin irritation or rashes are chlorine, water hardness, and pH. Residual chlorine levels were measured from water in all homes sampled as a part of this investigation. The World Health Organization (WHO) recommends a minimum concentration of 0.2 mg/L, but not to exceed 5.0 mg/L. When residual chlorine levels were below 0.05 mg/L, EPA collected samples for bacterial testing for total coliform and *E.coli*. Only 1 of the coliform tests was positive, which led to a request for the City of Flint to flush the water main to raise the chlorine level in the incoming water. The average chlorine level in homes tested for rash complaints was 0.60 mg/L, with a maximum detection of 2.2

mg/L, indicating that the levels were protective of microbial contamination, but not above levels that would cause irritation. The levels are also similar to those in the Detroit water system found in Table 4-1 (see Appendix C for a summary of the results for the inorganic and water quality indicators).

Water hardness is measured by the amount of calcium carbonate in the water. High water hardness has been known to be associated with skin irritation. While there is a range in hardness, the distribution of water hardness values was generally very close to the average of 100 mg/L of calcium carbonate, which is considered to be moderately hard water. The level is essentially the same as the level of hardness in the finished drinking water in Detroit (average hardness=105 mg/L). With regard to pH, levels ranged from 6.0 to 8.3. Only one home whose water pH was outside the secondary drinking water standard range, and only five readings were above the range found in for Detroit water (see Table 4-1).

Certain metals (see Table 4-1) have been associated with either allergic or irritant dermatitis. All arsenic, total chromium, and silver concentrations were below the lowest drinking water regulations. Small percentages of the copper (0.9%) and nickel (0.1%) concentrations exceeded the lowest drinking water regulations. Not all drinking water regulations are health-based, metals levels were also compared to health-based drinking water levels. Health-based drinking water levels are not typically set based on dermal effects. However, they are expected to be protective of skin exposure as those levels are designed to be protective of the most sensitive health effects. There are no health-based levels based on dermal irritation or allergenic potential. No nickel and silver water concentrations exceeded the health-based drinking water level shown in Table 4.1. Maximum concentrations for arsenic and copper were above the health-based drinking water levels, but the average concentrations were below. A total chromium (trivalent and hexavalent chromium) Maximum Contaminant Level Goal (MCLG) is available and all samples were below that level. The MCLG is the level of a chemical in drinking water below which there is no known or expected risk to health (non-enforceable public health goal).

Table 4-1. Summary of Detection Levels of Elements and Chemical Compounds that have been Associated with Rashes or Other Skin Problems

Contaminant	Concentration (µg/L; except as noted)	Drinking Water Regulations (µg/L)	% Above Regulations/ Comparison Values	Concentration at Detroit Water Plant (µg/L)	Health-based level for drinking water (µg/L)
Arsenic	7.1- max 0.7- average	10 (MCL)[1]	None	Not detected (less than 2)[2]	6 (RSL-child,nc)[3]
Chromium, total	5.2- max 0.4- average	100 (MCL)	None	0.28 (average)[4]	44 (RSL-nc)
Copper	4,800- max 86- average	1,000 (SMCL)[3] 1,300 (Action Level)[4]	0.9%	1.0 (average)[4]	1,300 [5]
Nickel	110- max 4.1- average	100 (HA lifetime)[6]	0.1%	Not detected (less than 10)[2]	390 (RSL-nc)[3]
Silver	10- max 0.2- average	100 (SMCL)[7]	None	Not reported	94 (RSL-nc)[3]
Chlorine	2.2 mg/L (max) 0.6 mg/L (average)	4.0 mg/L (MRDL)[8]	None	0.56 to 0.97 mg/L, (range)[4]	4.0 mg/L (MRDLG[9])
Hardness	115 mg/L (max) 97.8 mg/L (average)	No regulatory limit[10]	None	88 to 130 mg $CaCO_3$/L (range), 106 mg $CaCO_3$/L (average)[4]	No health-based level
pH	6 to 8.32 Average: 7.21	6.5 to 8.5 (SMCL)[5]	1% (below regs)	7.01 to 7.65 (range); 7.37 (average)[4]	No health-based level

Table 4-1 Footnotes

[1] MCL – US EPA Maximum Contaminant Level (the highest level of a chemical that is allowed in drinking water)

[2] Detroit Water and Sewerage Department, water testing results, June 2008

[3] RSL – U.S. EPA Risk-based Screening Level for tapwater exposure – this is a health-based level calculated to make sure people are not exposed to too much of this chemical from drinking water, skin contact, or breathing in the chemical

[4] Detroit Water and Sewerage Department, Water Quality Report, 2015

[5] Action Level for Lead/Copper Rule – US EPA Lead and Copper Rule (the action levels for the 90th percentile of compliance samples is based on technical feasibility of reducing lead and copper in drinking water through optimizing corrosion control)

[6] HA – US EPA health advisory level for drinking water (this is a health-based level set to make sure that people are not exposed to too much of this chemical in their drinking water over a lifetime)

[7] SMCL – US EPA Secondary Maximum Contaminant Level (non-mandatory water quality standards established only as guidelines for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL.)

[8] MRDL – US EPA Maximum Residual Disinfectant Level (the highest level of a disinfectant allowed in drinking water)

[9] MRDLG – US EPA Maximum Residual Disinfectant Level Goal - the level of a drinking water disinfectant below which there is no known or expected risk to health (does not include the consideration of the disinfection benefit of the chemical)

[10] Hardness definition: soft water 0-60 mg/L; moderately hard water 61-120 mg/L; hard water 121-180 mg/L; very hard water > 180 mg/L

Disinfection Byproducts Sub-Study

This study found the disinfection byproduct (DBP) levels are below regulatory limits and below health-based screening levels (results of the organic chemical testing are presented in Appendix C). Hot and cold water samples from six homes where residents also complained of rash were tested. Five homes, where there was a request to EPA for water sampling but where there were no concerns about rashes among the residents, were selected as comparison homes. Water was tested for DBPs, including trihalomethanes (THMs), haloacetic acids (HAAs), and haloacetonitriles; volatile organic compounds; and semi-volatile compounds.

Results for homes where residents reported rashes were compared to the comparison homes, to regulatory values for total THMs and HAAs, and to levels for these compounds that have been reported in the scientific literature. The results indicate that all of the values for the rash homes and the comparison homes are below EPA federal drinking water standards, WHO guidelines, and national statistics for DBPs. In addition, all of the results indicate that the levels of organic chemicals found in the residential water samples are within expected ranges that have been reported for chlorinated water systems.

Acetone was the only other organic compound that was detected. It was found in several homes where residents reported rash (max = 170 µg/L; average = 34 µg/L) and the comparison homes (max = 16 µg/L; average = 8.6 µg/L). The apparent difference in the acetone concentration between the rash and comparison group was the result of one home, where the acetone concentration was elevated for both hot and cold water. However, even the acetone level for that particular home was well below the level of health concern for ingestion of water (ATSDR screening level of 9,000 µg/L) and not likely to have effects on the skin.

Aesthetic Water Quality

In addition to the comparison to the primary drinking water standards and health-based criteria, it is also important to consider the aesthetic characteristics of the water (e.g., taste, odor, coloration, particles). EPA does have secondary, non-enforceable standards that are inclusive of those aesthetic effects. Appendix C shows a summary of the exceedances of regulatory criteria. The aesthetic secondary standards were exceeded for aluminum (44.5%), iron (11.9%), and manganese (4.3%). Residences where those exceedances occurred could have experienced an adverse effect on the taste, odor, and coloration of the water.

Substances that cause changes to water (e.g., color, odor, taste) are not usually harmful to human health; however, these changes are important drivers of decision-making about sources of water to use and suitable uses for water (WHO, 2011).

Historic Conditions: Flint River Water (April 2014–October 2015)

To evaluate changes in water quality at the time of the switch to the Flint River as the water source, reports from the Flint water treatment plant to the MDEQ were reviewed. These data were evaluated given the lack of residence-specific historic water sampling data at the time of the investigation. The available information is limited to a few water quality parameters, and reflects only the measurements taken at the water

treatment plant as water left the treatment plant and entered the distribution system. However, the profile of changes for pH, water hardness, and chlorine levels in the water leaving the plant demonstrates the instability in those parameters throughout the 18-month period (April 2014 to October 2015) in which the Flint River served as source water treated at the Flint water treatment plant and are likely to reflect variability in these levels at resident's homes (see Appendix C). Key examples are provided below:

- **Water Hardness**
  During the year prior to the Flint River switch (January 2013 to March 2014), the water hardness was consistently at 98 mg $CaCO_3$/L. However, during the period of April 2014 to October 2015, when Flint River water was being treated and distributed through the Flint water system, the average water hardness increased significantly to 173 mg $CaCO_3$ /L, with monthly spikes over 250 mg $CaCO_3$ /L. After the switch back to the City of Detroit water source in mid-October 2015, the water quality parameters returned to those measured prior to April 2014. Although there are no federal drinking water standards for water hardness, levels above 180 mg $CaCO_3$ /L are considered to be an indicator of very hard water. Hard water is associated with skin dryness and irritation (McNally, 1998; Miyake, 2004; Perkin, 2016).

- **pH**
  While Flint was using DWSD water (prior to April 2014 and after October 2015), pH level was consistently around 7.3. During the period of using Flint River water (April 2014 to mid-October 2015), pH increased significantly to an average of 7.7, with monthly spikes of pH over 8.5. Alkalinity is associated with skin dryness and irritation (WRc, Group 2011).

- **Chlorine**
  While Flint was using DWSD water (prior to April 2014 and after October 2015), the chlorine level of water leaving the Flint treatment plant had a consistent average free chlorine level of 0.9 mg/L. During the period of using Flint River water (April 2014 to mid-October 2015), the chlorine levels were irregular, with an average level of 2.0 mg/L. For several months during the summer and fall of 2014, the chlorine level exceeded 3.0 mg/L, which may have contributed to elevated levels of disinfection byproducts in the Flint water system observed during that time. Elevated chlorine levels are associated with skin dryness and irritation (Perkin, 2016).

It should be noted that these water quality measurements were taken at the plant as water entered the water distribution system. Measurements are not required to be taken at residences, so we cannot be certain that the measurements at the water distribution system and the conditions at individuals' residences were the same.

Summary of Water Sampling Data

Some exceedances of regulatory levels for some metals—including metals that have been known to be associated with skin irritation as a result of direct contact—were observed in a small number of Flint homes. However, there does not appear to be a general pattern of metals detections in homes where people with

rashes reside that would identify specific causative factors for the rashes. Some of the detected metals and minerals can cause the water to be yellow, brown, or taste metallic, even at low levels.

Other current water quality indicators, such as the level of acidity (as reflected in pH values) and water hardness, are consistently at a moderate level and similar to that for drinking water in Detroit. Therefore, it does not appear that these indicators are likely contributors to skin rashes at the present time.

Levels of organic chemicals found in the residential water samples are within expected ranges that have been reported for chlorinated water systems. A comparison between homes where individuals with complaints of rash resided in the pilot study showed no significant differences in the levels of DBPs in Flint homes where there were no complaints of rashes. It is unlikely that these chemicals contributed to the development of rashes.

However, it is clear from the historical water quality data that during the period of time when the City of Flint used Flint River water as its source, several water quality indicators were very unstable, and differ from Detroit water. Those indicators include significant increases in water hardness, pH, and chlorine, all of which have previously been associated with skin irritation and dryness. The water quality change during that time may have contributed to the onset or worsening of irritant effects among individuals using the water.

Section 5: Dermatologic Assessments

Demographics of the 122 participants who met the case definition and received dermatologic exams are displayed in Table 5-1. A comparison of the demographics of those who participated in the dermatologic screenings to the larger group of those who participated in the case interviews can be found in Appendix D. These groups were similar when compared according to mean and median age, sex, employment status, history of prior skin conditions, history of metal allergies, and reported hair loss. The two groups cannot be compared by race and ethnicity as these data were only gathered during the dermatologic assessments.

Table 5-1. (N=122)
Dermatology patient demographics

	N	%
Age		
<5	9	7.4
5-17	11	9.0
18-64	80	65.6
65+	22	18.0
Sex		
Female	71	58.2
Male	51	41.8
Race		
Black	70	57.4
White	51	41.8
Mixed race	1	0.8
Ethnicity*		
Non-Hispanic	35	97.2
Hispanic	1	2.8

*Only 36 individuals provided ethnicity information.

The demographics of the City of Flint as of the 2010 US Census are provided in Appendix D. Individuals who received dermatologic screening are fairly similar to the larger population of Flint.

Among the 122 patients screened, there were fewer individuals in the 5-17 age range and more in the 65+ age range in the patient population than the City of Flint population. The proportion of patients with black race (57.4%) is similar to the population of the City of Flint. The broad distribution of age allowed for the characterization of skin conditions that may vary in their expression by age. There was a higher proportion of patients with female sex (58.1%) compared with males; however, this does not necessarily reflect any known differences in skin-condition expression by gender. The most common diagnosis was eczematous dermatitis for which there is a female predominance during reproductive years (Osman, 2007); however, the self-selective nature of case ascertainment limits determining whether or not such a variable impacted the gender distribution of the study population.

Clinical categories are listed in Table 5-2. Of the 122 patients, 24 (19.7%) were in Category 1, which was unrelated to water exposure. The remainder were classified as being possibly water related (Categories 2-4), with the majority in Category 2 (dermatitis possibly related to water exposure). Dermatologists were unable to definitively state that any skin condition was causally associated with the water. The specific diagnoses and racial distribution in each category are provided in Appendix D.

Table 5-2. Dermatologist diagnoses classification scheme	
Clinical Category*	% (N)
1) Diagnoses **definitely unrelated** to Flint municipal water exposure	19.8% (24)
2) **Dermatitis possibly related** to water exposure	43.8% (53)
3) **Non-dermatitis skin conditions possibly related** with water exposure	22.3% (27)
4) **Resolved/inactive rash possibly related** with water exposure	14.0% (17)

*One individual had no skin condition based on clinical assessment.

Fifty-four (44.3%) patients were diagnosed with current or inactive eczematous dermatitis. Of 80 diagnosed conditions deemed possibly related to water exposure, 51 (63.8%) were mild, 18 (22.5%) were mild-moderate, and 11 (13.8%) were severe. Prescription medications were recommended for 83/117 (70.9%) patients. More detailed information is provided in Appendix D.

Month or year of symptom onset was available for 89% of clinically-screened participants. There was a higher proportion of participants given a diagnosis definitely unrelated to water in the period after October 2015 compared with before (26.5% and 18.9%, respectively). The overall proportion of participants who were identified as having either active dermatitis or non-dermatitis diagnoses possibly related to Flint municipal water exposure was higher among those with symptom onset preceding October 2015. The proportion of patients with clinically severe presentations was higher among those with onset prior to October 2015 compared with after October 2015 (15.4% and 5.6%, respectively). More detailed information is provided in Appendix D.

Several patients reported histories of symptom onset or worsening within minutes to hours after showering with Flint municipal water, followed by a lack of similar response when they began showering at locations not serviced by Flint municipal water. Respondents reported that any re-exposure to Flint municipal water through showering would elicit similar dermatologic reactions (often generalized itching with or without an erythematous rash with small papules).

Hair loss or alopecia was assessed by the dermatologists. While hair loss was reported by a significant proportion of study participants when interviewed (43.6%), only 14 of 122 (11.5%) reported hair loss during their clinical evaluations. Of these, 9 (7.3% of patients screened) were found to have objective signs of hair loss (e.g., breakage, clear thinning, patches of baldness) on examination. Half of the diagnoses (7 out of 14) made by dermatologists regarding hair loss were deemed to be definitely unrelated to contact with the Flint water. Many of the cases of hair loss which were classified as “possibly related” have no known cause (i.e. central centrifugal cicatricial alopecia-two cases) or are autoimmune in nature (i.e. alopecia areata-two cases). These disorders are not known to be related to any topical or systemic environmental exposure but since participants noted they seemed to improve when Flint water was stopped they were deemed “possibly related”. Two possibly related cases had mild telogen effluvium which is a temporary shedding known to be stress related and one other case was a child with eczema that had prominent scalp involvement.

Summary of Dermatologic Assessments

All four dermatologists observed a high level of general concern about the water from all the participants in the study. However, they concluded that the spectrum and severity of rashes among study participants was similar to that seen in their daily practices for the same time of year.

Findings suggest that diagnoses made after October 2015 were more likely acute and of limited duration, and less likely to be clinically severe, compared with chronic diagnoses, such as eczema, that were more likely to have manifested prior to the transition in water source. This is because:

- A higher proportion of participants were given a diagnosis definitely unrelated to Flint municipal water after October 2015 compared with before.
- The overall proportion of participants identified as having either active dermatitis or non-dermatitis diagnoses possibly related to exposure to Flint municipal water was higher for those with symptom onset before October 2015.
- The proportion of patients with clinically severe presentation (i.e. more significant skin conditions) was higher among those with onset before 2015.

Rash conditions have many etiologies, and while many of the observed rashes are possibly water-related, none of the clinical presentations resulted in a definite linkage to current water as the causative agent. It is important to note, however, that symptomology and residence-specific water-quality parameters when the Flint River water was in use are not available. This limits our ability to draw firm conclusions about the relationship between Flint River water and rashes.

The timing of symptom onset or worsening within minutes to hours of showering reported by patients versus the lack of similar response of showering in locations away from Flint is suggestive of a relationship between showering and the reported skin conditions. This close temporal relationship was identified among participants with rash onsets both before and after the transition back to water from DWSD. However, the intermittent nature of patients' symptoms made clinical assessment challenging, as there was often a lack of physical findings when patients were examined by dermatologists. Importantly, no presumptive or confirmed bacterial or viral infectious etiologies for rash were identified among the 122 patients screened.

Almost half of the diagnoses were some form of eczematous dermatitis. It should be noted that while the underlying causes of skin irritation may differ, the resulting rashes may look quite similar. Rash occurrences coincide with the cold and dry air during winter known to cause or exacerbate eczematous dermatitis in some individuals. Some individuals in the investigation reported changing their behavior in a manner that could make the rashes worse. Cessation of bathing altogether may contribute to some skin conditions, such as seborrheic dermatitis and folliculitis. Others reported applying rubbing alcohol or using or alcohol-based hand sanitizer directly on rashes, which can lead to further loss of moisture from the skin and increase the risk of skin irritation and itching.

These results are not generalizable to the population of Flint because most study participants were self-selected. Further, even though over half of participants who were interviewed were scheduled for evaluations, 38.9% of those scheduled did not present for their appointment, introducing an additional element of self-selection. Thus the results should be interpreted with caution and in keeping with study objectives.

Additional clinical follow up would help provide important information regarding the impact of treatment recommendations provided to patients' primary care providers. Additional information about resuming use of Flint municipal water for showering and bathing without further development of rash and other skin conditions would allow for a more complete understanding of the role of water and adequacy of clinical treatments. However, it should be acknowledged that decision-making regarding when and with what frequency to resume use of Flint municipal water is complex and involves individual assessments of water quality (including taste, odor, and color). Equally important will be the community's confidence in those charged with ensuring a high level of water quality in public water systems, as well as their own history of health.

Section 6: Relationship between Water Quality and Rashes

Both water sampling data and clinical assessments were available for 84 individuals. Because this investigation did not include a comparison group of unaffected individuals, we compared water for households in which residents' rashes were categorized as "possibly water-related" (categories 2-4) to that for residents whose rashes were deemed "unrelated to water" (category 1).

Descriptive statistics of metal and water quality levels for those parameters predetermined to be possibly related to rash conditions by clinical category and for hot and cold water are presented in Appendix C. Statistical analyses suggest that the overall water quality is similar across all rash categories. See Appendix E for a summary of statistical comparisons across groups.

The metals and other water characteristics that were chosen for this component of the analysis were those for which evidence exists in the scientific literature of an association with adverse skin effects: arsenic, chromium, copper, water hardness, nickel, silver, thallium, zinc, pH, and chlorine (WRc, 2011). The selection is based on evidence of either direct irritation (e.g., hardness, copper, arsenic, chlorine, pH), sensitization (e.g., nickel, chromium), or dermal effects resulting from ingestion (e.g., arsenic, thallium).
None of the levels of these metals were considered by participating dermatologists to be sufficiently high enough to be clinically significant or to cause rashes. For example, in the cold water samples, nickel levels were about 3 times higher in the 'possibly water-related' rash categories compared to the 'definitely not water-related' categories. However, levels in either case are well below the levels thought to elicit skin sensitization and reaction. In addition, it should be noted that hot water sampling did not indicate a difference between nickel levels across rash categories.

Nickel was included in the investigation because of its known sensitivity for some people. A large study of approximately 75,000 individuals found that 15.5% developed contact dermatitis in response to a patch test with nickel sulfate (5% in petroleum) (Uter, 2003). Studies of individuals that are known to be sensitive to nickel respond to much lower concentrations (0.03-0.1%), but no effect is reported at 0.01% (reviewed in ATSDR, 2006). Even the highest level of nickel found in current Flint municipal water is well below those found to induce dermatitis and 99.8% of samples were also below regulatory drinking water limits.

Other metals noted have a statistically significant elevation in the possibly water-related categories, including iron in hot and cold water samples, compared with water samples taken from homes of those with definitely not water-related rashes. While iron is not known to produce rashes or exacerbate skin conditions, it is associated with water discoloration, which was commonly reported in the questionnaire response.

Current water quality parameters such as hardness and chlorine were all at similar levels across the rash categories and as previously indicated are in within expected ranges.

As mentioned, data on symptomology and water-quality parameters at important intervals (i.e., pre water-switch period, water switch period, and post water-switch period) are not available, nor do we have water

quality data in from homes without rash complaints, limiting our ability to definitively associate water and rashes.

Analysis of Water Quality and Rash Evaluation Conclusions

We were not able to identify any current water quality parameters that might be causing or exacerbating rashes based on differences in current water quality and rash categories. These findings are consistent with the general assessment of water quality discussed previously (in Section 4, Summary of Water Sampling) that concluded there was no pattern of water contaminants or in exceedances of water-quality parameters that characterized the homes sampled for this investigation.

The lack of a common implicating exposure should be interpreted with caution, given the limitations of these data and the fact that samples were all taken at a single time from each household. Water quality and concentration of metals are subject to variability over time. It is possible a substance was present in the water at the time the participant's rash began but was no longer in the water at the time of testing. It is also possible that components of water quality before the switch from the Flint River back to the DWSD could account for some of the rashes seen in Flint residents. Unfortunately, residence-specific data on water composition and quality related to the actual timing of rash/skin irritation are not available, thus conclusions also take into account a review of historic water-quality parameters. As previously indicated, the literature on the relationship between water quality and skin conditions is limited. Although unlikely, it is possible that an unknown and unmeasured water-quality parameter or combination of parameters may be present that are or were affecting skin conditions in Flint. It is also possible that conditions during the time that the Flint River was used as the water source contributed to skin conditions. It is not possible, based on the information collected in this investigation, to assess the interaction between water quality and community stress on skin conditions.

Section 7: Discussion, Recommendations and Next Steps

This report summarizes and presents findings of the investigation of rash and hair loss complaints possibly associated with the Flint municipal water supply, whose source is currently Lake Huron. The investigation sought to evaluate a wide variety of contaminants (including those identified as the most likely to be linked with skin irritation or rashes) from residential samples collected from the most common sites of water usage and at different temperatures. No presumptive or confirmed bacterial or viral infectious etiologies for rash were identified among the 122 patients screened. It was not possible to provide an analysis of rashes in relation to water quality during the time that the Flint municipal water supply was sourced from the Flint River due to the lack of residence-specific water sampling data.

Although it is not something objective that can be easily quantified, one of the most significant observations in this entire investigation has been the general level of anxiety and actual fear that virtually all participants had about the safety of the water they were getting out of their tap. The questionnaire documented that a very high percentage of people changed their bathing/showering habits because of these concerns. This concern was heightened by the fact that people were previously told that their water was safe at a time when it smelled and looked abnormal and that they were receiving mixed messages from outside groups and various municipal authorities. For example boil-water advisories were issued, but municipal authorities also told people that boiling water did not eliminate lead. Although not part of the official dermatology assessment, all four participating dermatologists were quite struck by the level of anxiety and mistrust of participants, the majority of whom had completely stopped using the water to bathe and/or shower because of concern about the possible association of water exposure and their skin condition.

There was no specific contaminant, nor group of contaminants, in current water samples taken that suggest a primary causal factor associated with the occurrence of reported skin conditions or hair loss. Evaluating skin impacts related to exposure to metals in water is challenging because of limited information about the actual dermal dose associated with skin effects. Even with metals such as nickel and chromium, exposures reported in the literature as causing skin reactions are not directly comparable to exposures as a result of bathing, showering, and handwashing.

It is important to note, however, that during the period of time when the municipal water was sourced from the Flint River and when corrosion control was inadequate, and for a period of time following that, some levels of metals were likely higher. In addition, differences in other water-quality parameters such as hardness, chlorine and pH, supported by a review of historic data from the Flint water treatment plant, indicate that water quality parameters known to be associated with some skin conditions (hardness, pH and chlorine levels) were elevated. This is particularly relevant since a majority of the rashes reported in this study began prior to the switch back the Detroit water system.

Findings suggest that diagnoses made after October 2015 were more likely acute and of limited duration, and less likely to be clinically severe, compared with chronic diagnoses such as eczema, that were more likely to have manifested prior to the transition in water source.

In sum, while we were unable to find a consistent pattern relative to the rashes and current water quality, our findings were limited by the lack of historical data. Given the data on water quality during the time that water was sourced from the Flint River, one plausible hypothesis is that conditions present during that time could have triggered skin irritation, dryness and rashes, notably in susceptible individuals. Further, these conditions could have been exacerbated by a variety of factors, including seasonal household conditions (e.g. the heat being on with windows closed in the winter), self-care practices (e.g. use of some lotions and creams), and fear and anxiety associated with the water crisis overall. Unfortunately, the lack of historical data on either rash patterns in the community or residence specific water samples from that time period make drawing more definitive conclusions impossible.

Limitations

This investigation has several limitations:

1. The water samples for this rash investigation were collected from January 29 through early May 2016. The results of the water testing only reflect the conditions of the water in sampled homes at that time. Therefore, the actual water conditions corresponding to the time when rashes or hair loss began or became worse cannot be known.

2. There were no home-based water samples from residences with rash-related complaints prior to this investigation. As a result, it was not feasible to conduct a retrospective investigation of skin conditions that existed during the time the water was sourced from the Flint River.

3. Most rashes were self-reported. Only 25 participants were referred through a doctor's office. Thus, the study relied on a convenience sample, rather than a sample representative of the entire population of Flint. Therefore, results from this investigation are not generalizable to the entire population in Flint.

4. Not all participants agreed to a dermatology appointment, which limited confirmatory diagnoses. In addition, nearly 40% of participants were unable to keep scheduled appointments, which limited comparison data. Further selection bias might have been introduced as a result of this high proportion of scheduled appointments unable to be met.

5. About 13% of respondents could not provide any onset time period of rash/irritant symptoms and the majority of onset times provided were not specific.

6. The etiology of rashes, in general, involves the interaction of multiple factors, including host factors, genetic factors, and environmental factors that vary from person to person and between households. We were unable to assess the independent contribution of such factors to rashes.

7. Participation in the investigation was voluntary and is not generalizable to the larger Flint population. A comparison population from a similar sized city that did not experience corrosion of municipal water plumbing infrastructure was not available to establish a baseline of information on occurrence of rash.

Recommendations

Certain types of dermatitis can be difficult to resolve. However, most rashes are readily treatable. Residents who have persistent rashes are urged to seek medical care, either from their primary care provider or from a dermatologist. Fortunately, almost all Flint residents are covered by, or have access to, health insurance. In addition, there are two federally qualified health centers that can provide care to all Flint residents, regardless of background or ability to pay for care. Medicaid eligibility has been expanded, and additional resources have been made available to the federally qualified health centers to ensure that all Flint residents have access to care, including for investigation of rashes. Behavioral health services are also available for residents with symptoms related to stress and anxiety, which, as noted in this report, are quite common.

In light of the results of this investigation, the following recommendations are provided for individuals:

1. If you have a rash or are concerned that you may have a metal allergy, schedule an appointment with your primary care provider for evaluation, treatment, or referral to a specialists such as a dermatologist or allergist.

2. Take care of your skin, particularly if it is sensitive. Follow the tips from local dermatologists: http://www.michigan.gov/documents/flintwater/Dos_and_Donts_of_Rashes_Dr_Barkey_Final_530621_7.pdf

3. If water in your home is discolored or has an unusual odor, flush water until the discoloration disappears. If you want your water tested, contact the City of Flint or the MDEQ.

4. Flint residents are encouraged to discuss any adaptive strategies with their healthcare providers, , such as changes in showering frequency or source of water, changes in showering products, and general skin care changes.

Next Steps

1. MDHHS will conduct follow up interviews of study participants who received dermatologic screening assessments to determine whether participants received treatments recommended by dermatologists, the status of rash complaints, and the effect of re-exposure to municipal water following resolution of rash.

2. MDHHS will work with the Genesee County Medical Society volunteer dermatologists to provide guidance to primary care physicians on diagnosis and effective management strategies for the types of rashes most commonly diagnosed among study participants. This will build upon general guidance on the role of primary care physicians in the treatment of eczema that was provided by the dermatologists to the primary care physicians of study participants who were diagnosed with eczematous dermatitis. MDHHS and the dermatologists will continue working with the Genesee County Medical Society and

expanding outreach to include the Greater Flint Health Coalition and the Genesee County Osteopathic Society.

3. Complete results of this investigation will be posted by MDHHS online at http://www.michigan.gov/flintwater. It will also be posted online by the Agency for Toxic Substances and Disease Registry.

4. MDHHS will continue ongoing surveillance of rash and other related health complaints in Flint by monitoring trends in patient-reported data from Genesee County emergency departments via the Michigan Syndromic Surveillance System (MSSS). Further review of Flint municipal water data from periods before, during, and after the Flint River served as the municipal water source, in comparison to data from MSSS and the Michigan Medicaid program will help provide further insight into potential water quality changes temporally associated with rash.

5. EPA will continue to monitor the status of the Flint Water system.

6. The Department of Health and Human Services, including CDC/ATSDR, will continue to work with the MDHHS to monitor health issues of Flint residents that may be related to the water system.

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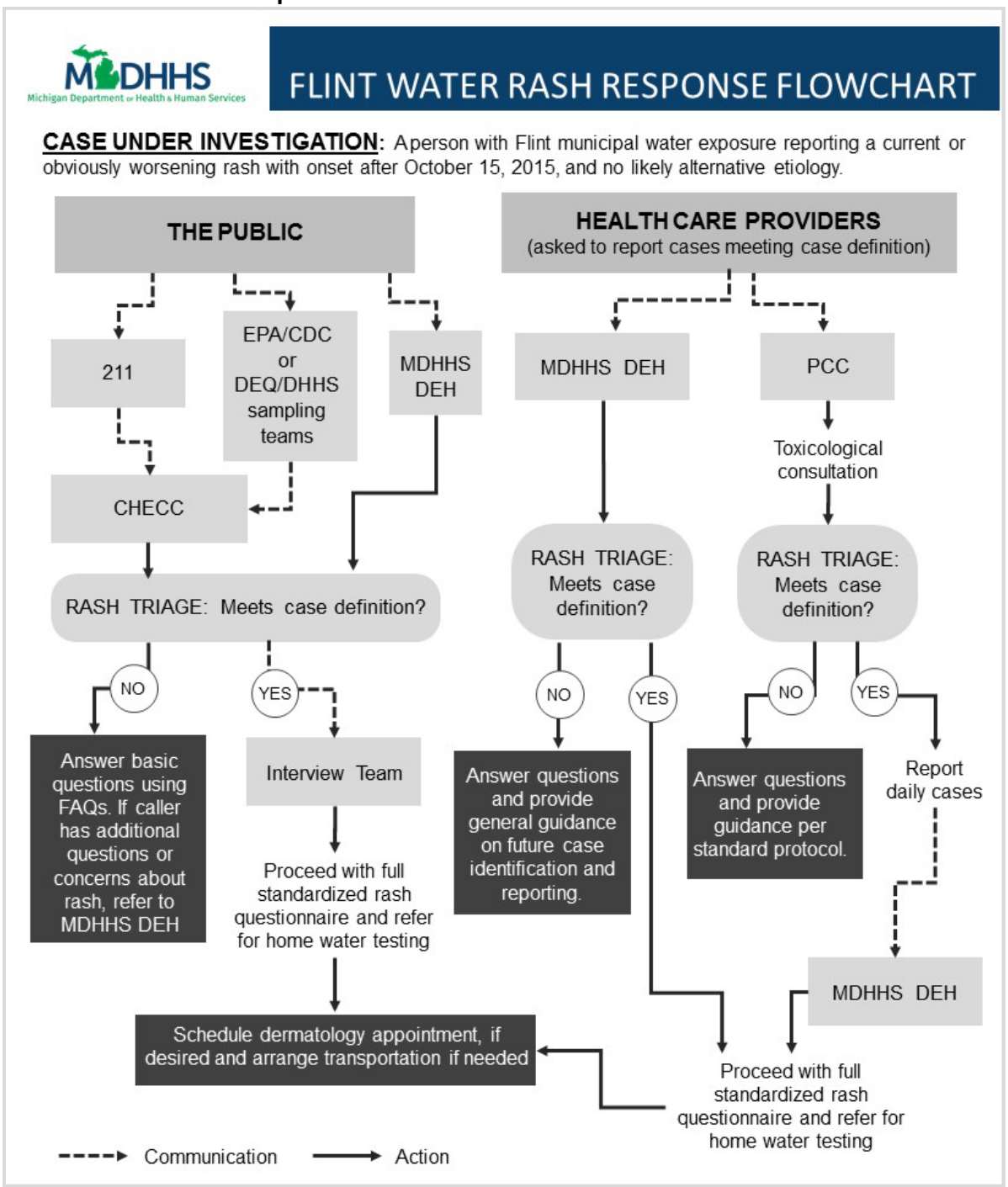
Appendices

Appendix A

A1. Flint Water Rash Response Flowchart



EPA: United States Environmental Protection Agency; **CDC**: Centers for Disease Control and Prevention; **DEQ**: Michigan Department of Environmental Quality; **DHHS**: Michigan Department of Health and Human Services; **MDHHS DEH**: MDHHS, Division of Environmental Health; **CHECC**: MDHHS Community Health Emergency Coordination Center; **PCC**: Poison Control Centers.

A2. Review of Prior CDC/ATSDR Rash-Related Investigations

The Centers for Disease Control and Prevention (CDC) and the Agency for Toxic Substances and Disease Registry (ATSDR) have conducted 11 outbreak investigations of illnesses with accompanying rashes since 1954. Five of the investigations contained only initial reports with minimal, preliminary information. An additional five contained preliminary or final reports detailing investigation methods and results. The remaining report was essentially a series of case studies.

The smallest investigation, in Fort Wayne, Indiana, had only 14 cases; the largest, in the Federated States of Micronesia, had 500 cases. Six of the outbreaks were associated with schools or schoolchildren, four were community-wide, and one was occupational. The majority of the rash outbreaks were likely infectious in nature, including three outbreaks with evidence for transmission of an unknown virus, two outbreaks of rubella, and two outbreaks of unknown but suspected infectious agents. Three outbreaks had insect etiologies: one caused by mites, one likely caused by mites, and one in which the rash illness followed a tick bite. Only the outbreak of hives had an unidentified environmental cause; it was associated with a wing of a school building where classrooms had both been flooded and covered in roof dust from construction.

One of the investigations used self-report to obtain cases, and five relied on clinicians identifying affected individuals. Another method of case identification was a community-wide survey using census data and a random sampling method.

The majority of the investigations involved questionnaires administered to cases. Two investigations involved clinical examination of cases, and the third investigation used a dermatologist examination to collect clinical data. One outbreak investigation comprised several case studies in a narrative format. Environmental and site investigations were carried out for three of the outbreak investigations. In two of those cases, entomologists examined plant matter from the worksite (the occupational outbreak) and randomly sampled homes (a community-wide outbreak) for evidence of mites. In the third, the wing of the school building with the highest attack rate of rash cases was tested for chemicals that could cause hives. Laboratory work on clinical specimens was performed for three of the outbreaks, two of which turned out to be rubella. The third showed evidence of viral infection, but no agent was identified. Five of the outbreak reports reviewed were only summaries that did not mention environmental or laboratory work.

CDC/ATSDR has also performed an investigation of health effects thought to be caused by increased chloramines in tap water. This community-wide investigation involved a questionnaire to identify symptoms and an inspection of home water-treatment systems. Findings of the investigation did not indicate a link between the changes in water treatment and symptoms.

Form Approved
OMB No. 0923-0051
Exp. Date
03/31/2018

Appendix B

B1. Standardized Questionnaire

Self-reported Rash Symptoms and Exposure to Flint Water
MDHHS Questionnaire

Note to the interviewer: script in italics is clarification for you, and is not to be read aloud to the interviewee. Please do not prompt answers (e.g. read out options "Yes", "No", Don't Know", "Refused") unless noted to.

INTRODUCTION SCRIPTS

For people referred through 211/CHECC and home visits:

Hello, my name is _____, and I work for the [Michigan Department of Health and Human Services/Agency for Toxic Substances and Disease Registry/Centers for Disease Control and Prevention]. We are working with the [Michigan Department of Health and Human Services/Agency for Toxic Substances and Disease Registry/Centers for Disease Control and Prevention] looking into reported rash symptoms related to exposure to Flint tap water. We received your name because you have reported rash symptoms [to the 211 phone number OR to an MDHHS or CDC representative who visited your home recently]. We would like to ask you some questions about your health, the health of your family, and your tap water usage. Your answers will help us understand what symptoms have been reported since the City of Flint switched its water source. The questions will take about 20 minutes. May we go ahead now with the questionnaire?

For people referred through healthcare providers:

Hello, my name is _____, and I work for the [Michigan Department of Health and Human Services/Agency for Toxic Substances and Disease Registry/Centers for Disease Control and Prevention]. We are working with the [Michigan Department of Health and Human Services/Agency for Toxic Substances and Disease Registry/Centers for Disease Control and Prevention] looking into reported rash symptoms related to exposure to Flint tap water. We received your name because you visited a healthcare provider to report rash symptoms and they forwarded your information to us. We would like to ask you some questions about your health, the health of your family, and your tap water usage. Your answers will help us understand what symptoms have been reported since the City of Flint switched its water source. The questions will take about 20 minutes. May we go ahead now with the questionnaire?

If yes, participation in this questionnaire is voluntary: if you feel uncomfortable answering any question, you do not have to answer and you may stop the interview at any time. However, any information you can provide will help us immensely.

IF NO, is there a convenient time when I can call you back?

Day: _____ Time: _____ AM / PM
Telephone: _____
CASE No: _____
Date: _____

Time interview began: _ _: _ _ AM / PM

Interviewers Initials: _____

BACKGROUND

1. First, I would like to ask if you contacted someone to report that you or someone you know had symptoms. Did you contact any person or organization to report these symptoms?

☐ No
☐ Yes
☐ Don't know
☐ Refused

1a. Can you please tell me who you contacted? (check all that apply)

☐ 211
☐ Genesee County Health Department
☐ Health care professional
☐ Emergency room
☐ Don't know
☐ Refused
☐ Other, please explain _____

1b. What prompted you to contact MDHHS or seek medical care?

_____

_____

1c. Are you calling for yourself or for someone else?

☐ Self
☐ Someone else

1d1. *If they are calling for someone else:* What is their name and relationship to you?

1d1a. Name: _____

1d1b. Relationship: _____

1d2. Could I please interview that person / May we continue with the interview?
(If child, ask parent if you can continue on with interview)

☐ Yes, interviewed other person
☐ Yes, interviewed parent or individual on phone who made contact for other person
Contact information: _____

☐ No, other person not available
☐ No, refused to be interviewed

2. First, I have a few questions about you (or your child/friend, if interviewing for another person).

2a. How old are you? _____

2b. What is your sex?

☐ Male
☐ Female

2c. Do you currently work?

☐ No
☐ Yes
☐ Refused
☐ Don't know

2c1. *IF YES*, can you please explain what you do? _____

HISTORY OF ILLNESS

3. As I mentioned before, we received your name because you reported symptoms. I am going to ask you about these symptoms.

3a. Did you experience a rash?

☐ No
☐ Yes
☐ Don't know
☐ Refused

IF YES, on what parts of your body did the rash occur?

☐ Face ☐ Arms ☐ Feet
☐ Neck ☐ Hands ☐ Other
☐ Torso ☐ Legs Explain: _____

IF YES, how big was the rash? (at widest)

☐ 0-3 inches
☐ 3-5 inches
☐ > 5 inches
☐ Don't know
☐ Refused

3a1. When did your rash start? Date: _____

3a1a. Have your symptoms improved, gotten worse, or stayed the same since October 16, 2015?

(Note: On October 16, 2015, City of Flint switched back to buying water from Detroit)

☐ Improved
☐ Gotten worse
☐ Stayed the same
☐ Refused
☐ Don't know

3a2. Do you still have a rash?

☐ No
☐ Yes
☐ Don't know
☐ Refused

Can you please describe your rash for me?

3a3. Hives (raised patches)?

☐ No
☐ Yes
☐ Don't know
☐ Refused

3a4. Raised bumps?

☐ No
☐ Yes
☐ Don't know
☐ Refused

3a5. Dry or flakey skin?

☐ No
☐ Yes
☐ Don't know
☐ Refused

3a6. Itchy skin?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

3a7. Painful skin?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

3a8. Other?
_____
_____
_____
_____

3a9. What activities cause the rash to occur?
- ☐ Washing dishes
- ☐ Doing laundry
- ☐ Cooking
- ☐ Showering
- ☐ Taking a bath
- ☐ Using a hot tub
- ☐ Drinking water
- ☐ Other, please explain _____

3a10. Once the rash appears, how long does it take to go away? _____
- ☐ Hours
- ☐ Days
- ☐ Has not gone away
- ☐ Don't know
- ☐ Refused

3a11. What makes the rash feel better? _____

3a12. What makes the rash feel worse? _____

3a13. Were you taking any new medicines when the rash started?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

IF YES, what kind? _____

Did you experience any other symptoms with the rash? Such as…

3b. Numbness or tingling?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

IF YES, Where did the numbness or tingling occur?
- ☐ Face
- ☐ Neck
- ☐ Torso
- ☐ Arms
- ☐ Hands
- ☐ Legs
- ☐ Feet
- ☐ Other

Explain_____

3c. Fever?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

IF YES, how high?

Time Course

When did your fever begin?

When did your fever end?

3d. Shortness of Breath?
- ☐ No
- ☐ Yes
- ☐ Don't know
- ☐ Refused

When did your s.o.b. begin?

When did your s.o.b. end?

3e. Wheezing?

☐ No
☐ Yes
☐ Don't know
☐ Refused

When did your wheezing begin?

When did your wheezing end?

3f. Diarrhea?

☐ No
☐ Yes
☐ Don't know
☐ Refused

When did your diarrhea begin?

When did your diarrhea end?

3g. Eye Irritation?

☐ No
☐ Yes
☐ Don't know
☐ Refused

When did the irritation begin?

When did the irritation end?

3h. Hair Loss?

☐ No
☐ Yes
☐ Don't know
☐ Refused

Please describe:

Quantity (e.g. strands, chunks)

Location on scalp (e.g. patchy, right side, etc.)

3i. Anything Else?

☐ No
☐ Yes
☐ Don't know
☐ Refused

Please describe:

Time Course

When did this symptom begin?

When did this symptom end?

Now I would like to ask you a few questions about your tap water use.

4. Is your home on municipal water, that is, do you get your water from the City of Flint?

☐ No
☐ Yes
☐ Refused
☐ Don't know

4a. *IF NO*, can you tell me the source of your tap water? _____

5. Do or did you have contact with Flint Water outside of your home?

☐ No
☐ Yes
☐ Refused
☐ Don't know

5a. *IF YES*, can you please explain where? _____

5b. *IF YES*, when did you start using Flint water at this location? _____

5c. *IF YES*, when did you stop using Flint water at this location? _____

5d. Have your symptoms improved or gone away since you changed your water use at this location?

- ☐ Improved
- ☐ Gotten worse
- ☐ Stayed the same
- ☐ Have not changed water use
- ☐ Refused
- ☐ Don't know

6. When your symptoms started, did you notice changes in your tap water quality (appearance, taste, smell) at home?

- ☐ No
- ☐ Yes
- ☐ Refused
- ☐ Don't know

6a. *IF YES*, can you please describe the change in water quality? _____

7. When your symptoms started, did you notice changes in your water pressure at home?

- ☐ No
- ☐ Yes
- ☐ Refused
- ☐ Don't know

7a. *IF YES*, did the water pressure: ☐ Increase? ☐ Decreased

8. Are you using a water filter for your water at home?

- ☐ No
- ☐ Yes
- ☐ Refused
- ☐ Don't know

8a. What type of filter are you using at home?

- ☐ Brita
- ☐ PUR
- ☐ Other_____

8b. When did you start using the filter? Date: _____

8c. How are you using your filter? _____

9. Are you using a different water source than normal for the following activities?

☐ Washing dishes
☐ Doing laundry
☐ Cooking, explain _____
☐ Showering
☐ Taking a bath
☐ Using a hot tub
☐ Drinking water, explain _____
☐ Brushing teeth, explain _____
☐ Other, please explain _____
☐ Refused
☐ Don't know

10. Have you changed your behavior or habits for bathing and/or showering?

☐ No
☐ Yes
☐ Refused
☐ Don't know

IF YES, can you please explain how your bathing habits have changed in the following ways:

10a. Frequency
☐ Shower less frequently
☐ Shower more frequently
☐ Don't know
☐ Refused

10b. Length
☐ Shorter showers
☐ Longer showers
☐ Don't know
☐ Refused

10c. Method
Please explain: *(e.g. use of wipes, sponges)*
_____
_____

11. Do you add anything to your water before using it?

☐ No
☐ Yes
☐ Refused
☐ Don't know

11a. *IF YES*, please explain what you add *(optional:* and the amount you use): _____
Ask about amount if it makes sense based on what they are adding

12. Have you changed your tap water use in any other way? _____

13. When did you start making these changes to your tap water use? Date_____

14. Have your symptoms improved, gotten worse, or stayed the same since you changed your water use?

☐ Improved
☐ Gotten worse
☐ Stayed the same
☐ Refused
☐ Don't know

15. What most influenced you to start making these changes to your tap water use?

☐ Symptoms
☐ Concerns for health
☐ Media
☐ Doctor's advice
☐ Other, please explain _____

SEEKING CARE

Note: Please ask these questions of all participants, including those referred by Poison Control.

16. Did you seek medical attention for any of the symptoms we just talked about?

☐ No
☐ Yes
☐ Refused
☐ Don't know

IF NO, it is important that you go see your primary care doctor or a physician for further evaluation. *SKIP TO 17.*

IF YES:

16a. Where did you go? (check all that apply)

☐ Primary Care Provider
☐ Emergency Department
☐ Urgent care
☐ Specialist (e.g. dermatologist, eye doctor, etc.)
☐ Alternative health care provider
☐ Other Explain: _____

16b. Were you hospitalized for this condition?

☐ Yes
☐ No
☐ Refused
☐ Don't know

16b1. *IF YES*, when?_____

16c. Did you receive a diagnosis?

☐ No
☐ Yes
☐ Refused
☐ Don't know

16c1. IF YES, what was the diagnosis?

16d. Did you receive treatment?

☐ No
☐ Yes
☐ Refused
☐ Don't know

16d1. IF YES, what was the treatment?

16e. Do you give permission for us to speak to your doctor (or dermatologist) and access your medical records about these visits to your doctor/the hospital? Medical records are very useful and enable us to add additional details to the information you have already given us. We will not access any other part of your medical records.

☐ No
☐ Yes

Please provide your doctor's name and contact information
16e1. Name: _____
16e2. Phone Number: _____

17. Have you tried any treatments or medications on your own?

☐ No
☐ Yes
☐ Refused
☐ Don't know

17a. *IF YES*, what was the treatment? _____

GENERAL HEALTH

Now I am going to ask you a few questions about your general health.

18. Has a doctor ever told you that you have any chronic health conditions, such as diabetes, heart disease, or lung disease?

☐ No
☐ Yes
☐ Refused
☐ Don't know

18a. *IF YES*, what are they? _____

18b. When were you told about this / these conditions? Date: _____

19. Has a doctor ever told you that you have asthma or seasonal allergies?

☐ No
☐ Yes
☐ Refused
☐ Don't know

19a. *IF YES*, what are they? _____

19b. When were you told about this / these conditions? Date: _____

20. Has a doctor ever told you that you have a skin condition, including psoriasis, eczema, or dermatitis?

☐ No
☐ Yes
☐ Refused
☐ Don't know

20a. *IF YES*, what skin conditions?_____

20b. When were you told about this / these conditions? Date: _____

21. Do you have any allergies to metals, foods, or anything else?

☐ No
☐ Yes
☐ Refused
☐ Don't know

21a. *IF YES*, what are they?_____

21b. When were you tested for this / these conditions? Date: _____

22. Do you currently take any medications?

☐ No
☐ Yes
☐ Refused
☐ Don't know

22a. *IF YES*, what are they?_____

23. Are you currently a smoker?

☐ No
☐ Yes
☐ Refused
☐ Don't know

23a. *IF YES*, how many packs per day?_____

24. We would like to schedule your home for water testing. EPA water quality experts would visit your home to take water samples, which would take from 30 to 60 minutes total, from arrival to departure. You must be present in the home during this time. Would you like the EPA to come test your water? (if someone has already had their water tested say "Even if you've had your water checked already, we are currently rechecking water after the switch back to Detroit water to focus on skin problems that people are currently having.")

☐ No
☐ Yes
☐ Refused
☐ Don't know

24a. *IF YES*, what is your:

Address: _____

(Street City State Zip)

Phone Number: _____

Best Day(s) for Testing:_____

Please expect a call from an EPA representative to set up a visit to test the water in your home.

We would like to schedule you to see a dermatologist if you are interested. Are you interested in seeing a dermatologist?
<If yes, go to Dermatology Referral form>

- ☐ No
- ☐ Yes
- ☐ Refused
- ☐ Don't know

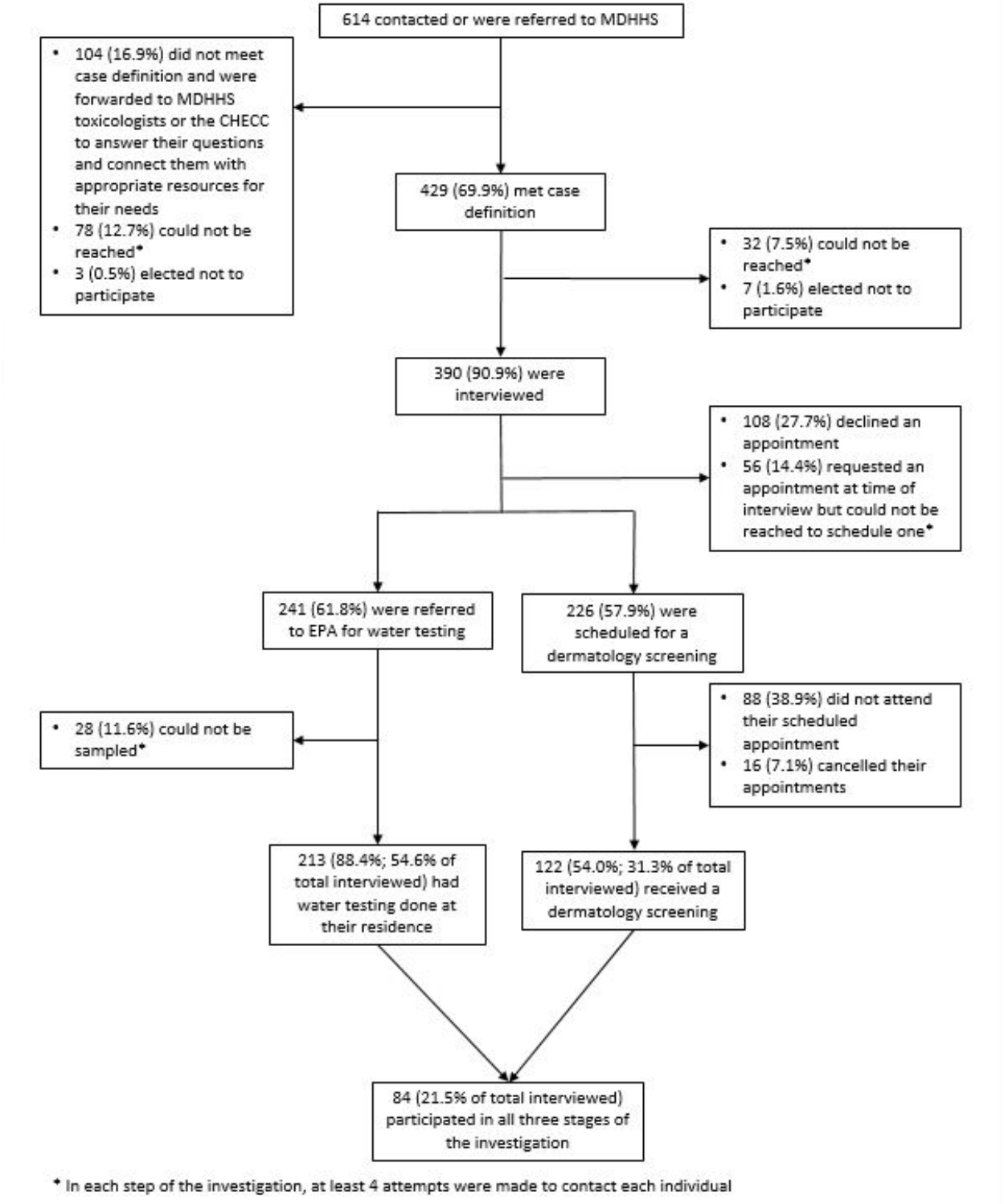
25. Is there anything else that you think I should know about?

That was the last question. Thank you for taking the time to answer our questions.

If you are interested in the results of this questionnaire and additional information on water disinfection, please refer to the Flint Water website at **http://www.michigan.gov/flintwater**.

Interview duration: _____ minutes

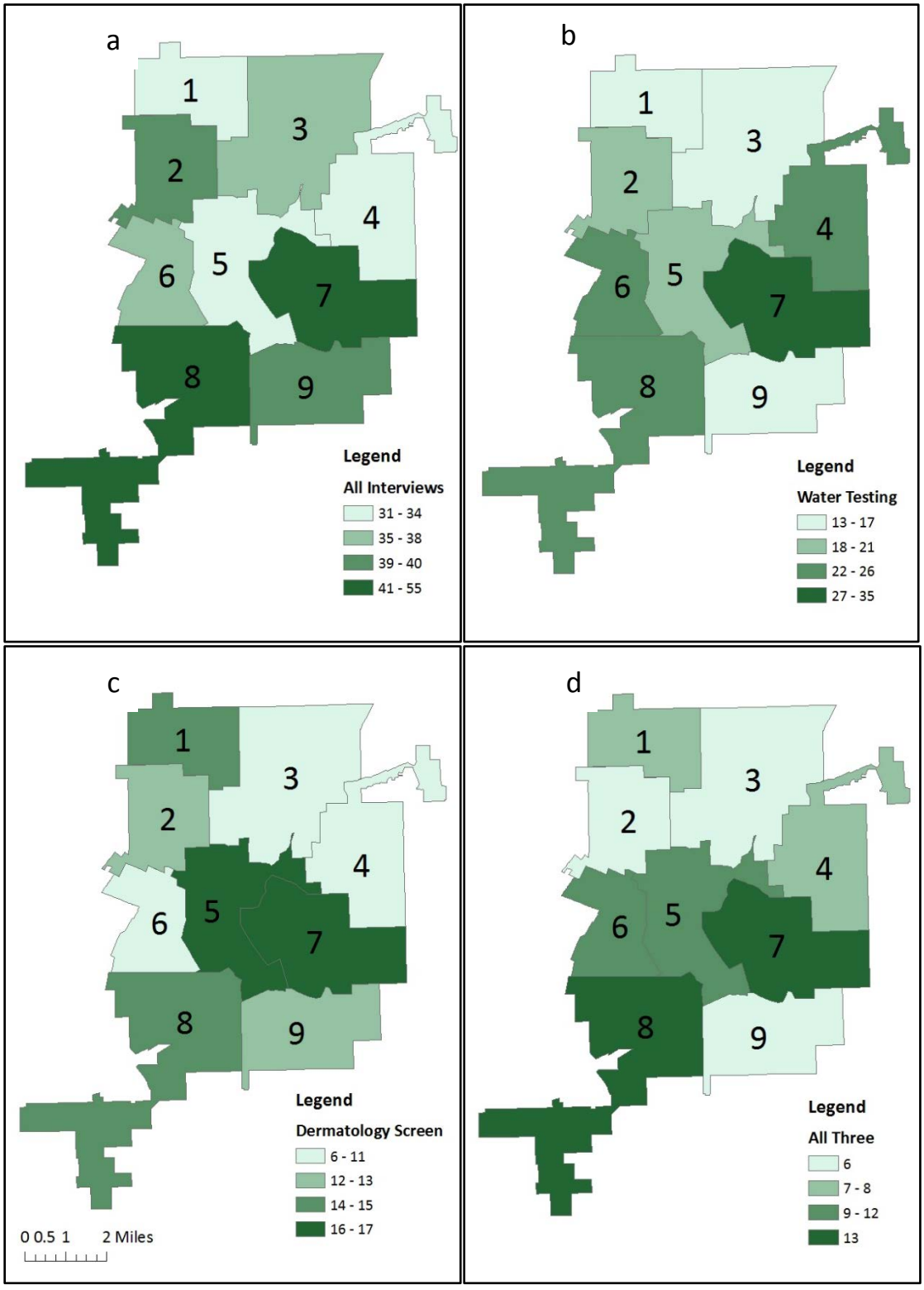
B2. Flowchart of Individuals Participating in the Rash Investigation



* In each step of the investigation, at least 4 attempts were made to contact each individual

B3. Counts of Individuals Participating in Each Stage of the Investigation by City Ward

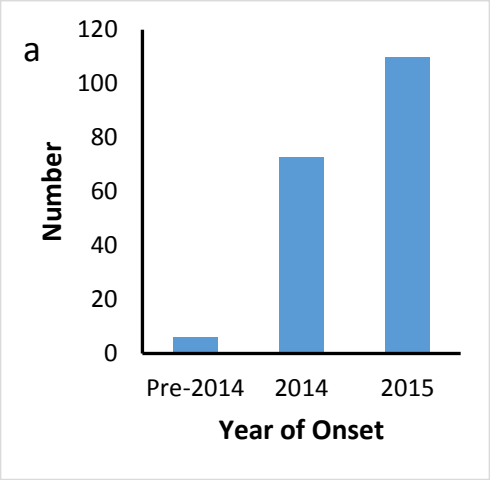
a) Individuals interviewed; b) Individuals who participated in water testing; c) Individuals who participated in a dermatology screening; d) Individuals who participated in all three stages of the investigation

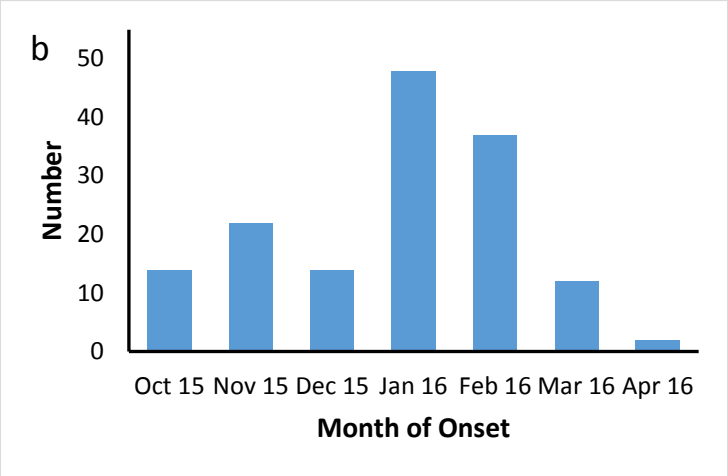


B4. Self-reported Rash Onset

a) Year of onset for pre-existing rashes that worsened after October 15, 2015 (n=189);

b) Month of onset for rashes that developed after October 15, 2015 (n=149).





Appendix C

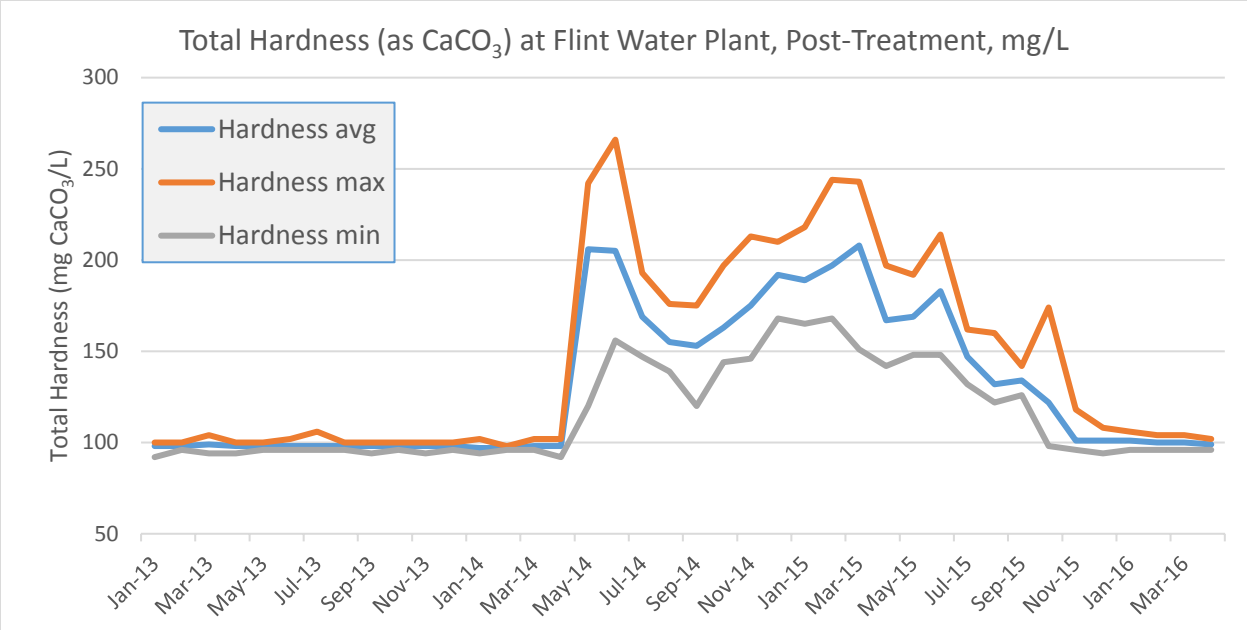
C1. Summary Statistics of Metal Concentrations in Residential Water

Contaminant	N	% Detected	Mean (ppb)	Median (ppb)	Std. Deviation	Min (ppb)	Max (ppb)
Aluminum	491	55.9	155	100.0	609	9.0	16,000
Antimony	221	25.1	0.6	0.4	0.4	0.2	1.1
Arsenic	495	56.3	0.7	0.5	0.7	0.2	7.1
Barium	850	96.7	14.9	13.0	15.3	1.1	160
Beryllium	330	37.5	0.1	0.4	0.1	0.1	1.1
Boron	498	56.6	42.5	23.0	114.1	12.0	1,600
Cadmium	250	28.4	1.1	0.4	1.5	0.1	26.0
Calcium	869	98.9	26,896	27,000	7,105	200	96,000
Chromium	171	19.5	0.4	0.3	0.5	0.2	5.2
Copper	856	97.4	86.1	28.0	266.5	1.1	4,800
Iron	568	64.6	223.0	80.0	814	16.0	17,700
Lead	673	76.5	25.1	0.9	177.8	0.1	3,350
Magnesium	869	98.9	8,186	7,885	3,682	48.0	46,000
Manganese	463	52.7	15.6	8.0	156.9	1.1	4,500
Molybdenum	498	56.7	5.6	0.2	5.6	0.3	16.0
Nickel	503	57.2	4.1	2.8	9.1	0.2	110.0
Potassium	847	96.4	1,162	980.0	2,253	59.0	56,000
Selenium	288	32.4	0.5	0.3	0.5	0.3	2.0
Silver	115	13.1	0.2	0.0	1.0	0.0	10.0
Sodium	879	100	6,348	4,700	9,921	3,900	110,000
Thallium	92	10.5	0.2	0.2	0.1	0.1	0.4
Tin	98	11.1	10.6	2.0	16.5	1.3	290.0
Vanadium	359	40.8	0.8	0.5	1.1	0.2	14.0
Zinc	668	75.2	163.2	25.7	988.7	7.3	27,000

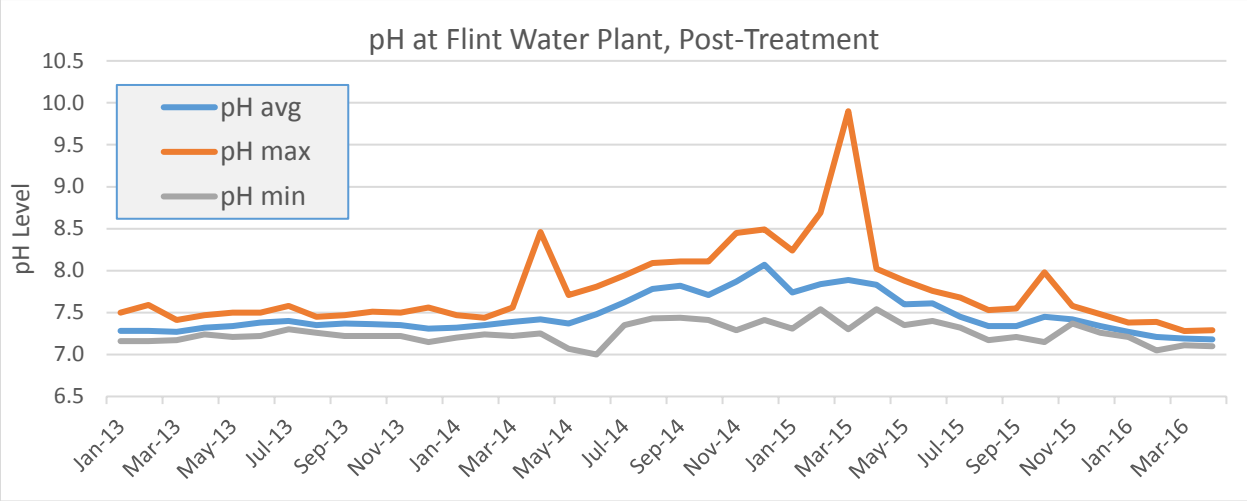
C2. Summary Statistics of Water Quality Indicators in Residential Water

Inorganic	N	% Detected	Mean (ppb)	Median (ppb)	Std. Deviation	Min (ppb)	Max (ppb)
Alkalinity	195	100	78.3	72.0	37.8	21.0	330
Chloride	342	100	9,860	9,100	4,934	8,280	52,000
Fluoride	342	100	632.2	630.0	76.9	140.0	1,100
Hardness	692	98.0	97.8	100.0	14.5	1.3	115.0
Sulfate	347	100	22,314	21,000	7,574	18,000	98,000
Total Dissolved Solids	191	100	123,403	120,000	14,833	88,000	210,000
Turbidity	13	52.0	0.7	0.4	1.2	0.1	4.7

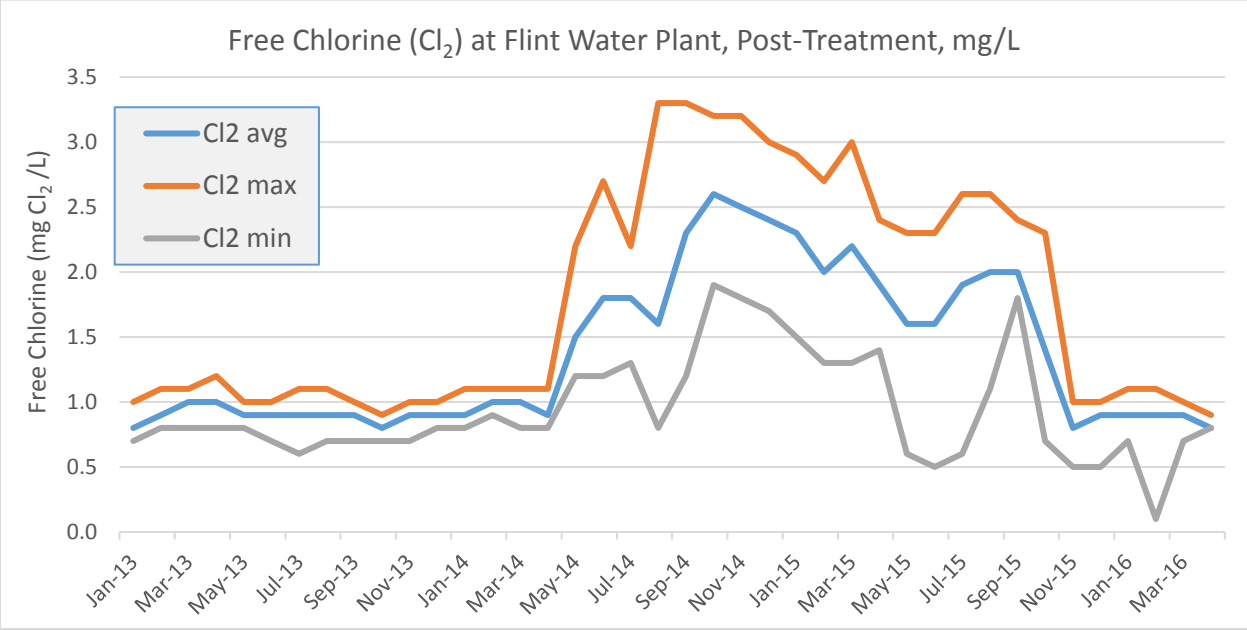
C3. Temporal Pattern of Total Hardness in Flint Water



C4. Temporal Pattern of pH in Flint Water



C5. Temporal Pattern in Chlorine Levels in Flint Water



C6. Summary of Other Metals Measured in Residential Water (not necessarily known to be associated with rashes or other skin problems)

Metal	Concentration (µg/L)	% Detection[1]	Drinking Water Evaluation Level (µg/L)	% Exceeding Evaluation Level	Concentration at Detroit Water Plant (µg/L)	Health-based level (µg/L)
Aluminum	16,000- max 155- average	55.9%	50-200 (SMCL)[2]	6.3%[3]	Max: 142 Average: 52 [Detroit plant tap water, 2015]	20,000 (RSL-child-nc)[4]
Antimony	1.1- max 0.6- average	25.1%	6.0 (MCL)[5]	None	Not detected (<0.6) [Detroit plant tap water, 2008]	4 (ATSDR-child,nc)[6]
Barium	160- max 14.9- average	96.7%	2,000 (MCL)[5]	None	Max: 10 [Detroit plant tap water, 2008]	2,000 (ATSDR-child,nc)[6]
Beryllium	1.1- max 0.10- average	37.5%	4 (MCL)[5]	None	Not detected (<0.4) [Detroit plant tap water, 2008]	20 (ATSDR-child,nc)[6]
Boron	1,600- max 42.5- average	56.6%	6,000 (HA lifetime)[7]	None	No levels available	4,000 (RSL-child-nc)[3]
Cadmium	26- max 1.1- average	28.4%	5 (MCL)[5]	1.1%	Not detected (<0.3) [Detroit plant tap water, 2008]	1 (ATSDR-child,nc)[6]
Iron	17,700- max 223- average	64.6%	300 (SMCL)[2]	11.9%	Max: 642 Average: 147 [Detroit plant tap water, 2015]	14,000 (RSL-child-nc)[4]

[1] There were 880 total measurements for each metal

[2] SMCL – US EPA Secondary Maximum Contaminant Level (non-mandatory water quality standards established only as guidelines for aesthetic considerations, such as taste, color, and odor. These contaminants are not considered to present a risk to human health at the SMCL)

[3] Detection limit (200 µg/L) is at the Upper SMCL

[4] RSL – U.S. EPA Risk-based Screening Level for tapwater exposure – this is a health-based level calculated to make sure people are not exposed to too much of this chemical from drinking water, skin contact, or breathing in the chemical

[4] MCL – US EPA Maximum Contaminant Level (the highest level of a chemical that is allowed in drinking water)

[6] ATSDR-health-based comparison value for non-cancer effect for exposure to a child

[7] HA – US EPA Health Advisory Level for Drinking Water (this is a health-based level set to make sure that people are not exposed to too much of this chemical in their drinking water over a lifetime)

Metal	Concentration (µg/L)	% Detection[1]	Drinking Water Evaluation Level (µg/L)	% Exceeding Evaluation Level	Concentration at Detroit Water Plant (µg/L)	Health-based level (µg/L)
Lead	3,350- max 25.1- average	76.5%	15 Action Level for Lead/ Copper Rule[8]	13.4%	Not detected (<2) [Detroit plant tap water, 2015]	0 (MCLG)
Manganese	4,500- max 15.6- average	52.7%	50 (SMCL)[2] 300 (HA lifetime)[7]	4.3%	Max: 18, Average: 2 [Detroit plant tap water, 2015]	430 (RSL-child-nc)[4]
Molybdenum	16.0- max 5.6- average	56.7%	40 (HA lifetime)[7]	None	No levels available	100 (RSL-child-nc)[4]
Selenium	2.0- max 0.5- average	32.4%	50 (MCL)[5]	None	Max: 1 [Detroit plant tap water, 2008]	50 (ATSDR-child,nc)6
Thallium	0.43- max 0.17- average	10.5%	2 (MCL)[5]	None	Not detected (<0.2) [Detroit plant tap water, 2008]	0.2 (RSL-child-nc)[4]
Tin	290- max 10.6- average	11.1%	No regulatory limit	Not applicable	No levels available	3,000 (ATSDR-child,nc)[6]
Vanadium	14.0- max 0.80- average	40.4%	4.5 (RDWC)[9]	4.2%	Max: 0.59 Average: 0.19 [Detroit plant tap water 2014]	86 (RSL-child-nc)[4]
Zinc	27,000- max 163.2- average	75.4%	5,000 (SMCL)[2] 2,000 (HA lifetime)[7]	0.9%	Not detected (<20) [Detroit plant tap water, 2015]	3,000 (ATSDR-child,nc)6

[8] Action Level for Lead/Copper Rule – US EPA Lead and Copper Rule (the action levels for the 90th percentile of compliance samples is based on technical feasibility of reducing lead and copper in drinking water through optimizing corrosion control)

[9] RDWC- MDEQ Residential Drinking Water Criteria

C7. Potential Health Effects Associated with Exposure to Metals Detected in Residential Water

Metal	What is it?	Potential Health Problems
Arsenic	• is a natural element • is commonly found in water from erosion of natural deposits	• skin damage • problem with the circulatory system • may increase a person's risk of developing cancer
Chromium, total	• is a natural element • could be released from steel and pulp mills • also from erosion of natural deposits	• allergic dermatitis
Copper	• is a natural element • is a required nutrient for our bodies to function • is a common metal in water pipes and faucets	• gastrointestinal distress (short-term exposure) • liver or kidney damage (long-term exposure) • people with Wilson's Disease should consult their health care provider
Lead	• is a natural element • is a common metal in water pipes made before 1986, solder, and faucets • also can be found in paint, dirt, bullets, fishing sinkers, make-up and lotions, food, and many other items	• can harm brain development in fetuses and children • can slow children's growth • can cause high blood pressure or kidney problems in adults
Nickel	• is a natural element • is used in stainless steel and alloys • can also be found in electroplating, mining, and refining metals	• allergic dermatitis • stomachaches (high amounts) • damage to blood and kidneys (high amounts)
Silver	• is a natural element • is used in alloys, solder, electronics and electrical equipment, and other products • could be released from ore mining and processing, product fabrication, electroplating	• skin discoloration (cosmetic effect) • graying of the white part of the eye (cosmetic effect) • allergic dermatitis

Metal	What is it?	Potential Health Problems
Thallium	• is a natural element • is used in electronics and alloys • could also be released from pharmaceutical manufacturing	• hair loss (high amounts in a short time) • kidney, intestine, or liver problems (high amounts in a short time)

(EPA 2016c, EPA 2016d, Sorg et al. 1998, ATSDR 2014, USGS 2016)

C8. Aesthetic or Cosmetic Issues Linked to Metals and Water Parameters

Metal or Water Parameter	What is it?	Potential Problems
Aluminum	• is a natural element • can be found in beverage cans, foil, antacids, and other consumer products • also is mixed with other metals to form aluminum alloys	• discolored water
Copper	• is a natural element • is a required nutrient for our bodies to function • is a common metal in water pipes and faucets	• metallic taste • blue-green staining
Iron	• is a natural element	• rusty colored water • sediment • metallic taste • reddish or orange staining
Manganese	• is a natural element • is used in steel production • is commonly found in water from erosion of natural deposits	• black to brown colored water • black staining • bitter metallic taste

Metal or Water Parameter	What is it?	Potential Problems
Silver	• is a natural element • is used in alloys, solder, electronics and electrical equipment, and other products • could be released from ore mining and processing, product fabrication, electroplating	• skin discoloration (cosmetic effect) • graying of the white part of the eye (cosmetic effect)
Zinc	• is a natural element • commonly found in water from erosion of natural deposits or from mining • common metal in water pipes and faucets	• metallic taste

(EPA 2016c, EPA 2016d, Sorg et al. 1998, ATSDR 2014, USGS 2016)

C9. Disinfection Byproducts and Other Organics Pilot Project

In the course of the investigation, it was decided that there should be an initial evaluation of additional chemical compounds that could be present in Flint drinking water. A pilot study was developed to evaluate the presence of a wide range of organic chemicals, including chemicals known as disinfection byproducts. Six homes (where residents complained of rash concerns, were surveyed, and were scheduled for dermatological appointments) were recruited to participate in the additional testing. Five homes (where there was a request to EPA for water sampling, but where no concerns about rashes among the residents) were selected as comparison homes. The water samples were tested for disinfection byproducts (DBPs), including trihalomethanes (THMs), haloacetic acids (HAAs), and haloacetonitriles; volatile organic compounds, and semi-volatile compounds.

The results of the organic chemical testing (shown below in Tables C9-1, C9-2, and C9-3) for the rash homes were compared to the comparison homes, to regulatory values for Total THMs and HAAs, and to levels for these compounds that have been reported in the scientific literature. The results indicate that all of the values for the rash homes and the comparison homes are below federal standards for DBPs. In addition, all of the results indicate that the levels of organic chemicals found in the residential water samples are within expected ranges that have been reported for chlorinated water systems.

Acetone was detected in several rash (max= 170 µg/L; average= 34 µg/L) and control (max= 16 µg/L; average= 8.6 µg/L) samples. The apparent difference in the acetone concentration between the rash and control group was the contribution of one rash home, where the acetone concentration was elevated for both hot and cold water. This result is clearly different from all of the other samples analyzed for volatile organic compounds, and there is no obvious explanation for this elevated reading. However, even this acetone level is well below the level that would be a concern for ingestion of water or likely to have effects on the skin.

Table C9-1. Pilot Project: Summary of Trihalomethane Concentrations in Control and Rash Residences

Contaminant	Control Group (n=5)				Rash Group (n=6)			
	Max (µg/L)		Mean (µg/L)		Max (µg/L)		Mean (µg/L)	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
Chloroform	13.4	36.0	9.3	23.1	13.1	46.8	9.0	29.4
Bromodichloromethane	6.0	10.5	5.2	8.3	6.2	13.1	5.2	9.2
Dibromochloromethane	2.0	3.0	1.8	2.6	2.1	3.9	1.8	2.8
Bromoform	nd*	nd	nd	nd	Nd	nd	nd	Nd
Total THMs	21.3	47.8	16.3	34.0	20.8	63.9	15.9	41.4

*nd = non-detect

Table C9-2. Pilot Project: Summary of Haloacetic Acid Concentrations in Control and Rash Residences

Contaminant	Control Group				Rash Group			
	Max (µg/L)		Mean (µg/L)		Max (µg/L)		Mean (µg/L)	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
pH	7.4		7.2		7.2		7.2	
Chlorine residual	0.7		0.5		0.7		0.6	
1,2,3-Trichloropropane	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
2-Bromobutanoic acid	10.0	10.0	9.8	9.8	10.0	9.9	9.6	9.6
Bromodichloroacetic acid (BDCAA)	2.9	2.9	2.4	2.2	2.9	2.0	2.6	2.0
Chlorodibromoacetic acid (CDBAA)	nd	nd	nd	nd	nd	nd	nd	Nd
Tribromoacetic acid	nd	nd	nd	nd	nd	nd	nd	Nd
Dibromoacetic acid	nd	nd	nd	nd	nd	nd	nd	Nd
Dichloroacetic acid	17.2	12.3	9.7	8.8	11.7	13.8	8.3	8.6
Monobromoacetic acid	nd	nd	nd	nd	nd	nd	nd	Nd
Monochloroacetic acid	nd	nd	nd	nd	nd	nd	nd	Nd
Trichloroacetic acid	5.4	6.1	4.1	4.1	5.3	4.9	4.2	3.4
Total Haloacetic acids (HAA5)	22.7	16.5	13.8	12.9	17.0	18.7	12.5	12.0

Table C9-3. Pilot Project: Summary of Haloacetonitrile Concentrations in Control and Rash Residences

Contaminant	Control Group				Rash Group			
	Max (µg/L)		Mean (µg/L)		Max (µg/L)		Mean (µg/L)	
	Cold	Hot	Cold	Hot	Cold	Hot	Cold	Hot
1,1,1-Trichloro-2-propanone	1.9	0.3	1.3	0.2	1.6	0.2	1.1	0.2
1,1-Dichloro-2-propanone	0.4	0.6	0.3	0.3	0.3	0.4	0.3	0.3
Bromochloroacetonitrile	0.7	0.6	0.6	0.3	0.6	0.6	0.6	0.3
Chloropicrin	0.3	0.3	0.2	0.2	0.3	0.4	0.2	0.2
Dibromoacetonitrile	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Dichloroacetonitrile	1.6	1.1	1.3	0.6	1.5	0.9	1.2	0.5
Trichloroacetonitrile	nd	nd	nd	nd	nd	nd	nd	Nd
Chloral hydrate	4.4	7.5	2.4	2.7	3.2	5.1	2.0	2.3

C10. Summary of Comparison Values for Disinfection Byproducts in Residential Drinking Water

Water Quality Parameter	EPA, 2002[10] (range : µg/L)	WHO, 2011[11] (µg/L)	Liu and Reckow, 2015[12] (µg/L)	Liu and Reckow, 2015[13] (µg/L)	AWWA-WQTC, 2015[14]	EPA MCL (µg/L)[15]	EPA Health Advisory (µg/L)[16]	EPA RSL (µg/L)[17]	ATSDR (µg/L)[18]	WHO (µg/L)
Chloroform	27-41		10 (cold) 38 (hot)		30 (median)	80	70	0.22 (c) 97 (nc)	100 (nc-child)	300
Bromodichloromethane	4.7-36		2.5 (cold) 5.5 (hot)				100 (DWEL)	0.13 (c) 380 (nc)	0.56 (c) 200 (nc-child)	60
Bromoform	nd-2						1,000 (DWEL)	3.3 (c) 380 (nc)	4.4 (c) 200 (nc-child)	100
Dibromochloromethane	0.7-14		0.3 (cold) 0.7 (hot)				60	0.87 (c) 380 (nc)	900 (nc-child)	100
Total Trihalomethanes	38-86	<100	12 (cold) 42 (hot)	25 (cold) 38 (hot)						
Bromochloroacetonitrile	0.3-2							na	na	Na
Dibromoacetonitrile	nd-0.1							na	na	70
Dichloroacetonitrile (DCAN)	2.8-8			1.8 (cold) 0.1 (hot)				na	na	20
Trichloroacetonitrile	nd-0.1							na	na	Na
Chloral Hydrate	6.9-15	<10						na	na	100

[10] Weinberg HS et al. 2002. The Occurrence of Disinfection By-Products (DBPs) of Health Concern in Drinking Water: Results of a Nationwide DBP Occurrence Study. EPA/600/R-02/068 (Distribution Systems data summarized from Tables 9,11,13, 15 for Plant 4 using Chlorine Disinfection).

[11] World Health Organization. 2011. Guidelines for Drinking-Water Quality, 4th Edition. Geneva, Switzerland: WHO.

[12] Liu B and Reckhow DA. 2015. Disparity in Disinfection Byproducts Concentration between Hot and Cold Tap Water. Water Research 70:196-204.

[13] Liu B and Reckhow DA. 2015. Impact of Water Heaters on the Formation of Disinfection By-products. J Amer Water Works Assoc 2015.107.0080.

[14] Samson C, Seidel C, Bartrand T and Via S. 2015. Assessing DBP Occurrence: Impacts of the Stage 2 DBPR. AWWA-WQTC Proceedings; Salt Lake City, UT (Summary of more than 10,000 testing results reported by water suppliers nationally).

[15] EPA Maximum Contaminant Level represents the federal drinking water standard (https://www.epa.gov/dwstandardsregulations).

[16] EPA Health Advisory Level (https://www.epa.gov/dwstandardsregulations).

[17] EPA Regional Screening Levels.

[18] ATSDR Screening Levels, based on Minimal Risk Levels (http://www.atsdr.cdc.gov/mrls/index.asp).

Water Quality Parameter	EPA, 2002[10] (range : µg/L)	WHO, 2011[11] (µg/L)	Liu and Reckow, 2015[12] (µg/L)	Liu and Reckow, 2015[13] (µg/L)	AWWA-WQTC, 2015[14]	EPA MCL (µg/L)[15]	EPA Health Advisory (µg/L)[16]	EPA RSL (µg/L)[17]	ATSDR (µg/L)[18]	WHO (µg/L)
Chloropicrin	0.2-0.6	<5		nd (cold) 0.6 (hot)				0.83 (n)		Na
1,1-Dichloro-2-propanone	1							na		
1,1,1-Trichloro-2-propanone (TCP)				1.8 (cold) <0.1 (hot)				na		
Dibromoacetic acid (DBAA)	nd-2.9				20	60		na	na	
Dichloroacetic acid (DCAA)	17-25	<20	5 (cold) 15 (hot)	10 (cold) 15 (hot)				79 (nc) 1.5(c)	0.7 (c)	50
Monobromoacetic acid (MBAA)	nd							na	na	
Monochloroacetic acid (MCAA)	nd-7.8	2.1					0.07	na	na	
Trichloroacetic acid (TCAA)	20-35		8 (cold) 8 (hot)	8 (cold) 8 (hot)			20	390 (nc) 1.1 (c)	0.5 (c)	
Bromochloroacetic acid (BCAA)	1.7-7.3		0.7 (cold) 1.0 (hot)	0.8 (cold) 0.9 (hot)				na	na	
Bromodichloroacetic acid (BDCAA)	3.6-12		0.7 (cold) 1.2 (hot)	0.45 (cold) 0.3 (hot)				na	na	
Tribromoacetic acid (TBAA)	nd							na	na	

Appendix D

D. Dermatologic Assessment Form

Flint Dermatological Assessment Investigation

ID: _____ Date: _____

Name of Person Evaluated: _____ **Phone number**: _____
Street Address: _____ **City**: _____ **State**: _____ **Zip**: _____

Primary Care Provider
Name: _____
City: _____
Phone: _____
Fax: _____

Information Provided to Person Evaluated (initial): _____
I received the following documents:
□ Signed Medical/HIPAA Release Form
□ Dry Skin Tips – American Academy of Dermatology/CDC
□ Copy of letter to Primary Care Provider about evaluation
□ Copy of general tips for Primary Care Provider about managing eczema
□ Copy of Dermatological Assessment Form sent to Primary Care Provider
□ Other: _____

DEMOGRAPHICS

DOB: __/ __ / __ **Sex:** □ Male □ Female □ N/A **Occupation:** _____ **Ethnicity:** □ Hispanic □ Not Hispanic

Race: □ American Indian/ Alaskan Native □ Asian □ Black □ Native Hawaiian/ Pacific Islander □ White

HISTORY OF PRESENT ILLNESS
Chief Complaint: _____

Symptoms	Onset	Location	Duration	Severity/Characteristics
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____
_____	_____	_____	_____	_____

Aggravating factors: □ Showering □ Bathing □ Washing hands □ Other: _____

Alleviating factors: _____

Notes: _____
_____

PREVIOUS TREATMENTS FOR CURRENT CONDITIONS / EFFECTIVENESS

PAST DERMATOLOGIC HISTORY

	Description	Onset Date	Status
□ Dry/Sensitive skin	_____	_____	_____
□ Eczema	_____	_____	_____
□ Psoriasis	_____	_____	_____
□ Skin infections	_____	_____	_____
□ Alopecia	_____	_____	_____

Notes/other: _____

PAST MEDICAL HISTORY

□ Asthma □ Autoimmune disease: _____ □ Allergies (seasonal, meds, metals, etc):_____

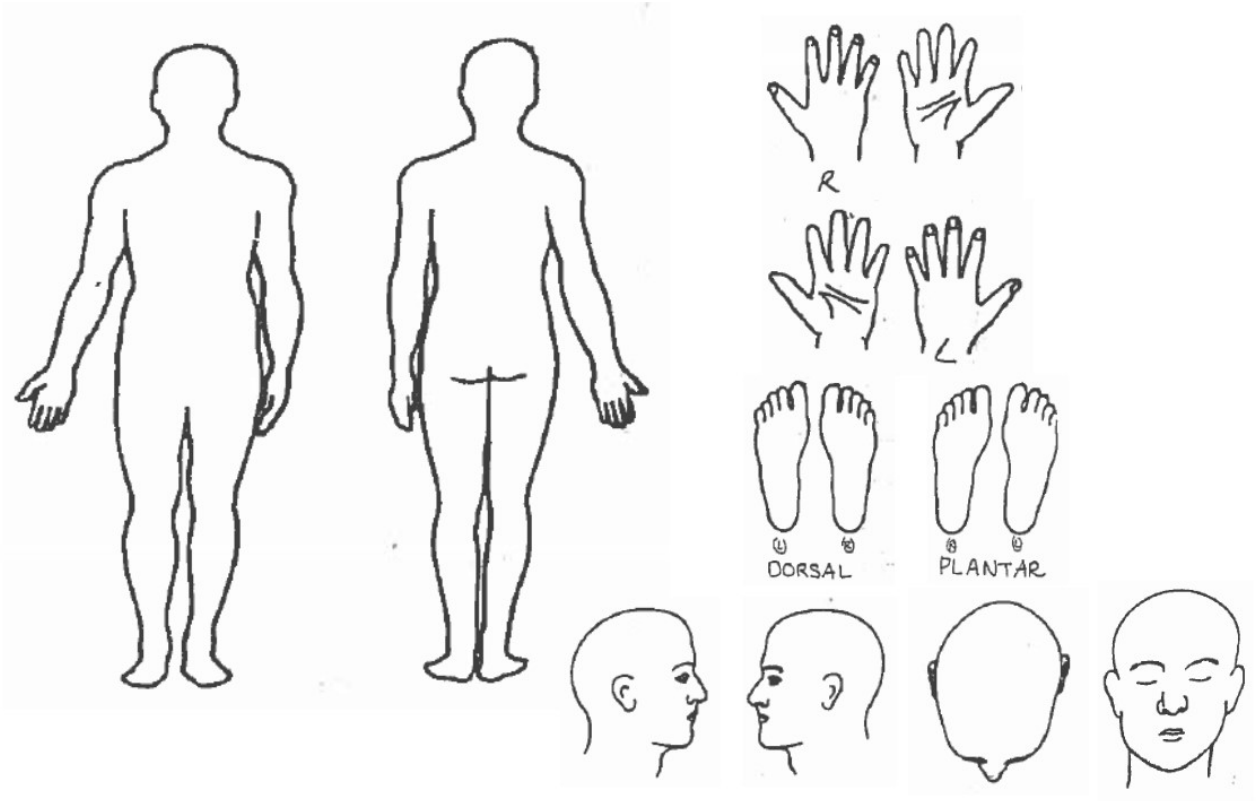
□ Notes/other: _____

CURRENT MEDICATIONS (Prescription and over the counter)

PHYSICAL EXAMINATION

Vital Signs (if obtained) _____ □ Photo(s) taken

Skin Examination – Circle and identify findings, Size (BSA), Important characteristics:



Notes: _____

_____

ASSESSMENT OF RELATIONSHIP OF SKIN CONDITION TO WATER EXPOSURE (Circle)

Definitely unrelated Possibly related Probably related Definitely related Unknown

ASSESSMENT/DIAGNOSES

RECOMMENDATIONS

Signature: _____ Date:_____

Physician (circle): Bishr Al Dabagh, MD - Walter Barkey, MD - Kevin Gaffney, MD - Robert Soderstrom, MD

I understand that I have a skin condition that requires a follow-up examination. I also understand that it is my responsibility arrange for a follow-up examination with my primary care provider, and any further evaluation and treatment by a dermatologist will be coordinated by my primary care provider.

_____

Examinee initials

D2. Dermatologic Diagnoses, by Category

Clinical Categories		N (%)
1) Diagnoses definitely unrelated to exposure to Flint municipal water	1. Tinea capitis 2. Granuloma annulare 3. Multiple scalp actinic keratoses 4. Tinea cruris / onychomycosis 5. Id eruption (autoeczematization) secondary to URI 6. Localized pustular psoriasis of the palms and soles (2) 7. Chronic plaque type psoriasis 8. Tinea versicolor (KOH positive) 9. Scabies (2) 10. Morbilliform drug rash secondary to sulfa 11. Allergic contact dermatitis to a product used to resurface countertops 12. Pseudofolliculitis barbae (2) 13. Skin picking syndrome (dermatitis artefacta) 14. Milia 15. Tinea incognito 16. Intertrigo 17. Seborrheic dermatitis 18. Arthropod bite (unrelated temporally to water)	24 (19.8%)
2) Dermatitis possibly related to water exposure	1. Eczematous dermatitis (9) 1a. asteatotic eczema (13) 1b. atopic dermatitis (16) 1c. hand eczema (2) 1d. hyperkeratotic eczema of the palms/soles 1e. nummular dermatitis (3) 1f. Eczema craquele 2. Psoriasiform dermatitis 3. Seborrheic dermatitis with eczematous component (3) 4. Contact dermatitis 5. Lichen simplex chronicus (4) 6. Intertrigo	53 (43.8%)
3) Non-dermatitis skin conditions possibly associated with water exposure	1. Resolving abscess vs ruptured epidermal inclusion cyst (culture negative) 2. Acquired ichthyosis 3. Telogen effluvium (2) 4. Generalized pruritus without rash (6) 5. Chronic folliculitis (2) 6. Urticaria (2) 7. Prurigo papularis (2) 8. Arthropod assault reaction (still listed as possibly related because it was worse with exposure and better with avoidance of Flint water) 9. Papular urticaria 10. Seborrheic dermatitis / intertriginous dermatitis 11. Symptomatic dermatographism (2)	27 (22.3%)

	12. Scarring alopecia c/w central centrifugal cicatricial alopecia (2) 13. Alopecia areata/totalis 14. Vulvar / perineal / perianal dysesthesias without objective findings 15. Urticarial dermatitis (2) 16. Erythema ab igne 17. Acneiform eruption of uncertain etiology 18. Localized dysaethesia (temporally related to water change)	
4) Resolved/inactive rash possibly associated with water exposure	1. Resolved eczematous dermatitis (3) 2. Resolved pruritic localized papular eruption 3. Post inflammatory hyperpigmentation/changes (2) 4. Resolved asteatosis (2) 5. Resolved atopic dermatitis (3) 6. Resolved contact dermatitis 6. Resolved eruption/rash of uncertain etiology (2) 7. Resolved folliculitis/cellulitis 8. Resolved generalized pruritus (possibly associated with red papules) (2) 10. Resolved hair loss	17 (14.0%)
Note – One individual had no skin condition based on clinical assessment, several individuals had more than one diagnosis but were classified by the principal diagnosis.		

D3. Demographics: Interviews, Water Testing, and Dermatologic Screening

Demographic of Interest	All Case Interviews			Received Water Testing			Received Dermatologic Screening			Population of Flint, MI US Census data, 2010		
	n	%	Total	n	%	Total	n	%	Total	n	%	Total
Age Groups												
<5	28	7.2	388	15	7.0	213	9	7.4	122	8,177	8.0	102,434
5-17	56	14.4	388	29	13.6	213	11	9.0	122	19,737	19.3	102,434
18-64	237	61.1	388	137	64.3	213	80	65.6	122	63,521	62.0	102,434
65+	67	17.3	388	30	14.1	213	22	18.0	122	10,999	10.7	102,434
Female	254	65.1	390	142	66.7	213	71	58.2	122	53,294	52.0	102,434
Black	not collected			not collected			70	57.4	122	57,939	56.6	102,434
Hispanic	not collected			not collected			1	2.8	36	3,976	3.9	102,434
Unemployed Adults	213	72.0	296	114	70.8	161	67	67.7	99	10,653*	5.8*	182,886*
Reported Skin Conditions	71	18.2	390	48	22.5	213	26	21.3	122	not collected		
Reported Metal Allergies	15	3.8	390	8	3.8	213	6	4.9	122	not collected		
Reported Hair Loss	175	45.7	383	92	44.2	208	54	45.0	120	not collected		

*Statistics for Flint Metropolitan area in 2015 from Bureau of Labor Statistics (http://data.bls.gov/pdq/SurveyOutputServlet), not the US Census Bureau (http://www.census.gov/quickfacts/table/PST045215/2629000)

D4. Tables of Dermatologic Data

Table D4-1. Severity of Rash for Each Clinical Category (n=80)*

Severity	Clinical category			
	2		3	
	n	%	n	%
Mild	39	73.6	12	44.4
Mild-Moderate	8	15.1	10	37
Severe	6	11.3	5	18.5

*Severity was only determined for categories 2 and 3

Table D4-2. Racial and Temporal Distribution of Rash Clinical Category (N=122)

Clinical category	Race				Onset					
	White		Black		before October 16, 2016		after October 16, 2016		Missing	
	n	%	n	%	n	%	n	%	n	%
1	15	29.4	9	12.9	14	18.9	9	26.5	1	7.1
2	21	41.2	31	44.3	33	44.6	12	35.3	8	57.1
3	8	15.7	19	27.1	19	25.7	6	17.6	2	14.3
4	6	11.8	11	15.7	8	10.8	6	17.6	3	21.4
TOTAL	51		70		74		34		14	

Table D4-3. Racial and Temporal Distribution of Rash Severity (n=80)*

Severity	Race				Onset					
	White		Black		before October 16, 2016		after October 16, 2016		Missing	
	n	%	n	%	n	%	n	%	n	%
Mild	20	69.0	31	62.0	32	61.5	11	61.1	8	80.0
Mild-Moderate	3	10.3	15	30.0	12	23.1	6	33.3	0	0
Severe	6	20.7	4	8.0	8	15.4	1	5.6	2	20.0
TOTAL	29		50		52		18		10	

*Clinical categories 2 and 3 only

Table D4-4. Distribution of Recommended Topical Steroids Strength

Topical Steroid Classification Group	n	%
Medium (group 4)	35	50.0
Lower-mid (group 5)	11	15.7
Lowest (group 7)	9	12.9
Super high (group 1)	8	11.4
Low (group 6)	3	4.3
High (group 2)	3	4.3
High (group 3)	1	1.4
TOTAL	70	100.0

*Several individuals were prescribed two classes of steroids

Appendix E

E1. Description of Statistical Methods Used to Analyze Combined Data

The distribution of the data for the levels of select contaminants was evaluated using a Shapiro-Wilks test to determine the normality of the data within the *not possibly related* and *possibly related* rash groups. The results from this test and an assumption of the independence between the two groups were used to determine that a Wilcoxon Mann Whitney test could be used to evaluate the possible relationships between an individual's exposure to different levels of select contaminants and the their rash diagnoses.

An initial test for the normality of the distribution of the two populations (unrelated and possibly related) for each selected contaminant was performed using a Shapiro-Wilks test. The null hypothesis for this test proposes that the true population is normally distributed around the population mean. A significance alpha value of 0.05 was used to evaluate the resulting p-values of this test. The contaminants' p-values for the Shapiro-Wilks test that were less than 0.05 provided enough statistical evidence to reject the null hypothesis with 95% confidence that the finding was not by chance. After observing the results of the test, all but one of the clinical category groups rejected the null hypothesis that the data was from a normal distribution. These results were used to determine that a statistical test for non-normally distributed data could be considered.

The two populations separated into the unrelated and possibly related groups were deemed to be independent even though some individuals lived in the same household. Since each patient was given one clinical category for his or her rash diagnoses, each individual could be independently matched up with a household reading for the measurements across the selected contaminants, and all individuals would be considered independent of one another.

Since the majority of the data was not normally distributed and the samples were assumed to be independent, a Wilcoxon Mann Whitney test was conducted. The null hypothesis for this test states that the true population means of the unrelated and possibly related groups are the same. While this test uses rank methodologies to compare the means across the two groups, the raw values of these contaminant concentrations were recorded for the unrelated and possibly related rash groups (Table E2). Normality approximations were taken due to a computational software limitation that inhibited exact values to be calculated in the amount of time available to conduct this analysis. Exact values would be ideal, but this approximation would suffice if more samples could be collected to create a more normal distribution within the two populations.

In order to utilize these exact methodologies, different clinical category combinations within the unrelated and possibly related groups were compared using the same Wilcoxon Mann Whitney analysis in scenarios that limited the readings to only hot water. These comparisons limited the number of samples so that exact methods could be more feasibly conducted in a reasonable amount of time.

Table E2 shows the comparison of average concentrations of specific contaminants detected in all samples (hot and cold) that had been initially determined to be of a potential interest for skin effects, comparing the Clinical Categories of Unrelated (#1 and #5) with the Possibly Related Categories (#2, #3, #4). Table E3 is a comparison of the descriptive statistics for contaminant concentrations among Clinical Category 1, 2, and 3. Most average values were no different between the groups. Some comparisons were statistically significant, but no findings were determined to be clinically significant..

Table E2. Average Concentrations for Select Contaminants comparing Clinical Categories for Rashes Not Possibly Related Versus Rashes Possibly Related [1,2]

Contaminant	Unrelated	Possibly Related
Arsenic	0.3	0.4
Chromium	0.4	0.5
Copper	75.0	81.5
Hardness	98.7	98.9
Nickel	1.2	3.5
Silver	0.0	0.4
Thallium	0.2	0.2
Zinc	166.5	357.8

[1]Combination of cold and hot water samples

[2]Units are mg/L

Table E3. Comparison of Contaminant Water Concentrations for Different Clinical Categories[3]

Contaminant	Clinical Category	N	Mean (µg/L)	Median (µg/L)	Q_25 (µg/L)	Q_75 (µg/L)	Min (µg/L)	Max (µg/L)	Std_Dev
Alkalinity	1	13	67.8	71	70.0	72.0	21	79	14.3
Alkalinity	2	38	72.6	72	70.0	74.0	68	80	3
Alkalinity	3	15	74.1	74	71.0	78.0	69	80	3.5
Aluminum	1	9	49.2	26	21.0	49.0	18	150	45.9
Aluminum	2	19	60.7	35	21.0	78.0	15	224	56.9
Aluminum	3	12	161.2	47.5	23.5	180.0	17	780	237.3
Antimony	1	3	0.2	0.2	0.2	0.2	0.2	0.2	0
Antimony	2	4	0.2	0.2	0.2	0.3	0.2	0.3	0.1
Antimony	3	7	0.3	0.2	0.2	0.5	0.2	0.6	0.2
Arsenic	1	8	0.2	0.2	0.2	0.3	0.2	0.3	0
Arsenic	2	18	0.3	0.3	0.2	0.3	0.2	0.4	0.1
Arsenic	3	12	0.3	0.3	0.2	0.4	0.2	0.5	0.1
Barium	1	13	13.4	13.4	13.0	14.0	11	15	1
Barium	2	42	13.4	13	12.4	14.0	11.4	16	1.1
Barium	3	16	14	13.2	13.0	15.0	12	19	1.8
Beryllium	1	6	0.2	0.2	0.1	0.4	0.1	0.4	0.1

[3] Hot water samples

Contaminant	Clinical Category	N	Mean (µg/L)	Median (µg/L)	Q_25 (µg/L)	Q_75 (µg/L)	Min (µg/L)	Max (µg/L)	Std_Dev
Beryllium	2	7	0.2	0.1	0.1	0.3	0.1	0.4	0.1
Beryllium	3	9	0.1	0.1	0.1	0.2	0.1	0.3	0.1
Boron	1	9	19	17	15.0	19.0	13	34	6.6
Boron	2	18	21.2	18	15.0	20.0	15	43	8.6
Boron	3	12	27.5	20	17.5	23.0	14	87	21.5
Cadmium	1	2	0.3	0.3	0.1	0.4	0.1	0.4	0.2
Cadmium	2	5	0.3	0.2	0.2	0.3	0.2	0.4	0.1
Cadmium	3	6	0.9	0.3	0.2	0.9	0.1	3.3	1.2
Calcium	1	13	26453.8	26300	26000.0	27000.0	25000	28100	774.2
Calcium	2	42	26600	27000	26000.0	27200.0	24400	28100	1016.2
Calcium	3	16	26412.5	26000	25500.0	27600.0	25000	28000	1100.8
Chloride	1	13	9233.8	9200	9040.0	9500.0	8860	9500	233.4
Chloride	2	38	9151.6	9100	9000.0	9320.0	8470	9800	298.3
Chloride	3	15	9142.7	9140	9000.0	9280.0	8900	9400	146.6
Chromium	2	6	0.2	0.2	0.2	0.3	0.2	0.4	0.1
Chromium	3	3	0.2	0.2	0.2	0.2	0.2	0.2	0
Copper	1	13	43.6	29	18.0	49.9	4.5	170	44.4
Copper	2	42	34.9	30.7	16.2	44.6	4.5	110	24.8
Copper	3	16	35.5	34	14.2	39.1	5.8	99	25.1
Fluoride	1	13	656.9	670	610.0	680.0	570	720	47.1
Fluoride	2	38	611.1	610	570.0	650.0	510	710	49.9
Fluoride	3	15	597.3	610	500.0	670.0	480	700	78.6
Hardness[4]	1	13	99	99.2	96.6	101.1	93.7	104.1	2.9
Hardness[4]	2	42	99.3	99.9	97.0	101.5	89.2	105.5	3.7
Hardness[4]	3	16	99.6	100.3	95.5	103.6	93.7	104.8	4.3
Iron	1	8	52.1	33.5	20.5	84.4	17	123	39.8
Iron	2	18	88.7	70.5	40.0	131.0	23	210	52.8
Iron	3	14	139.1	114	53.0	190.0	25	340	105.3
Lead	1	12	0.6	0.4	0.2	0.9	0.1	2.2	0.6
Lead	2	24	3.2	0.7	0.5	1.3	0.4	20	6.3
Lead	3	14	4.1	0.8	0.4	8.3	0.3	20	6.2

[4] Units are mg/L

Contaminant	Clinical Category	N	Mean (µg/L)	Median (µg/L)	Q_25 (µg/L)	Q_75 (µg/L)	Min (µg/L)	Max (µg/L)	Std_Dev
Magnesium	1	13	8021	8100	7700	8200	7600	8800	374.9
Magnesium	2	42	8004	8000	7800	8190	6870	9260	408.9
Magnesium	3	16	8194	8315	7750	8510	7600	9100	453
Manganese	1	6	3.7	2.1	1.9	3.3	1.8	11	3.6
Manganese	2	14	7.8	4	2.6	9.0	1.1	31	8.8
Manganese	3	15	10.8	8.6	2.6	17.7	1.5	38	9.9
Molybdenum	1	9	0.5	0.5	0.5	0.6	0.5	0.6	0
Molybdenum	2	18	0.5	0.5	0.5	0.5	0.3	0.6	0.1
Molybdenum	3	12	0.6	0.5	0.5	0.6	0.5	0.7	0.1
Nickel	1	8	1.1	0.8	0.8	1.3	0.5	2.7	0.7
Nickel	2	17	1.2	0.8	0.6	1.6	0.5	3.6	1
Nickel	3	13	4.2	2.5	0.8	4.1	0.3	14.1	4.8
Potassium	1	13	962	960	950	980	890	1030	36.6
Potassium	2	36	986	980	945	1000	890	1200	66.7
Potassium	3	16	978	981	935	1000	900	1100	55.9
Selenium	1	4	0.4	0.3	0.3	0.5	0.3	0.7	0.2
Selenium	2	7	0.5	0.6	0.4	0.6	0.3	0.9	0.2
Selenium	3	9	0.6	0.5	0.3	0.8	0.3	1.6	0.4
Silver	2	1	0	0	0.0	0.0	0	0	.
Silver	3	2	5	5	0.0	10.0	0	10	7.1
Sodium	1	13	4715	4700	4700	4800	4400	5130	172
Sodium	2	42	4802	4800	4700	4940	4400	5200	213
Sodium	3	16	4730	4700	4600	4875	4400	4990	175
Sulfate	1	13	21562	21000	21000	22000	19200	26000	1958
Sulfate	2	38	21468	21000	20000	23000	18800	25000	1902
Sulfate	3	15	21773	21000	20700	23000	20000	25000	1524
Thallium	1	1	0.1	0.1	0.1	0.1	0.1	0.1	.
Thallium	2	1	0.1	0.1	0.1	0.1	0.1	0.1	.
Thallium	3	1	0.2	0.2	0.2	0.2	0.2	0.2	.
Tin	3	3	1.9	1.9	1.8	2.1	1.8	2.1	0.2
TotalDissolved Solids	1	10	124000	121000	112000	130000	110000	150000	13433

Contaminant	Clinical Category	N	Mean (µg/L)	Median (µg/L)	Q_25 (µg/L)	Q_75 (µg/L)	Min (µg/L)	Max (µg/L)	Std_Dev
TotalDissolved Solids	2	23	124521	122000	116000	130,000	102000	158000	13594
TotalDissolved Solids	3	9	139556	130000	122,000	150,000	116000	210000	29577
Turbidity	2	5	0.4	0.4	0.3	0.6	0.3	0.6	0.1
Vanadium	1	7	0.4	0.4	0.3	0.4	0.3	0.5	0.1
Vanadium	2	17	0.3	0.3	0.3	0.4	0.2	0.6	0.1
Vanadium	3	12	0.5	0.4	0.4	0.6	0.2	0.7	0.2
Zinc	1	9	56.7	32	17.4	53.0	12	160	57.4
Zinc	2	19	86.7	36	13.0	74.0	7.6	420	124.9
Zinc	3	15	177.9	63	12.4	122.0	12	1800	451.4

*****Q_25 represents the first quartile or the median of the lower half of the data set. This means that about 25% of the numbers in the data set lie below this number and about 75% lie above it. Q-75 represents the third quartile or the median of the upper half of the data set. This means that about 75% of the numbers in the data set lie below this number and about 25% lie above it.