3rd International Conference on Public Policy (ICPP3)

June 28-30, 2017 – Singapore

T16P13 - Policy to Sustain Drinking Water Topic : Sustainable Development and Policy Session 1

Policy to Sustain Drinking Water

Water Quality Index (WQI) is a realistic public policy to monitor and prevent drinking water related illness in North America.

Author(s)

Stephanie Baiyasi-Kozicki - Central Michigan University - United Statesstephaniebaiyasi@yahoo.com Zigmond Kozicki - University of Detroit Mercy-zigpsych@sbcglobal.net

Date of presentation

Thursday, June 29th 10:30 to 12:30 (Block B 3 - 5

Water Quality Index (WQI) is a realistic public policy to monitor and prevent drinking water related illness in North America.

Stephanie Baiyasi-Kozicki - stephaniebaiyasi@yahoo.com - Central Michigan University - United States
Zigmond Kozicki - zigpsych@sbcglobal.net - University of Detroit Mercy

Abstract

The United States (US) currently does not have a drinking water quality index. The recent crisis in Flint, Michigan, has brought the need for a US drinking water quality index to the forefront of discussion and anticipated action. Flint is located 70 miles north of Detroit in Michigan and has roughly 98,310 residents, 41.6% of which live below the poverty line (CNN, 2016). The median household income in Flint is $24,679 as compared to $49,087 for other Michiganders. Residents in Flint, Michigan, were exposed to high levels of lead and pathogens in their drinking water which resulted in 10 deaths due to *Legionella* infection and many children exposed to high lead levels in their drinking water.

The Flint, Michigan, drinking water emergency demonstrates why communities in the United States need a Water Quality Index (WQI). The EPA should provide a Water Quality Index similar to the Air Quality Index (AQI). The Flint Water emergency demonstrates how vulnerable thousands of people can become when they are not informed of potential health threats in their drinking water. The Flint, Michigan, drinking water disaster is a result of a flawed National and State policy regarding drinking water testing. The public health disaster could have been avoided if local and state health agencies had properly conducted regular point-of-use drinking water testing for contaminants and opportunistic pathogens. Each U.S. State should now consider operating a Water Applied Testing and Environmental Research (WATER) Center to support public health surveillance of drinking water. These WATER centers should be independent of State and local agencies and provide unbiased results.

Utilizing a WQI is a realistic policy in North America as proven by the Canadian Council of the Ministers of the Environment who developed a drinking water quality index in 2001 (Government of Newfoundland and Labrador, 2016). A water quality index has the intent of providing a tool for simplifying the reporting of water quality data (Government of Newfoundland and Labrador, 2016).

Introduction

What do people in any community need to prevent drinking water related illness? The 2014-2017 Flint, Michigan, USA drinking water emergency demonstrates why communities in the United States and probably in North America need a Water Quality Index (WQI).

In 2015, it became public knowledge that population health threats in Flint, Michigan, developed as a result of people being exposed to municipal water contaminated with toxic lead and opportunistic pathogens (OPs). It would be wrong to say that this happened only because of a decision by the State governor's emergency manager to discontinue using water from Lake Huron and replace it with Flint River water to save money. The disaster in Flint, Michigan, was set in motion decades earlier. The Flint River drinking water emergency is a result of a flawed national policy which allowed improperly conducted or infrequent point-of-use water testing for contaminants and opportunistic pathogens to remain the standard.

The Planning Fallacy: The Flint Water Public Health Disaster

In November 2011, Michigan Gov. Rick Snyder, declared that Flint, Michigan, was in a state of financial emergency. He appointed the first in a series of four unelected managers who controlled the municipal government. The mandate for these emergency managers was to cut costs and balance budgets. Up until the emergency managers turned the municipality over to an advisory board, the governor's appointees implemented a series of reforms they claimed would return Flint to financial solvency. One such reform involved the emergency managers canceling Flint's longstanding water agreement with the Detroit Water Authority in order to join a newly formed regional water authority that had proposed to build a pipeline to Lake Huron. *"Boosters proclaimed that the pipeline would save the city $18 million over eight years, but it could not be completed until well into 2016. To meet immediate water needs, Flint's emergency managers elected to use the polluted Flint River"* (Highsmith, 2016).

The decision by the appointed emergency managers fell into what decision making experts Thaler and Sunstein (2008) recognize as the "planning fallacy" In this fallacy, the forecasts regarding the switchover to Flint River water were flawed and biased. The city emergency manager and the Michigan Department of Environmental Quality (MDEQ) apparently expected the switchover to be without public health risk and to result in a cost savings. They considered the water quality from the Flint River to be adequate to meet US National Public Drinking Water Standards (NPDWR) standards. They had a bias toward saving money and ignored the safety risks.

Flint, Michigan, like most cities in the United States of America is trapped in a community infrastructure decline because of decades of political inertia. "At the dawn of the 21st century, much of the USA drinking water infrastructure is nearing the end of its useful life" (American Society of Civil Engineers, 2016). Flint, Michigan, like many communities in the United States, has miles of lead pipes that should have been systematically replaced on or after June of 1986 with the passage of section 1417 of the Safe Drinking Water Act (SDWA) which prohibited the use of lead pipes, solder and flux in the United States of America (EPA, 2016b). Until the 1950s, these galvanized pipes contained lead and had a layer of zinc inside to inhibit the lead leaching into the drinking water. Various chemical reactions can corrode the zinc layer and then the flowing water can pick up lead which ends up being consumed by community water users (Fox, 2016).

> *Although Congress banned lead water pipes 30 years ago, between 3.3 million and 10 million older ones remain, primed to leach lead into tap water by forces as simple as jostling during repairs or a change in water chemistry* (Wines & Schwartz, 2016).

As a result of the Flint Emergency Managers' decision on April 25, 2014, the Flint water authority began using the Flint River as the municipal drinking water source (Felton, 2016; MLive, 2015). In hindsight, before the switch to the Flint River water, the Flint water authority should have extensively tested the water distribution system for known contaminants and pathogens. There should have been baseline measurements of the water quality. After the switch on April 25, 2014 to the Flint River water, there should have been continual (at least weekly) monitoring for all known contaminants and pathogens.

> *"Experts say the testing could have been done before the switch from the Detroit system. But officials from the Michigan Department of Environmental Quality (MDEQ) note that that kind of testing isn't required under federal drinking-water rules and has never been done in Michigan. What's more, they said, the Flint River water, treated in the city's plant, was already approved as a backup supply in case of interrupted service from Detroit.*
>
> *Other experts said the testing is more nuanced, part art and part science. Still, they acknowledge that by examining things such as the acidity of water and other factors, engineers could have estimated how much corrosion to expect once water from the Flint River was pumped into homes and businesses across the city"* (Wisely & Erb, 2015).

Events in the community in 2014-2015 should have been sufficient to alert the MDEQ to begin adequately testing the Flint drinking water.

- General Motors announced in October 2014 that it was pulling its engine plant off Flint water after workers there began noticing rust spots on newly machined parts. The city of Flint water authority and the emergency manager approved letting GM switch to Lake Huron water from neighboring Flint Township, but didn't change its own water treatment procedures.
- Water testing in the fall of 2014 found E. coli in the city's water system, prompting "boil water" notices. The city's procedures for killing the E. coli produced chemical by-products known as trihalomethanes (THMs), which can cause cancer with long-term

exposure. The city had to adopt additional measures to reduce the THMs (Wisely & Erb, 2015).

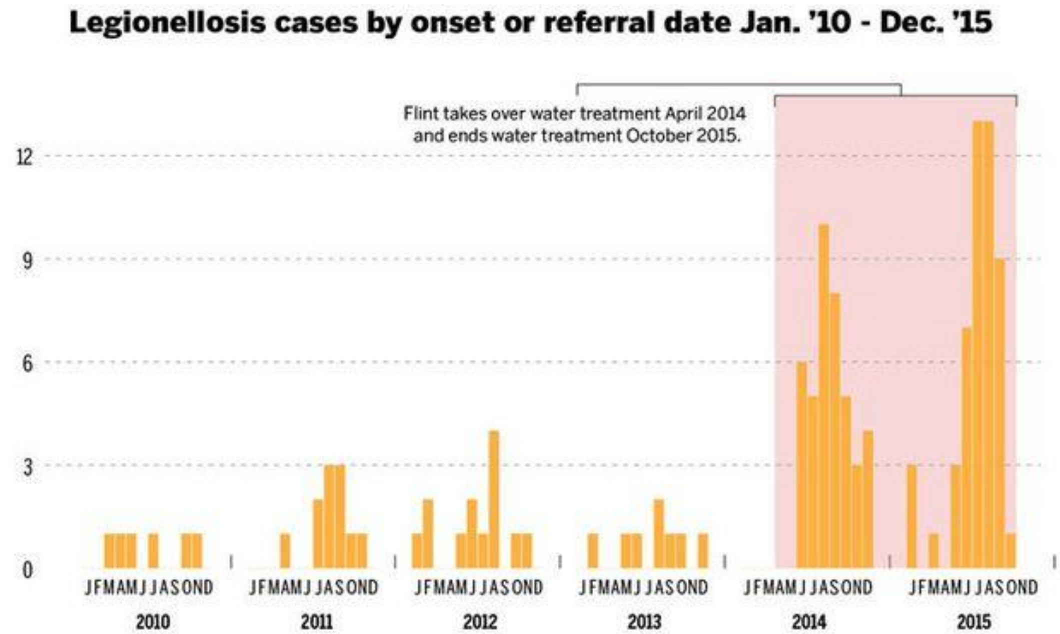
- The University of Michigan-Flint alerted city officials that it found elevated lead levels in its water in January 2015, prompting the school to shut off some drinking fountains and add water filters to others (Wisely & Erb, 2015).
- An internal report from the Michigan Department of Health and Human Services warned that lead poisoning rates "were higher than usual for children under age 16 living in the City of Flint during the months of July, August and September, 2014 (Delaney, 2015). It should have become obvious to the Flint Water Authority and the MDEQ by July of 2014 that Flint's drinking water had become contaminated (Bouffard, 2016). The Genesee county government eventually declared a public health emergency and told people to stop drinking the Flint River water in October of 2015 (Delaney, 2015).

It was already too late for many Flint water users when, a year after the switch to Flint River water in April of 2015, researchers from Virginia Polytechnic University (AKA Virginia Tech) tested the Flint drinking water at the request of a Flint water user and they discovered leads levels in that water that the U.S. Environmental Protection Agency classifies as hazardous waste (Korth, 2016).

Methods and Data

In addition to thousands of people being poisoned with lead, seventy-eight people in the county contracted *Legionella* disease during 2014-2015. "The presence of *Legionella* in Flint was widespread," said Dr. Janet Stout, a research associate professor at the University of Pittsburgh and a national expert on the disease. "The (laboratory) results show that strains (of the bacteria) were throughout the water system." The *Legionella* outbreak killed 12 people in 2014 and 2015. Although no *Legionella* was found in Flint Township, which never used Flint River water, the bacteria was found in Flint tap water at various locations, supporting the theory that interrupted corrosion control in Flint caused a release of iron, nutrients and depleted chlorine residual into the entire distribution system, supporting the abundance of *Legionella*. (Fonger, 2017). See Figure 1. *Legionella* Outbreak Flint Michigan 2014-2015.

Figure 1. *Legionella* Outbreak Flint Michigan 2014-2015



Source: MLive, 2017

There is no apparent good excuse for not testing the water, especially in the weeks following the switch to Flint River water when Flint residents began to complain about the smell and the taste of the water. These complaints should have provided a good reason to identify, by testing, the drinking water contents. If the City of Flint had a Water Quality Index (WQI), residents could have been warned and water management efforts to mitigate the emergency would have been initiated.

Local and State Officials failed to follow the Federal water testing procedures

In the United States, Federal drinking water compliance monitoring consists of two six-month sampling rounds. In Flint, Michigan, from June 2014 through December 2014, the city tested 100 homes. “By law, the same 100 homes were supposed to have been sampled again during the second six-month round of testing, which began January 1, 2015. There is a '90th percentile test' used to determine compliance, if more than 10 percent of those samples are above the federal action level of 15 parts per billion, the city would fail to meet the lead action level, and would be required to immediately alert the public to the problem and start taking steps to reduce lead in water” (Guyette 2015).

In Flint, Michigan, however, the second round of testing ended with only 71 samples collected by the city, instead of the 100 minimum previously required. In response, the MDEQ made a decision and an exception stating that because Flint's population is less than 100,000, the 71 homes tested would be sufficient. Surprisingly, of the 71 homes that were sampled in 2015, only 13 were from the previous list tested in round one. Moreover, all of those 13 homes showed low levels of lead during the initial round. None of the homes with lead above the action level tested in 2014 were selected. "This is called 'cherry picking’ sites to find low lead, and it is against the law," according to Virginia Tech researcher Marc Edwards (Guyette, 2015).

In January 2015, city officials issued boil orders because of coliform bacteria problems. This was another opportunity to complete a comprehensive test of the Flint water system and possibly discover that opportunistic pathogens and lead levels in the water were a threat to the public It is noteworthy to point out that at the point in time of the boil orders, the Detroit water authority offered to reconnect Flint back to their Lake Huron water system, but the emergency manager did not support the reconnection in part because it would cost the city of Flint about $1 million a month for water from the Detroit Water Authority. Water quality was apparently not considered by the emergency manager as a determinant in the decision to reconnect to the Detroit water source. (MLive, 2015).

There has been criticism directed at the slow response of the U.S. Environmental Protection Agency (EPA) and blame has been aimed at this agency. However, it is important to understand the role of the EPA in this water emergency. The EPA has a history of deferring authority to each U.S. State government to manage water quality.

> *“Since EPA's founding in 1970, the Agency's regulatory powers and responsibilities have been the subject of intense debate. Much of that debate has been specific to EPA and the problems it handles: protection of public health and restoration of the natural environment. There is, however, a larger context: nothing less than the role of the federal government at large, and how that role should be defined and redefined as the nation's needs change”* (Lewis, 1988).

The lack of intervention by the EPA in Flint is characteristic of the EPA approach, which is to rely and expect State officials to manage drinking water in their communities and follow national primary drinking water regulations (NPDWRs). Certainly “the slow responses of local, state and federal officials to this crisis, as well as their penchant for obfuscation, prolonged the lead exposure” and possibly allowed for the infiltration of opportunistic pathogens (Highsmith, 2016).

The Environmental Protection Agency developed in part because of the work completed by the Federal Water Quality Administration (FWQA) which was formed in 1965 and the National Air

Pollution Control Administration (NAPCA) which originated as a research body in 1955. The FWQA and NAPCA were originally part of the Public Health Service. Both of these federally administered programs were foundational for the creation of the EPA. As such, these programs influenced the mission of the EPA to be more committed to public health than to environmental protection. In the United States, public health *"…has a pattern of not intervening in any problem unless invited by state officials"* (Lewis, 1988). As a result of this policy, the United States enforcement of water quality has a strong reliance on state government officials. The Flint water crisis occurred under the authority of the State MDEQ and the State governor's emergency manager. The EPA waited for the State of Michigan to invite them to intervene.

Inadequate Water Testing Exposed Thousands of People to Toxins

The 98,000 residents of Flint, a rust belt city, have been grappling with a public health crisis for more than two years since the state, in a move to save money, switched the city's water supply from Lake Huron to the Flint River (Almasy, 2017).

Approximately 90,000+ people in Flint, Michigan, were exposed to toxic water and opportunistic pathogens in part because the MDEQ did not enforce Federal rules regarding water testing. This environmental disaster was preventable if a WQI was in operation and the human suffering could have been mitigated. The testing would have revealed that among other things, lead levels were high which would have alerted people that the failure to use proper anti-corrosive agents was leaching lead into the city's water. The water testing would have also revealed that opportunistic pathogens in the water system were probably increasing during the transition to the Flint River water.

Fortunately for Flint residents, in April of 2015, Virginia Tech water researcher, Dr. Marc Edwards, received a water sample from a Flint resident, Lee Anne Walters. Walters sent the sample to Edwards after he was recommended by a source within the Michigan EPA office. That water sample tested at twice the level of lead that would normally be considered hazardous waste. After testing the Flint water sample, the Virginia Tech engineering team led by Dr. Marc Edwards, at their own expense, completed four sampling and public relations trips to Flint between early August and December of 2015. The Virginia Tech drinking water testing team was not compensated by the State of Michigan or invited by the MDEQ to conduct drinking water testing in Flint, Michigan. With the help of Flint residents, they distributed 300 home testing kits and had 276 returned for analysis. In addition, they tested 20 homes and businesses in Flint and took more than 100 samples from large buildings. The Virginia Tech researchers revealed what the MDEQ should have discovered - that there were very high lead levels in the Flint water system after the switch to Flint River water (Korth, 2016).

What is worth mentioning is that Virginia Polytechnic University is located 543 miles from Flint, Michigan. The research and testing team drove more than nine hours to reach Flint, Michigan.

There are at least five universities in the State of Michigan that could have been involved in the Flint water testing. The MDEQ and the Flint based Genesee County Health Department could have been testing the water and alerted the Flint community about a waterborne threat. Unfortunately, they were not utilized to conduct drinking water testing.

Equally significant and happening about the time the Virginia Tech team was busy testing Flint drinking water, Flint Hurly Medical Center pediatrician, Dr. Mona Hanna-Attisha, took it upon herself to conduct epidemiological studies of children to determine their exposure to lead in the water. Her unfunded research amazingly met the Class II CDC standard for testing. Her research ultimately alerted the Genesee County Public Health Department and the community on September 24, 2015, that the toxic water in Flint, Michigan, had poisoned hundreds of children with lead. Dr. Mona Hanna-Attisha conducted research at Flint Hurley Medical Center using data from over 1700 Flint infants and children. The research conducted at Flint Hurley Medical Center demonstrated that children in Flint, Michigan, experienced elevated lead levels in their blood after the city switched back to using the Flint River as a drinking water source.

State officials initially disputed the findings of both the Virginia Tech researchers and Dr. Mona Hanna-Attisha. Eventually the state officials accepted their research and agreed that lead levels are elevated in Flint children. More than 8,000 Flint children are likely effected by lead poisoning (Erb, 2015).

The MDEQ may have intentionally ignored Freedom of Information Requests (FOIA) requests for information about their own water testing results. Marc Edwards, a civil engineering professor from Virginia Tech University and a nationally renowned expert on water treatment, put the blame squarely on the Michigan Department of Environmental Quality, the agency in charge of overseeing the safety of Flint's drinking water (Brush, 2015). A congressional investigation was conducted in 2016 to determine the reasons for the Flint water public health disaster.

Congressional Republicans quietly closed a year-long investigation into Flint, Michigan's crisis over lead in its drinking water, faulting both state officials and the Environmental Protection Agency for contamination that has affected nearly 100,000 residents. They concluded that federal officials were slow in detecting high levels of lead in the water and did not act fast enough once the problem was discovered. "The committee found significant problems at Michigan's Department of Environmental Quality and unacceptable delays in the Environmental Protection Agency's response to the crisis," wrote Rep. Jason Chaffetz, R-Utah. "The committee also found that the federal regulatory framework is so outdated that it sets up states to fail" (Daly, 2016).

> *Ultimately, water problems in Flint and elsewhere [in the United States] suggest a failing in society's concept of water, said Henry L. Henderson, the Midwest program director for the Natural Resources Defense Council. "We see safe and sufficient water as a*

human right," he said. "It needs to be approached as a public service matter, not a private commercial commodity." (Wines & Schwartz, 2016).

The Oversight of Drinking Water

Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices. Most water quality indices rely on normalizing, or standardizing, data parameters according to expected concentrations and some interpretation of 'good' versus 'bad' concentrations. Parameters are often then weighted according to their perceived importance to overall water quality and the index is calculated as the weighted average of all observations of interest (Pesce & Wunderlin, 2000; Stambuk-Giljanovic, 2003; Sargaonkar & Deshpande, 2003; Liou et al., 2004; Tsegaye et al., 2006). A summary of the indices are provided in Table 1 (United Nations Environment Programme, 2007).

Table 1: Summary of indices developed which assess water quality on a national or global level

Index	**Objective**	**Method**	**Use/ Distribution**	**Author**
The Scatterscore index	**Water quality**	**Assesses increases or decreases in parameters over time and/or space**	**Mining sites, USA**	**Kim and Cardone (2005)**
The Well-being of Nations	**Human and Ecosystem**	**Assesses human indices against ecosystem indices**	**Globally**	**Prescott-Allen (2001)**
Environmental Performance Index	**Environmental health and ecosystem vitality**	**Uses a proximity-to-target measure for sixteen indices categorized into six policy objectives**	**Globally**	**Levy et al. (2006)**
Index of River Water Quality	**River health**	**Uses multiplicative aggregate function of standardized scores for a number of water quality parameters**	**Taiwan**	**Liou et al. (2004)**
Overall Index of Pollution	**River health**	**Assessment and classification of a number of water quality parameters by comparing**	**India**	**Sargaonkar and Deshpande (2003)**

		observations against Indian standards and/or other accepted guidelines e.g.WHO		
Chemical Water Quality Index	**Lake basin**	**Assesses a number of water quality parameters by standardizing each observation to the maximum concentration for each parameter**	**USA**	**Tsegaye et al. (2006)**
Water Quality Index for Freshwater Life	**Inland waters**	**Assesses quality of water against guidelines for freshwater life**	**Canada**	**CCME (2001)**

Source: United Nations Environment Programme, 2007

Canadian Government North America

Drinking Water Quality Index (WQI)

A Water Quality Index is a means by which water quality data is summarized for reporting to the public in a consistent manner. It is similar to the ultraviolet (UV) index or an air quality index, and it tells us, in simple terms, what the quality of drinking water is from a drinking water supply.

The Canadian Council of Ministries of the Environment (CCME), in 2001, developed a WQI with the intent of providing a tool for simplifying the reporting of water quality data. Prior to the implementation and modification of the WQI for reporting drinking water quality in Newfoundland and Labrador, pilot level testing was carried on selected public water supply systems and a paper describing the "Modification and Application of the CCME WQI for the Communication of Drinking Water Quality Data in Newfoundland and Labrador" was published in the national journal "Water Quality Research Journal of Canada" to allow scientific scrutiny of the use of the CCME WQI for drinking water quality reporting. The methodology described in the paper has been further refined to screen and highlight current aesthetic exceedances. The WQI is a summary tool and does not replace detailed analysis of drinking water quality data.

Essentially the WQI is calculated using guidelines for Canadian drinking water quality. The WQI measures the scope, frequency, and amplitude of water quality exceedances and then combines the three measures into one score. This calculation produces a score between 0 and 100. The higher the score the better the quality of water. The scores are then ranked into one of the five categories described below:

- Excellent: (WQI Value 95-100) - Water quality is protected with a virtual absence of impairment; conditions are very close to pristine levels. These index values can only be obtained if all measurements meet recommended guidelines virtually all of the time.
- Very Good: (WQI Value 89-94) - Water quality is protected with a slight presence of impairment; conditions are close to pristine levels.
- Good: (WQI Value 80-88) - Water quality is protected with only a minor degree of impairment; conditions rarely depart from desirable levels.
- Fair: (WQI Value 65-79) - Water quality is usually protected but occasionally impaired; conditions sometimes depart from desirable levels.
- Marginal: (WQI Value 45-64) - Water quality is frequently impaired; conditions often depart from desirable levels.
- Poor: (WQI Value 0-44) - Water quality is almost always impaired; conditions usually depart from desirable levels.

WQI scores are computed for each public water supply system that has been sampled in a sampling season. The same variables are used in the computation of the WQI for all public water supply systems and only the six most recent samples are used. However if a public water supply system is on a boil water order, or it has a current contaminant exceedance, or has a THMs average above the drinking water quality guideline, a WQI score is not computed (Government of Newfoundland and Labrador, 2017).

US Federal Government

In the United States of America, the Environmental Protection Agency (EPA) is ultimately responsible for setting the maximum allowable level of a contaminant (MCL) in a public drinking water supply. The MCL works in conjunction with the national primary drinking water regulations (NPDWRs). NPDWRs are legally enforceable standards that protect public health by limiting the levels of contaminants in public drinking water (EPA, 2015, December 8; The National Institute of Environmental Health Science, 2015).

The EPA also maintains a Contaminant Candidate List (CCL). This is 100 potentially risky chemicals and 12 microbes that are known or expected to be found in public water systems, but are not yet regulated. These are contaminants that are currently not subject to any proposed or promulgated national primary drinking water regulations, but are known or anticipated to occur in public water systems. Contaminants listed on the CCL may require future regulation under the Safe Drinking Water Act (SDWA). The EPA has also required water systems to test for 80 additional contaminants to see whether they merit regulation (EPA, 2016, February 8; Wines & Schwartz, 2016).

EPA sets legal limits on over 91 contaminants in drinking water. The legal limit for a contaminant reflects the level that protects human health and that the water treatment systems can achieve using the best available technology. EPA rules also set water-testing schedules and methods that water systems must follow. See Table 2 for a summary of drinking water contaminants over time. The SDWA gives individual states the opportunity to set and enforce their own drinking water standards if the standards are at a minimum as stringent as EPA's national standards (EPA, 2015, November 9).

Table 2. EPA History of Recognizing Contaminants to Drinking Water

Time Frame	Number of Contaminants
1974–1986	22
1986–1996	83
1996-2014	91

Source: EPA, 2015

US State Government

The State Review Framework (SRF) consistently assesses EPA and state enforcement of the Clean Water Act (CWA), the Clean Air Act (CAA), and Resource Conservation and Recovery Act (RCRA). The SRF was designed collaboratively in 2004 by EPA and the Environmental Council of the States (ECOS) (EPA, 2015, July 21).

The ECOS is the national non-profit, non-partisan association of state and territorial environmental agency leaders. The purpose of ECOS is to improve the capability of state environmental agencies and their leaders to protect and improve human health and the environment of the United States of America (ECOS, 2016). The ECOS Water Committee was established to facilitate discussions among State colleagues concerning important water related issues. It is mostly a voluntary organization.

> ECOS' Executive Director and General Counsel, Alexandra Dapolito Dunn, provided an official statement about the Flint water emergency. *"As a national organization dedicated to state to state experience sharing and capacity building, ECOS will take proactive steps in our programs, educational opportunities, and dialogues to reduce the possibility of repeating events similar to those that led to Flint's serious situation."* (ECOS, 2016).

Currently in the United States, the Waterborne Disease and Outbreak Surveillance System (WBDOSS) is the primary source of data concerning the scope and health effects of waterborne disease. The CDC and the EPA periodically review outbreak reports from U.S. states and jurisdictions and report on outbreak characteristics, including the water systems, venues, settings, numbers, and causes of outbreak-related illnesses. Because the water testing in the United States is essentially left up to each State to administer and given that local community water systems determine the method and often the frequency of testing and reporting, the WBDOSS is most often underreporting waterborne drinking water threats to public health.

In the United States, there is some interest in a developing a WQI. The State of Washington, for example, has developed a basic WQI intended as a tool to summarize and report routine stream monitoring data. This is not intended to rate drinking water. The State of Washington's WQI is a unitless number ranging from 1 to 100; a higher number is indicative of better water quality. Scores are determined for temperature, pH, fecal coliform bacteria, dissolved oxygen, total suspended sediment, turbidity, total phosphorus, and total nitrogen. Constituent scores are then combined and results aggregated over time to produce a single yearly score for each sample station. This report presents the methodology behind the WQI and the results of a trend analysis on monthly WQI scores at long-term monitoring stations (Washington State Department of Ecology, 2016).

Discussion

The human tragedy in Flint, Michigan, should remind all of us that there is an ongoing threat in every American city from contaminants and waterborne pathogens. The poisoning of thousands of people with lead in the drinking water in Flint, Michigan, and the outbreak of *Legionella pneumophila* could have been avoided if the city and state had an effective water testing protocol. Adequate water testing would have exposed the threat(s) and resulted in warning the Flint residents about the lead and opportunistic pathogens in the water. Appropriate action could have prevented this public health water emergency (Warren, 2016).

The water emergency in Flint, Michigan, should alert the U.S. Congress that they need to upgrade the Safe Drinking Water Act (SDWA) standard for water testing in the United States. Testing and treatment of drinking water is authorized through the EPA by the SDWA. The United States needs a national water testing program with labs in 50 states conducting daily drinking water testing at the point of use. Flint, Michigan, is equivalent to ground zero for the latest waterborne threat in America and presents a call to everyone in the water industry and national and state leaders to take action to improve and increase drinking water testing.

If the United States EPA tested water daily at all 15,000 health care facilities, at government buildings and public schools in the United States we could have a Water Quality Index (WQI) similar to the Air Quality Index (AQI). The AQI is an index for reporting daily air quality. It tells you how clean or polluted your air is, and what associated health effects might be a concern for you (EPA, 2016a). We need the same kind of measure for water. If we had had a WQI in Flint, Michigan, 100,000 people could have probably avoided lead poisoning and at least nine people who died from the exposure to *L. pneumophila* would probably be alive. Although there is no globally accepted composite index of water quality, some countries and regions have used, or are using, aggregated water quality data in the development of water quality indices (Rickwood &

Carr, 2007). With direction from the US Congress, the states could, under the direction of the EPA, develop a WQI in each US State.

Drinking Water Threats

The present U.S. monitoring system for lead poisoning is not working. The city of Flint is the most recognized example of a failed monitoring system. Incredibly, Flint is also an example of how a community hospital could be used to utilize epidemiology data to identify a threat to people and reverses the threat from a waterborne source. Consider that there are 3,143 counties in the United States and only 1,573 reported lead poisoning data in 2014. Forty-four percent of those counties reported no confirmed cases of lead in the bloodstream of people (CDC, 2015). This suggests that surveillance of lead exposure is probably not occurring in about 50% of the US counties.

> *The drinking water community needs better data from several perspectives, including health effects data. Right now the drinking water community seems to be chasing smaller and smaller risks in drinking water. Are we at the margins of science for future regulations providing a "meaningful opportunity for risk reduction" as required by the SDWA (noting that that decision is the sole judgment of the USEPA Administrator)? This uncertainty makes it more challenging to explain rate increases to customers when additional treatment is needed for compliance with regulations when the underlying science is debatable at best* (Roberson, 2014).

In addition to lead, there are a host of threats in drinking water that are enhanced risks to the very young, old, pregnant, and immunocompromised individuals living in America (Leclerc, Schwartzbrod, & Dei-Cas, 2002). Unfortunately, the common practice in the United States is to almost exclusively rely on regular testing at the water plant and not necessarily at the point of use. In addition, most testing protocols do not fully consider all of the possible contaminates and pathogens in a given local water risk pool.

According to the National Resource Defense Council (NRDC) (2003), tap water can contain a vast array of contaminants and some show up repeatedly in the water of U.S. cities:

- Lead - can enter drinking water supplies from the corrosion of pipes and plumbing fixtures and can cause brain damage in infants and children
- Pathogens (germs) - can make people sick, especially those with weakened immune systems, the frail elderly and the very young

- By-products of chlorine treatment such as trihalomethanes (THMs) and haloacetic acids - may cause cancer and reproductive problems
- Arsenic - may cause cancer, serious skin problems, birth defects and reproductive problems
- Radon, the rocket fuel perchlorate and other carcinogens or otherwise toxic chemicals which may create health problems

"The presence of OPs in drinking water is a danger that is not directly addressed by existing Federal Regulations" (Garner, 2015). The recognized opportunistic premise plumbing pathogens include:

- *Legionella pneumophila*,
- *Mycobacterium avium* and other nontuberculous mycobacteria (NTM),
- *Pseudomonas aeruginosa*.

(Falkinham, Pruden, Edwards, & LeChevallier, 2015)

Legionella and *Mycobacterium avium* complex (MAC) are environmental pathogens that have found an ecologic niche in drinking and hot water supplies. Numerous studies have reported Legionnaires' disease caused by *L. pneumophila* occurring in residential and hospital water supplies. In addition, Norwalk virus and Norwalk-like viruses are recognized as the major causes of waterborne illnesses world-wide. The most striking concern is that enteric viruses such as caliciviruses and some protozoan agents, such as *Cryptosporidium*, are the best candidates to reach the highest levels of endemic transmission, because they are ubiquitous in water intended for drinking, being highly resistant to relevant environmental factors, including chemical disinfecting procedures (Leclerc, Schwartzbrod, & Dei-Cas, 2002).

The American Water Works Association (AWWA) (2008) has made it known that there is a need for a more comprehensive approach to monitoring and managing U.S. drinking water. "The best available, peer-reviewed science must remain the foundation for the development of national drinking water regulations … Clearly, more research is needed before science-based decisions on many trace contaminants can be made … AWWA recommends that EPA consider additional options for both increased transparency to stakeholders and stakeholder engagement in future CCLs" (AWWA, 2008). Had there been a comprehensive approach to monitoring and managing Flint River water, the poisoning of 100,000 could have been avoided. The challenge is to expand water testing for known contaminants and pathogens and in more locations throughout the United States.

> The Safe Drinking Water Act currently recognizes 91 contaminants when in reality tens of thousands of chemicals are used in the United States, including more than 8,000 being monitored by the EPA. Many of the health effects of these chemicals remain unclear. Studies have linked an array of unregulated chemicals to cancer, hormonal changes and

other health problems. Some regulated contaminants haven't had their standards updated since the 1970s and new pollutants have not been added to the list since 2000 (McLendon, 2011).

Researchers and people in the water industry recognize that problems extend beyond lead contamination. Many other potentially harmful contaminants have yet to be evaluated let alone end up making it to the EPA list to be regulated. Efforts to address these threats usually encounter a pushback from the business sector including agriculture and mining because they fear cost increases that come with new standards. In addition, opposition can come from politicians, who are ideologically opposed to regulation (Wines & Schwartz, 2016).

A Joint Effort

Canary in the Coal Mine

What should the people of Flint, Michigan, and the United States expect from their government with regard to having water that is safe to drink? The Federal Emergency Management Agency (FEMA) has developed guidelines that are intended to mitigate any threat to people in the United States. If these guidelines have meaning, then a WQI is a logical method to protect a population from potential waterborne threats (FEMA, 2016 - or 2012? as in references...). See Table 3 for the FEMA Mitigation Mission Area Capabilities and Preliminary Targets.

The US FEMA guidelines promote a shared responsibility in protecting life and property (FEMA, 2012). The joint effort according to FEMA is described as "an integrated approach to emergency management and is based on solid general management principles and building partnerships with the community to protect life and property. For an integrated system, local, State, and Federal governments, as well as private-sector agencies and individuals and families, must share responsibility for applying resources effectively at every stage and phase of emergency management. While every part of the system has its own role and function, responsibility is shared among all. A joint effort results in a product that reflects the insights, experiences, and skills of the entire team" (FEMA, 2012).

Mitigation

Mitigation activities take place prior to, during, and after an incident. See Table 3 for an overview. Mitigation capabilities are those necessary to reduce or eliminate long-term risk to persons or property, or lessen the actual or potential effects or consequences of an incident. These include:

- Understanding, recognizing, communicating, planning for, and addressing risks.

- Building resilient systems, communities, and infrastructure to reduce vulnerability to incidents
- Identifying, analyzing, and planning for area threats and hazards.

Table 3. Mitigation Mission Area Capabilities and Preliminary Targets

Planning	Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or community-based approaches to meet defined objectives.
Public Information and Warning	Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard and, as appropriate, the actions being taken and the assistance being made available.
Operational Coordination	Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.
Community Resilience	Lead the integrated effort to recognize, understand, communicate, plan, and address risks so that the community can develop a set of actions to accomplish Mitigation and improve resilience.
Long-Term Vulnerability Reduction	Build and sustain resilient systems, communities, and critical infrastructure and key resources lifelines so as to reduce their vulnerability to natural, technological, and human-caused incidents by lessening the likelihood, severity, and duration of the adverse consequences related to these incidents.
Risk and Disaster Resilience Assessment	Assess risk and disaster resilience so that decision makers, responders, and community members can take informed action to reduce their entity’s risk and increase their resilience.
Threats and Hazard Identification	Identify the threats and hazards that occur in the geographic area; determine the frequency and magnitude; and incorporate this into analysis and planning processes so as to clearly understand the needs of a community or entity.

Source: FEMA, 2012

In order for the FEMA mitigation team mission to be successful the United States EPA provide a Water Quality Index (WQI) similar to the Air Quality Index (AQI).

Avoiding the Next Water Disaster

Flint, Michigan, is the site of one of the worst man-made public health emergencies related to unsafe drinking water in the United States. The decline in the Flint water system began decades before the crisis with the decay of drinking water infrastructure. The lack of an adequate policy made it a national disaster (Durando, 2016). The Flint water crisis is also the product of larger structural problems which, in Flint, included deindustrialization, disinvestment and depopulation which essentially depleted Flint's tax base and made it impossible to improve or maintain the city's crumbling infrastructure (Highsmith, 2016). The Flint public health emergency is a warning that unless changes are made, more communities will experience waterborne public health threats.

Here are changes that should be considered in order to avoid another water poisoning like what occurred in Flint, Michigan, in the United States:

- The EPA should provide a Water Quality Index similar to the Air Quality Index.
- The United States Congress needs to raise the priority of the nation's drinking water to the highest level of funding. To do so, Congress should appropriate a significant increase in funding for water quality research, water management, water infrastructure projects, water testing, water conservation projects and public education about water quality and water conservation. The actual amount should be tied to a strategic plan.
- The United States Congress in cooperation with the Executive Branch needs to create independent testing labs in each of the 50 U.S. States. These labs can become the responsible entity organized to act in conjunction with the national water research to certify water quality at the point of use. The State Labs could support a Water Applied Testing and Environmental Research (WATER) Center that would become the location where all relevant information about water quality and quantity would be analyzed. These state centers should serve to provide education and act as a research incubator for best practices related to water management. They would operate in conjunction with colleges and universities.
- The United States Congress should either pass legislation or request the U.S. Environmental Protection Agency and the U.S. Geological Services in conjunction with community public health agencies to take action to utilize existing government supported assets (i.e., government buildings, public schools, hospitals and healthcare facilities, military installations and government installations located in national parks, publicly held land, lakes, rivers and wetlands) to become water testing sites to create thousands of data points which could be used to provide the most accurate daily water quality index of the U.S. water supply.
- Members of the EPA and the water research community need to meet annually at the behest of the U.S. Congress to share information and promote the best practices in managing water. This annual congressional hearing should promote "a national conversation". The result of this annual meeting should also provide advisement about the state of the nation's water supply. This public disclosure should become useful to public policy planners and population health administrators to develop an ongoing and dynamic strategic plan regarding water quality and quantity for the United States population.
- Private industry should be given incentives to develop the most efficient and effective methods for producing safe and reliable drinking water for both humans and animals in the United States.

A National Infrastructure Water System plan needs to be developed and appropriations by the U.S. Congress should be provided to begin the overdue process of rebuilding our nation's crumbling infrastructure. The estimated national infrastructure replacement requires approximately $40 billion per year (Water Utility Council, 2012).

Conclusion

The United States Government, by investing in water quality and water quantity management, ensures that the public health and economic benefits for all things related to water is maximized. "While the private sector has a key role to play in making innovation happen, government must provide three key public-good inputs that allow innovation to blossom: investments in human capital, infrastructure, and research" (Pool & Erickson, 2012). Section 1442 of the SDWA authorizes the EPA to conduct research, studies, and demonstrations related to the causes, treatment, control, and prevention of diseases resulting from contaminants in water (Tiemann, 2014). Water research must be given sustained support and be unimpeded. The EPA must provide meaningful oversight and develop by way of evidence-based research health-based drinking water standards. Water testing should be ongoing to support a WQI for US communities. Decades of avoiding evidenced research about the quality of US water and the effect on the health of the U.S. population has become a national security issue.

References

American Water Works Association. (2008, May 21). Comments of the American Water Works Association (AWWA) on the draft Contaminant Candidate List 3 (CCL3) as published in the February 21st Federal Register (73 FR 9628). Retrieved from http://www.awwa.org/Portals/0/files/legreg/documents/AWWACCL3Comments.pdf

Almasy, S. (2017, January 25). Flint water lead amounts improve, below federal limits. *CNN*. Retrieved from http://www.cnn.com/2017/01/24/health/flint-water-crisis/index.html

American Society of Civil Engineers. (2016). 2013 report card for America's infrastructure. Retrieved from http://www.infrastructurereportcard.org/drinking-water/

Bouffard, K. (2016, January 21). *Legionella* bacteria no longer in Flint hospital's water. *Detroit News*. Retrieved from http://www.detroitnews.com/story/news/politics/2016/01/22/legionnaires-bacteria-found-tests-mclaren-medical-centers-water/79183428/

Brush, M. (2015, October 1). Who's to blame for Flint's water crisis? Virginia Tech researcher points the finger at MDEQ. *Michigan Radio*. Retrieved from http://michiganradio.org/post/whos-blame-flints-water-crisis-virginia-tech-researcher-points-finger-mdeq#stream/0

CDC. (2015, June 2). Strength-of-Evidence Classification for Waterborne Disease & Outbreaks. Retrieved from http://www.cdc.gov/healthywater/surveillance/outbreak-classifications.html

CDC. (2015, August 22). Waterborne Disease & Outbreak Surveillance Reports. Retrieved from http://www.cdc.gov/healthywater/surveillance/surveillance-reports.html

CDC. (2015, December 15). CDC's State surveillance data. Retrieved from http://www.cdc.gov/nceh/lead/data/state.htm

CNN. (2016). Flint water crisis time line. Retrieved from http://www.cnn.com/2016/01/20/health/flint-water-crisis-timeline/

CNN. (2016, December 21). Flint water crisis fast facts. Retrieved from http://www.cnn.com/2016/03/04/us/flint-water-crisis-fast-facts/

Daly, M. (2016, December 16). House quietly closes Flint. Mich water investigation. *Associated Press*. Retrieved from https://apnews.com/1f88599ad426455f8089060dc8d83307/dem-lawmaker-michigan-gov-snyder-stonewalling-flint

Delaney, A. (2015, December 21). Michigan Ignored 'Conclusive Evidence' Of Flint Lead Poisoning, Researcher Says. *Huffington Post*. Retrieved from http://www.huffingtonpost.com/entry/flint-michigan-water-lead_us_56784055e4b0b958f657595c

Durando, J. (2016, January 20). How water crisis in Flint, Mich., became federal state of emergency. *USA today*. Retrieved from http://www.usatoday.com/story/news/nation-now/2016/01/19/michigan-flint-water-contamination/78996052/

Environmental Council of States. (2016, February 3). Press statement on Flint water crisis. Retrieved from https://www.dropbox.com/s/bqsy39hc2l78jcq/ECOS%20Press%20Statement%20on%20Flint%20%282%29%20%281%29.pdf?dl=0

Environmental Protection Agency. (2014, February). Air quality Index. EPA-456/F-14-00 Retrieved from http://www.epa.gov/airnow/aqi_brochure_02_14.pdf

Environmental Protection Agency. (2015). Drinking water glossary, U.S. EPA, http://www.epa.gov/safewater/pubs/gloss2.html

Environmental Protection Agency. (2015, July21). State review framework for compliance and enforcement performance. Retrieved from http://www.epa.gov/compliance/state-review-framework-compliance-and-enforcement-performance

Environmental Protection Agency. (2015, November 9). Drinking water regulation information. Retrieved from http://www.epa.gov/dwreginfo/drinking-water-regulatory-information

Environmental Protection Agency. (2015, December 8). Table of Regulated Drinking Water Contaminants http://www.epa.gov/your-drinking-water/table-regulated-drinking-water-contaminants

Environmental Protection Agency. (2016a). Air Quality Index (AQI) basics Retrieved from http://airnow.gov/index.cfm?action=aqibasics.aqi

Environmental Protection Agency. (2016b). Section 1417 of the Safe Drinking Water Act: Prohibition on use of lead pipes, solder, and flux. EPA Drinking water contaminants, standards and regulations. Retrieved from http://www.epa.gov/dwstandardsregulations/section-1417-safe-drinking-water-act-prohibition-use-lead-pipes-solder-and

Environmental Protection Agency. (2016, January 6). Drinking water requirements for states and public water systems: lead and copper rule. Retrieved from http://www.epa.gov/dwreginfo/lead-and-copper-rule

Environmental Protection Agency. (2016, February 8). Contaminant Candidate List (CCL) and regulatory determination. Retrieved from http://www.epa.gov/ccl/draft-contaminant-candidate-list-4-ccl-4

Erb, R. (2015, October 12). Flint doctor makes state see light about lead water. *Detroit Free Press*. Retrieved from http://www.freep.com/story/news/local/michigan/2015/10/10/hanna-attisha-profile/73600120/

Falkinham, J. O., Pruden, A., Edwards, M., & LeChevallier, M. W. (2015, June). Opportunistic premise plumbing. doi: 10.3390/pathogens4020373 PMCID: PMC4493479

Felton, R. (2016, January 16). Flint water crisis. What went wrong? *The Guardian*. Retrieved from http://www.theguardian.com/environment/2016/jan/16/flints-water-crisis-what-went-wrong

FEMA. (2012). IS-230.c - Fundamentals of Emergency Management. Retrieved from https://emilms.fema.gov/IS230c/FEMsummary.htm

Fonger, R. (2017, February 16). CDC finds first genetic link between Legionnaires' outbreak, Flint water. *MLive*. Retrieved from http://www.mlive.com/news/flint/index.ssf/2017/02/cdc_finds_first_genetic_link_b.html

Fox. M. (2016, January 20). Flint water crisis isn't the first and won't be the last. *NBC News*. Retrieved from http://www.nbcnews.com/storyline/flint-water-crisis/flint-water-crisis-isn-t-first-won-t-be-last-n500626

Government of Newfoundland and Labrador. (2016, October 20). Drinking water quality index. Retrieved from Drinking Water Quality Index | Water Resources Management

Government of Newfoundland and Labrador. (2017, May 15). Drinking water quality index. Retrieved from http://www.mae.gov.nl.ca/waterres/quality/drinkingwater/dwqi.html

Guyette, C. (2015, September 16). An ACLU Michigan investigation has found a stream of irregularities in Flint's water tests. *Detroit Metro Times*. Retrieved from http://www.metrotimes.com/Blogs/archives/2015/09/16/an-aclu-of-michigan-investigation-has-found-a-stream-of-irregularities-in-flints-water-tests

Highsmith, A. R. (2016, January 29). Flint's toxic water crisis was 50 years in the making. *Los Angeles Times*. Retrieved from http://www.latimes.com/opinion/op-ed/la-oe-0131-highsmith-flint-water-crisis-20160131-story.html

Korth, R. (2016, January 23). Virginia Tech researchers fought for Flint in water crisis. *The Roanoke Times*. Retrieved from http://www.roanoke.com/news/education/higher_education/virginia_tech/virginia-tech-researchers-fought-for-flint/article_56fb09da-9e6a-5e11-9085-b48893e2380d.html

Leclerc, H., Schwartzbrod, L., & Dei-Cas, E. (2002). Microbial agents associated with waterborne diseases. *Crit Rev Microbiol. 28*(4):371-409. PMID: 12546197

Lewis, J. (1988, March). Looking backward: a historical perspective on environmental regulations. *EPA Journal*. Retrieved from http://www.epa.gov/aboutepa/looking-backward-historical-perspective-environmental-regulations

McLendon, R. (2011). How polluted is U.S. drinking water? *Mother Nature Network*. www.mnn.com/earth-matters/translating-uncle-sam/stories/how-polluted-is-us-drinking-water

MLive. (2015). How Flint water crisis emerged. Retrieved from http://www.mlive.com/news/flint/index.ssf/2015/10/how_the_flint_water_crisis_eme.html#0

MLive. (2017, February 16). Figure 1. *Legionella* Outbreak 2014-2015 Retrieved from http://media.mlive.com/newsnow_impact/photo/Genetic%20connections%20to%20Legionnaires-02.jpg

National Institute of Environmental Health Science. (2015). MCL.

Pesce, S. F., & Wunderlin, D. A. (2000). Use of water quality indices to verify the impact of Cordoba City (Argentina) on Suquia River. *Water Research*, *34*, 2915-2926.

Pool, S., & Erickson, J. (2012). The high return on investment for publicly funded research. *Center for American Progress*. www.americanprogress.org/issues/technology/report/2012/12/10/47481/the-high-return-on-investment-for-publicly-funded-research/

Rickwood, C., & Carr, G. M. (2007). Global Drinking Water Quality Index Development and Sensitivity Analysis Report. Burlington, Ontario: United Nations Environment Programme Global Environment Monitoring System (GEMS)/Water Programme. ISBN 92-95039-14-9. www.un.org/waterforlifedecade/pdf/global_drinking_water_quality_index.pdf

Roberson, J. A. (2014, August). The middle-aged Safe Drinking Water Act. *Journal of American Water Works Association, 106*, 8. DOI:10:5942/JAWA.2014.106.0118

Sargaonkar, A., & Deshpande, V. (2003). Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environmental Monitoring and Assessment 89*, 43-67.

Stambuk-Giljanovik, N. (2003). Comparison of Dalmation water evaluation indices. *Water Environment Research, 75*(5), 388-405.

Thaler, R. H., & Sunstein, C. R. (2008). Nudge: Improving decisions about health, wealth and happiness. *Yale University Press*. ISBN 978-0-300-12223-7

Tiemann, M. (2014). Safe drinking water act (SDWA): A summary of the act and its major requirements. *Congressional Research Service*. fas.org/sgp/crs/misc/RL31243.pdf

Tsegaye, T., Sheppard, D., Islam, K. R., Johnson, A., Tadesse, W., Atalay, A., & Marzen, L. (2006). Development of chemical index as a measure of in-stream water quality in response to landuse and land cover changes. *Water, Air, and Soil Pollution 174*, 161-179.

United Nations Environment Programme. (2007). Global Drinking Water Quality Index Development and Sensitivity Analysis Report Prepared. Global Environment Monitoring System (GEMS)/Water Programme. Page 3- 8. Retrieved from http://www.un.org/waterforlifedecade/pdf/global_drinking_water_quality_index.pdf ISBN 92-95039-14-9

Wines, M., & Schwartz, J. (2016, February 8). Unsafe lead levels in tap water not limited to Flint. *The New York Times*. Retrieved from http://www.nytimes.com/2016/02/09/us/regulatory-gaps-leave-unsafe-lead-levels-in-water-nationwide.html?ref=topics

Wisely, J., & Erb, R. (2015, October 11). Chemical testing could have predicted Flint's water crisis. *Detroit Free Press*. Retrieved from http://www.freep.com/story/news/local/michigan/2015/10/10/missed-opportunities-flint-water-crisis/73688428/

Water Utility Council. (2012). Buried No Longer: Confronting America's Water Infrastructure Challenge. AWWA, Denver. Retrieved from www.awwa.org/Portals/0/files/legreg/documents/Burie