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Flint, Michigan: Three years after the water crisis, where are we now?

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Abstract

In April 2016, the nation shined a spotlight on Flint, Michigan where the news of contaminated river water resulted in elevated blood lead levels in the city's children. Flint residents and community organizers had complained about the brown, smelly water for months before public officials and news organizations came to town. Flint-area healthcare providers and academics held forums and established research groups to investigate potential health problems related to the water crisis. Nurses at the University of Michigan-Flint, the local health department, and Federal health agencies collaborated to hold lead blood-drawing clinics for Flint community residents, including children. This article reports on three topics: a water crisis overview, where Flint is two and a half years later, and clinical implications for nurses and other healthcare providers.

Water crisis overview

Due to a financial crisis in the city of Flint, the governor of Michigan appointed an emergency manager (EM) to find cost savings measures for the city (Table 1). In April 2014, the EM terminated a contract with Detroit to use filtered water from Lake Huron and the city began using the Flint River as their primary source of drinking water [1]. Less than a month after the switch to the new water source, residents began complaining about the water's color, smell, and taste. Several boil alerts were issued due to elevated E. coli and total coliform levels in the water. Because the red corrosive water was damaging car parts at the Flint General Motors Corporation plant [2], the company's management decided to switch from Flint River water to Flint Township water, which still came from the Detroit water system. Despite complaints, Flint residents continued using Flint River water until October 16, 2015, when they switched back to water from the Detroit Water and Sewage Department due to elevated blood lead levels (BLLs) discovered in the city's children.

Dangers of lead exposure

According to the Agency for Toxic Substances & Disease Registry [3], lead is a dangerous toxin. The main target for lead toxicity in humans is the nervous system. Elevated lead levels (≥10μg/dl) pose health effects that include the following: seizures, stupor, delirium, coma, or death. Lead toxicity may manifest as hypertension, behavioral changes, decreased concentration, peripheral neuropathy, ataxia, tremor, headache, loss of appetite, weight loss, fatigue, muscle and joint aches, gout nephropathy lead colic, and anemia. In addition, the American College of Obstetricians and Gynecologist (ACOG) [4], pose that the nervous systems of children and developing fetuses are most susceptible to the damaging effects of this neurotoxin.

Vulnerable populations

Research indicates [5] that the way lead is stored in the body makes prenatal and postnatal exposure especially dangerous for the pregnant/lactating woman, fetus and nursing infants. Lead exposure during pregnancy and lactation can have lasting adverse effects distinct from exposure during other life stages, which includes the ability to conceive, maintain a healthy pregnancy, and to have a healthy infant.

Approximately 99% of the lead taken into the adult's body excretes as waste within a couple of weeks in comparison to 32% of lead taken into a child's body [3]. Additionally, childhood lead exposure can later effect females in their childbearing years, due to lead stored in the bone as a results of prior exposure, which mobilizes (in pregnancy and lactation) into maternal blood and breast milk, and adversely affects the developing fetus or nursing infant [5].

Nicholson and Cleeton [6] reported the policy changes, which reflects a continuous reduction in the Blood Lead Level (BLL) requiring public health initiatives, to reduce and monitor a child's lead level exposure. In the 1960's public health, intervened when a child's BLL was 60 μg/dl, which changed to 30μg/dl in 1975, 25 μg/dl in 1985, and 10 μg/dl in 1991. In 2012, the Advisory Committee on Childhood Lead Poisoning Prevention recommendation was 5ug/dl or more as an unhealthy exposure. Presently, the CDC reference value (≥5μg/dl) is the standard for identification of children with elevated BLL. ACOG [4] acknowledges the identified lower BLL and its effects on maternal health and infant outcomes.

Even though child BLLs have declined over the last 30 years, current estimates suggest that 4.5 million homes in the U.S. are exposed to high levels of lead and that half a million preschool aged children have elevated BLLs [7]. Lead a significant hazard, particularly in older homes (built before 1978) due to concentration of lead paint are often located in urban areas. Additionally, residual lead in soil from former

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Table 1. The Flint Water Disaster Timeline

Date	Event
2011	Michigan Takes over Flint's budget; A financial manager takes over; A study finds that making Flint River water drinkable would require treatment with an anti-corrosion agent at a cost of $100/day
April 2014	Flint River becomes new water source; Public officials publicly drink flint River water
May 2014	Foul water starts coming into homes
January 12, 2015	Detroit Water and Sewerage Department offers to reconnect Flint to its water supply and waive the $4 million connection fee; Flint officials decline this offer
February 26, 2015	The Environmental Protection Agency (EPA) and Michigan's Department of Environmental Quality discuss the high levels of Lead (Pb) found in water
July 2015	Internal EPA memo leaked showing high Pb levels at one woman's home which gave her son Pb poisoning; Regional EPA official states that "conclusions would be premature"
August 2015	Virginia Tech (VT) researchers launch their own investigation
Early September 2015	DEQ disputes VT researchers' findings about corrosion and lead leaching
September 2015	State publicly disputes a doctor's 'findings of elevated Pb levels in children; After a week, they change course and say she was right.
October 8, 2015	Flint is reconnected to Detroit water supply
October 19, 2015	State environmental chief admits mistake; States that adding the anti-corrosion agent that would have cost the state $100 a day would have prevented 90% of Flint's water problems
November 2015	Federal lawsuit filed by residents against governor, state of Michigan, the city of Flint, and other defendants; DEQ was not treating the river water with an anti-corrosive agent, in violation of federal law resulting in the water eroding the iron water mains, turning the water brown, and causing the seepage of lead into tap water.
December 29, 2015	DEQ chief quits
January 2016	Governor ask for FEMA's help; Water distribution activated by Michigan National Guard; Governor asks for federal aid, apologizes saying, "I will fix it"; Releases 250 pages of emails about Flint, dating back to 2014; One DEQ email explains that General Motors suspended use of Flint River water as "It was rusting car parts"
January 22, 2016	Legionnaires; disease bacteria found in water; Flint hospital officials say they noticed an increase in Legionnaires' cases coming in after Flint switched its water supply to Flint river.
January 28, 2016	Senators propose $600 million in federal funding for Flint with $200 million for healthcare of those affected by lead and $400 million for infrastructure; State gives $28 million in aid to Flint;$4 million used to treat children affected by lead; Other monies used for unpaid water bills, study of water system infrastructure, nine more school's nurses and supplies.
February 1, 2016	EPA regional administrator quits
February 9, 2016	Flint mayor says "$55 million needed to replace lead pipes"
February 19, 2016	Signs of Improvement, according to VT research group "Lead levels in drinking water are much better, but people should keep using lead filters and bottled water."
February 27, 2016	Governor's staff knew about Legionnaires' cases; The governor's office was warned by a DEQ official not to call the drinking water safe because of an increase in Legionnaires disease in the county almost a year before Gov. Snyder publicly disclosed the emergency.
April 20, 2016	Charges filed included tampering with evidence, willful neglect of duty, misconduct in office, evidence tampering, and violating the Safe Drinking Water Act
April 25, 2016	$229 million class action complaint filed representing 514 residents seeking more than $220 million from EPA due to negligence
July 29, 2016	Six state workers charged with crimes ranging from misconduct in office to willful neglect of duty; One official allegedly told an employee to delete emails about blood Pb data from July 2014
November 10, 2016	Judge orders bottled water to homes
December 20, 2016	Four officials charged with felonies; Two former emergency managers and two water plan officials accused of misleading the state's treasury department into letting the city borrow millions of dollars to participate in a pipeline project that required it to switch temporarily to Flint River water.
January 24, 2017	Lead levels are within standards; The MDEQ stats that lead levels in the city's water tested is below the federal limit in a six-month study
February 17, 2017	Report states institutional racism contributed to Flint's crisis; The Michigan Civil Rights Commission issues a 129-page report saying, "deeply embedded institutional, systemic, and historical racism' indirectly contributed to the ill-fated decision to tap the Flint River for drinking water as a cost-saving measure.

industrial sites and high traffic areas (lead gas deposits) are more profound in urban areas.

Prenatal exposure

According to Weiszecker [8], lead absorption primarily occurs in the respiratory, gastrointestinal and integumentary systems. Lead binds to hemoglobin carried in blood plasma. Its half-life is approximately 1 month in blood and 20 to 30 years in the bone. Greater than 90% of lead incorporates into the skeleton. Conditions that cause demineralization like pregnancy and lactation can lead to lead mobilization from maternal bone. Research findings from the CDC [5] indicates that lead crosses the placenta by passive diffusion and detected in the fetal brain by the end of the first trimester. Bijoor, Sudha and Venkatesh [9] identifies the central nervous system of the developing fetus as a principle target to lead toxicity. Xie and colleagues [10] examined low-level prenatal lead exposure of 252 mother-infant pairs. They concluded even low lead exposure (2.52 μg/dl-3.20 μg/dl) is associated with decreasing birth weights and lengths. Grossman and Slusky [11] reviewed detailed geocoded data containing births in Michigan from 2008 to 2015. Exploiting variation in timing of births, they found that the overall general fertility rates decrease12 percent and fetal death rates increased by 58 percent in Flint following the water change [11,12]. Their findings indicate that the sex ration of babies born in Flint skewed slightly to more females following the water change. Results from other scientific research have shown that male fetuses were more fragile than were female fetuses after the water switch. Additionally, babies born in Flint during this time; were born a half-week earlier, weighed nearly 150 grams lighter, and gained 5 grams per week less, than babies born in other areas at the same time.

Aizer *et al.* [7] studied the relationship of children BLL's and future test scores. The study concluded that by reducing lead levels from 2.7 μg/dl (below the CDC value of 5μg/dl) to zero micrograms per deciliter, would increase mean reading and math scores to 9 and 6 percent of a standard deviation.

In Flint, 4 in 10 families live below the poverty line, unemployment is high, and the majority population is Black. According to Bellinger [13], an elevated water lead concentration adds to an environment that

is already at risk. The incident of BLL concentration 5 µg/dl was more than three times as high among Flint children compared to neighboring municipalities [14].

Legionella outbreak

Legionella pneumophila bacterium (L. pneumophila: hereafter referred to as Legionella) received its name from an American Legion Convention in 1976 where attendees developed a new type pneumonia later named Legionnaires' disease [15]. The disease often goes undiagnosed, causing its incidence to be underestimated. Legionella bacteria, is naturally found in fresh water environments; however it can become a health concern when allowed to grow and spread in potable water systems [16].

Risk factors

Most healthy people exposed to Legionella do not acquire the disease [17]. However, risk factors that increase the chance of contracting the disease: being 50 years of age or older; being a former smoker; having a chronic lung disease such as emphysema or chronic obstructive pulmonary disease (COPD); and having a weakened immune system from medication or immune system diseases such as diabetes, cancer, or kidney failure.

Symptoms and diagnostic testing

Typically, two to 14 days after exposure patients with Legionnaires' disease often presents with pneumonia symptoms that include, cough, shortness of breath, headache, muscle aches, fever and radiographic pneumonia [18]. Since the above symptoms are often present with pneumonia caused by other organisms, it is necessary to conduct a confirmatory diagnostic test for Legionnaires' disease. Confirmatory test include; sputum culture, bronchoalveolar lavage and the Legionella urinary antigen test [18]. Additionally, screening is also encouraged for patients who failed outpatient antibiotic treatment for community-acquired pneumonia (CAP), patients with a severe pneumonia requiring intensive care; immunocompromised patients with pneumonia; patients who traveled away from home within 10 days before illness onset; and all patients with pneumonia in the setting of a Legionnaires' disease outbreak. In a study by Rathore [19], he found that pneumonia patients with prominent extrapulmonary manifestations, including diarrhea, confusion and neurologic symptoms should also be assessed for a Legionella infection.

Legionnaires disease and maternal child health

Vimerati *et al.* [20] published a case report in the *Journal of Perinatal Medicine* of a 32-year-old white woman, gravida 1, para 1 at 28 weeks gestation that presented with a five-day history of dyspnea, back pain, productive cough, and two days of fever (38°C). The patient received fluids and cephalosporin after a chest x-ray showed right sided pneumonia and a sputum gram stain indicative of an inflammatory process. The treatment lead to an initial decrease in temperature. Even though the initial ultrasound showed normal fetal biometry and morphology, 36 hours after maternal complaint of decreased fetal movement, an ultrasound diagnosed fetal death. Three weeks after the fetal demise and patient transferred to the chest disease service a serum specimen tested positive for Legionella bacterium. The authors concluded that when acute pneumonia complicates a pregnancy; consider Legionella as a possible pathogen. However rare, it is the second most common etiology of CAP.

Yiallouros *et al.* [21] identified a nosocomial Legionella infection in term neonates caused by cool mist ultrasonic humidifier in a hospital nursery. The atypical symptoms of Legionellosis seen in the neonates-such as lethargy, food denial, abnormal temperature, fever and respiratory distress-were detected for the first time in this population. The CDC advises against the use of large-volume, room humidifiers that create aerosol in hospitals. CDC suggest daily disinfection, and fill only with sterile water. Hines *et al.* [22] calculated exposure dosages from six common in-home water sources and estimated that the ultrasonic and cool-mist humidifier exposure pathways produced the highest exposure doses of the bacteria.

In January 2016, a Flint area hospital indicated they noticed an increase in Legionnaires' disease cases after Flint switched its water supply to the Flint River (Table 1). Ninety-one cases of and 12 deaths from Legionnaires' disease brought attention to the already recovering community. Environmental engineers from Virginia Tech University hypothesized that certain factors resulting from the Water Crisis would stimulate an abundance of Legionella [23]. These factors are as follows:

- Loss of residual disinfectant due to the high chlorine demand of iron corrosion;
- Elevated levels of iron and other microbial nutrients present in water (due to the lack of anti-corrosive use in the water plant);
- Increased temperature due to warmth of the Flint Water Source; and
- The conduciveness to Legionella growth and survival in water found in large buildings as Legionella known to be problematic in hot water lines.

According to Yan's [24] Flint Water Disaster Timeline (Table 1), in February 2016—almost a year before the governor publicly declared a state of emergency—the governor's staff was warned by the Department of Environmental Quality not to declare the drinking water safe due to the increase in Legionnaires' disease cases in the county.

Soon, city, county, state, and national health agencies coordinated an investigation into the cause of the crisis. The chief medical inspector and his associates came to town to coordinate clinics, health information sites, and water distribution centers. Neighboring universities, health agencies, healthcare workers, and volunteers helped distribute vital information, bottled water, and household tap filters. The local university held community informational forums to disseminate information about the dangers of lead-tainted water. Some neighborhoods had a replacement of six thousand service lines before work ceased, due to the cold Michigan winter weather. Work resumed in the spring of 2018 to replace the 9,000 remaining service lines. No other U.S. city has completed such a comprehensive water service line replacement. After declaring the Flint public water was safe to drink, the state of Michigan no longer supplied bottled water to the residents. Despite this declaration, many nonprofit organizations and churches continue to support Flint residents with bottled water. According to Dr. Mona Hanna-Attisha, a pediatrician instrumental in uncovering the lead crisis in children, "residents are encouraged to stay on filtered and bottled water until all lead pipes are replaced" [25].

After all that has transpired, naturally, there is a lack of trust between the Flint's citizens and its public officials. Many questions remain. In April 2014, only a month after the initial switch to Flint River water, residents complained of the foul-smelling, reddish-tinged water flowing from their taps. However, the complaints were ignored. Flint has a postindustrial economy with 40% of the population living at the poverty level. If Flint were an affluent suburb with a median family gross income of $100,000, would public officials have been more responsive

to the constituents? The search for answers to these questions likely will continue for years.

Where we are now

Flint residents returned to using Huron Lake water from the City of Detroit on October 16, 2015. Two and a half years later, residents continue to drink bottled water as their trust in their water quality and safety and some public officials have been lost. Meanwhile, researchers are still counting the human costs of this crisis.

From May 2017 through September 2017, dredging of the Flint River began to remove contaminated sediments, specifically coal tar by-products from the operation of a manufacturing gas plant in the 1920s. The plant converted coal and oil to gas and distributed it to the public for heating and cooling. The manufacturers were not responsible for disposal of the plant's by-products, resulting in coal tar discarded in the river. During the dredging, 75,000 cubic yards of river bottom was removed and replaced with sand, clay, and gravel. The restoration of the river bottom is now in a natural state for macro- and micro-invertebrate habitat [26]. Presently, there are no mechanisms in place to determine ill effects from possible consumption of coal tar by-products during the use of the Flint River as a water source.

Clinical implications

Healthcare professionals who work in areas with publicly announced environmental contaminations due to unsafe water (lead levels, Legionella, contaminated sediments) must be prepared to assess their patients' health presentations and home environments. Any patients arriving at clinics or hospital emergency centers with complaints of pneumonia that have not responded to routine antibiotics, an assessment for Legionnaires' disease is crucial. Incorporation of assessments for stress and anxiety levels into the plan of care and referral to appropriate health services is paramount. Employing interdisciplinary teams of nurses, physicians, public health educators, and social workers is fundamental to keeping a community healthy.

As nurses, we must continue to see our patients as complex individuals and care not only for their immediate health but also inquire about their family, environment, nutritional, and educational needs. We must seek and be willing to learn about specific environmental and health issues in the communities we serve. For example, Flint's north side was designated a food desert when the only full-sized grocery store closed in 2014. This situation eliminated easily accessible healthy nutrition options, particularly for low- income people. However, residents are pleased about several recent additions to the community: a grocery store with a plethora of healthy nutritional selections, which provided 80 new jobs to the community. The grocery store recently opened a "Soul Food Restaurant" within the building to provide nutritional selections of culturally specific food. Additionally a Dollar Store opened providing the community with low cost products in comparison to higher end drug and grocery chains [27]. The newly renovated Flint Farmers Market, open three days a week, offers fresh fruits and vegetables at affordable prices. As healthcare professionals, we must continue to collaborate and support the residents of the communities we serve. Being empathetic to their needs can help rebuild the trust lost during the horrific, human-manufactured water crisis.

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