

LEAD

IN

MILWAUKEE DRINKING WATER



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Abstract

The presence of lead in drinking water is an important public health issue, which has a devastating effect on the human body. Lead was historically used to produce pipes to carry water into people's homes, schools, offices and other public buildings. "It is a ubiquitous heavy metal that has been used for centuries as a constituent in various products such face powder, ceramic glazing, gasoline, plumbing, radiation shielding, children's toys and paint." (National Institute of Health). Lead toxicity is a worldwide problem and is not safe for anyone, but it poses the greatest risk for young children under the age of six. Because lead bears unique physical and chemical properties that makes it suitable for a large number of applications, for which humans have exploited its benefits from historical times and thus it has become a common environmental pollutant.

This paper will limit its scope on the city of Milwaukee, Wisconsin but will reference similar papers across the globe. In Milwaukee, over 45% of the 169,816 water service lines owned by the city contains lead, and 93% serve residential properties. This paper aims to use Geographic Information System (GIS) analysis to identify geographical locations with more or a significant proportion of the lead service lines, health issues associated with lead in human body, sources, signs and symptoms of lead toxicity.

Introduction

Lead exposure in the United States of America has decreased significantly over the past several decades, and this was because of the introduction of legislation restricting the use of lead in paints and fuels/gasoline. “With the decline in atmospheric emissions of lead, water has assumed new importance as the largest controllable source of lead exposure in the USA” (Gonda 2017). Lead is present in tap water to some extent because of its dissolution from natural sources, but primarily from household plumbing systems in which the pipes, solder, fittings or service connections to homes contain lead.

Until 2014, plumbing fixtures with as much as 8% lead-by-weight could be legally labelled “lead free”. While the allowable percent is now reduced to 0.25%, fixtures installed prior to the revision remain in use in the U.S. Because of the way lead-by-weight averages are calculated, even some newer fixtures can release significant concentrations of lead (SCILINE, 2018).

The presence of lead in drinking water constitutes an ecological and human health concern. According to a research conducted in 2002 by the French National Institute for Industrial and Environmental Risks (INERIS), lead particularly targets the nervous system, blood cells and kidney, which is more likely to have devastating or permanent adverse effects on young children under the age of 5, or 6 years in some cases. This particularly affects the development of the brain and nervous system.

Homes built prior to 1930 had water pipes that were primarily made from lead. These pipes can be identified because the piping tends to have a dull gray color when scratched with a key or metallic object, and a magnet will not stick to the pipe. In buildings built between the 1930’s and early 1980’s, copper pipes were often used, but the solder contained elevated levels of lead. Efforts

to ensure that Americans have access to clean drinking water stem back from its roots (1930's) up to the landmark legislation of the Clean Water Act in 1972 (Tarlock, 2009; Water Research Center; United States Environmental Protection Agency). Despite this, lack of access to clean drinking water continues to be a prevalent issue that affects the entire country, including the city of Milwaukee. The hazardous effects of lead in drinking water came to the forefront of the nation's attention with the crisis in Flint, Michigan. While the City of Milwaukee had already been working on its issues with lead pipes, the crisis in Flint served as a catalyst for Milwaukee residents to focus their attentions on it as well.

In Milwaukee, over 45% of 169,816 service lines in Milwaukee contains lead, and 93% serve residential properties. This accounts for over 76,141 residential properties that are serviced by lead laterals and service lines (Figure 5). Considering how dangerous lead is when consumed, particularly by infants, and with the fact that many of these service lines are serving residents in low-income communities. This is an equity issue and needs to be addressed by the City of Milwaukee. Health reports shows that children from these communities are currently posed with more threat and have the highest observed lead poisoning rates in the city (Ziegler, Ekhard E., et al 1978).

The City has made steps in abating lead from homes and has had some remarkable success in past decades in reducing the number of children with lead poisoning. However, the issue of lead pipes remains an overwhelming issue in Milwaukee. According to Senator LaTonya Johnson, "In Milwaukee, out of 26,000 children under the age of 6 tested – 2,200 had elevated levels of lead in their blood." That is 8.6 percent of children at risk of lead poisoning. In Flint - Michigan, it was only 4.9 percent. That is nearly double the popular Flint crisis in Michigan.

Health effects of Lead

There are various well-established adverse health effects of lead in human body, even at low level of intake. Young children below the age of six, pregnant women, and their developing fetuses are the most vulnerable populations to the risks associated with lead poisoning. This is because young children usually consume more water and their bodies are actively developing, which facilitates the bioaccumulation of lead (Ziegler, Ekhard E., et al, 1978). Children, due to their childish behavior, are more prone to ingest and inhale dust contaminated with lead (Landrigan, 2002).

If too much lead enters the body from drinking water or other sources, it can cause serious health problem for both adults and children, although more severe in children. The presence of high level of lead in a child's blood stream can cause convulsions, coma, organ failure, major neurological damage and eventually death. In adults, it can lead to encephalopathy, enzymatic inhibition, hypertension, kidney and liver damage. At low levels, it can increase the risk of heart disease, cognitive decline, and adverse reproductive outcomes in adults (Sanborn, Margaret D., et al). At moderate to low levels of lead exposure it can cause learning disabilities, hearing, loss and inhibit growth in young children (Canfield, Richard L., et al 2003).

Pregnant women who have elevated blood lead levels are at a risk of premature birth or of babies with a low birth weight. "The fetus may be adversely affected at blood lead concentrations well below 25 µg per deciliter" (Bellinget et al., 1987). Blood lead levels in the neonate were found to be higher than simultaneous maternal lead levels (Shannon, 2003; Bellinger, 2005). Emaciated women with substantial exposure to lead prior to pregnancy are considered to be at increased risk. The brain is the most sensitive organ to lead exposure (Cleveland et al., 2008). In a child's developing brain, synapse formation is greatly affected in the cerebral cortex by lead. Lead also

interferes with the development of neurochemicals, including neurotransmitters, and organization of ion channels (Casarett et al., 2007). Lead poisoning also causes loss of neuron myelin sheath, reduction in the number of neurons, it interferes with neurotransmission and decreases neuronal growth (Pearson & Schonfeld, 2003).

Symptoms of Lead Poisoning

Lead contamination causes a variety of symptoms, which includes abnormal or behavioral problems, which could vary amongst individuals of different ages, sizes and body metabolism. The signs of lead poisoning could mimic a cold flu or other gastrointestinal diseases. Lead symptoms for children may include the following: mental retardation, fatigue, cramps, vomiting, irritability, sleep disorder, poor appetite, constipation, delayed development, loss of hearing and energy, weight loss, learning issues, and trouble sleeping. While symptoms for adults may be similar but less intense or obvious. These includes: Fatigue, impaired concentration, decline in mental function, headache, seizures, encephalopathy, loss of memory, muscle pain, loss of hearing, mood disorder, irritability, pain or tingling in the extremities, nausea, indigestion, constipation, abdominal aches and pains. Pregnant women may have a miscarriage, premature birth or stillbirth; men may suffer from impotency, high blood pressure and kidney problems (Robertson 2018).

Unlike these afore-mentioned contaminants, lead will accumulate within the body over time. Lead will tend to be stored in major organs of the body, such as the brain, kidneys, and bones, etc. It can be stored in child's blood for months and bones for many decades. Some of the effects of lead poisoning cannot be cured, but it is possible to reduce exposure to lead (Water Research Center).

Sources of Lead in Milwaukee Drinking Water

Lead can enter drinking water when pipes and plumbing fixtures that contain lead corrode, especially where the water has high acidity or low mineral content. The primary route for lead poisoning in drinking water is not old contamination of the water by leaded fuels, old batteries or some hazardous waste site, the primary route is the distribution system used to carry water to your home and more importantly the plumbing within your home. Household plumbing may be the cause for lead in your drinking water. In older homes, lead was used to make the piping and/or solder (Water Research Center). According to the National Conference of State Legislatures, there are three main sources of lead in water:

- **Lead pipes:** Lead service lines are the pipes that connect the water main under the street to a building's plumbing. Lead pipes were also used inside the house but it is not as common as lead service lines. Congress banned use of lead pipes in 1986. These are the most common sources of lead contamination in Milwaukee household drinking water.



Figure 1. Lead in Drinking Water Sources (Source: Milwaukee Water Works)

- **Leaded solder:** Solder is used to connect copper pipe and fittings. Congress banned the use of leaded solder in 1986.
- **Leaded alloys:** Brass is frequently used in faucets and other plumbing components. In 1986 Congress limited the amount of lead in brass to 8 percent (close to the level of lead typical of products at the time) and later in 2014 reduced the limit to a much lower level (0.25 percent).

Figure 2 further illustrates possible locations where these three main sources of lead in water could be present in a school or most building facilities.



Figure 2. Lead in Drinking Water Sources (Source: Edwards, 2009)

Lead Testing

Lead in household drinking water could be tested in several ways, but the most accurate way of testing for lead is through screening test or analyzed by a certified laboratory. Other ways may require testing a service line to see if it is made of lead, copper or galvanized steel.

How to test a service line for lead

Testing a service line for lead could be tricky, but definitely not difficult. In Milwaukee houses, private service lines are usually located in the basement but it could also be on the first floor. It runs from the street water main into the build and ends by the water meter and a shut-off valve, which regulates the water pressure. To test the pipe or service line that extends into the build, you need a magnet to see if it sticks to the pipe. If it sticks, the service line is made of galvanized steel. This is safe. If it does not stick, use a key or a metallic object to scratch the pipe. If the scratch is copper-colored like a penny, the service line is copper. This is safe, but if the scraped area is shiny and silver, the service line is made of lead, which means, it is not safe to drink from it.

Figure 3 further illustrates the extent of the service line, where to test for lead.

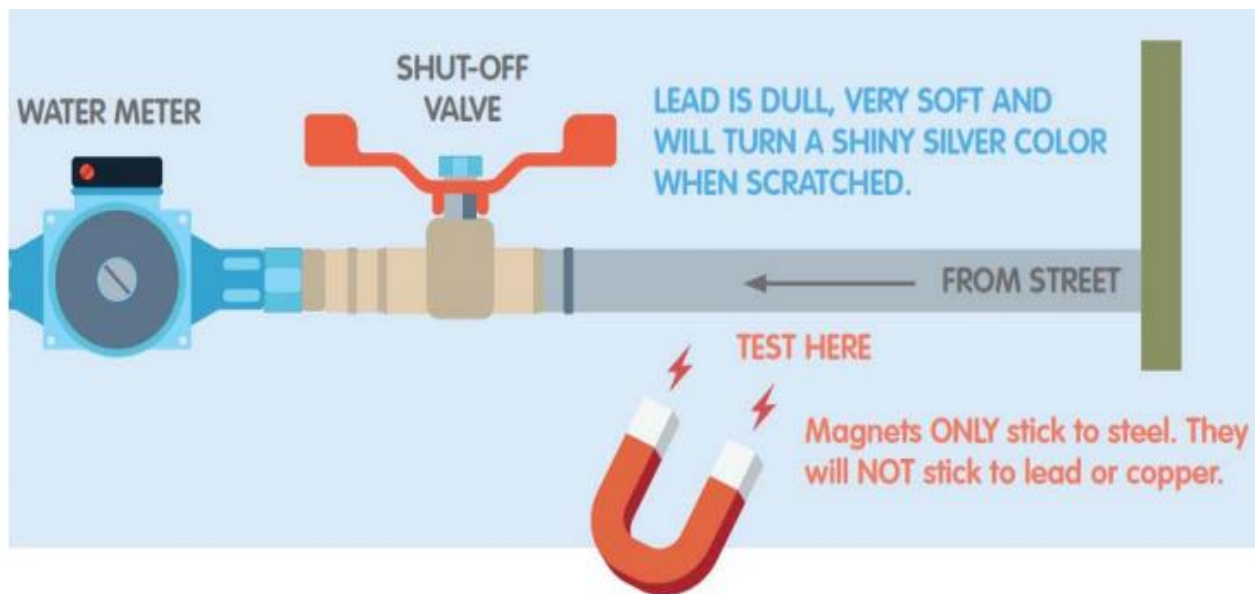


Figure 3. Testing service line for Lead (Source: Milwaukee Water Works)

GIS Analysis of Lead in Milwaukee City

Geographic Information System (GIS) is a good way to create a visual representation of Milwaukee properties where lead service lines still need to be replaced. ESRI ArcGIS Pro software was used to run the analysis with the data gathered from the city of Milwaukee Water Works.

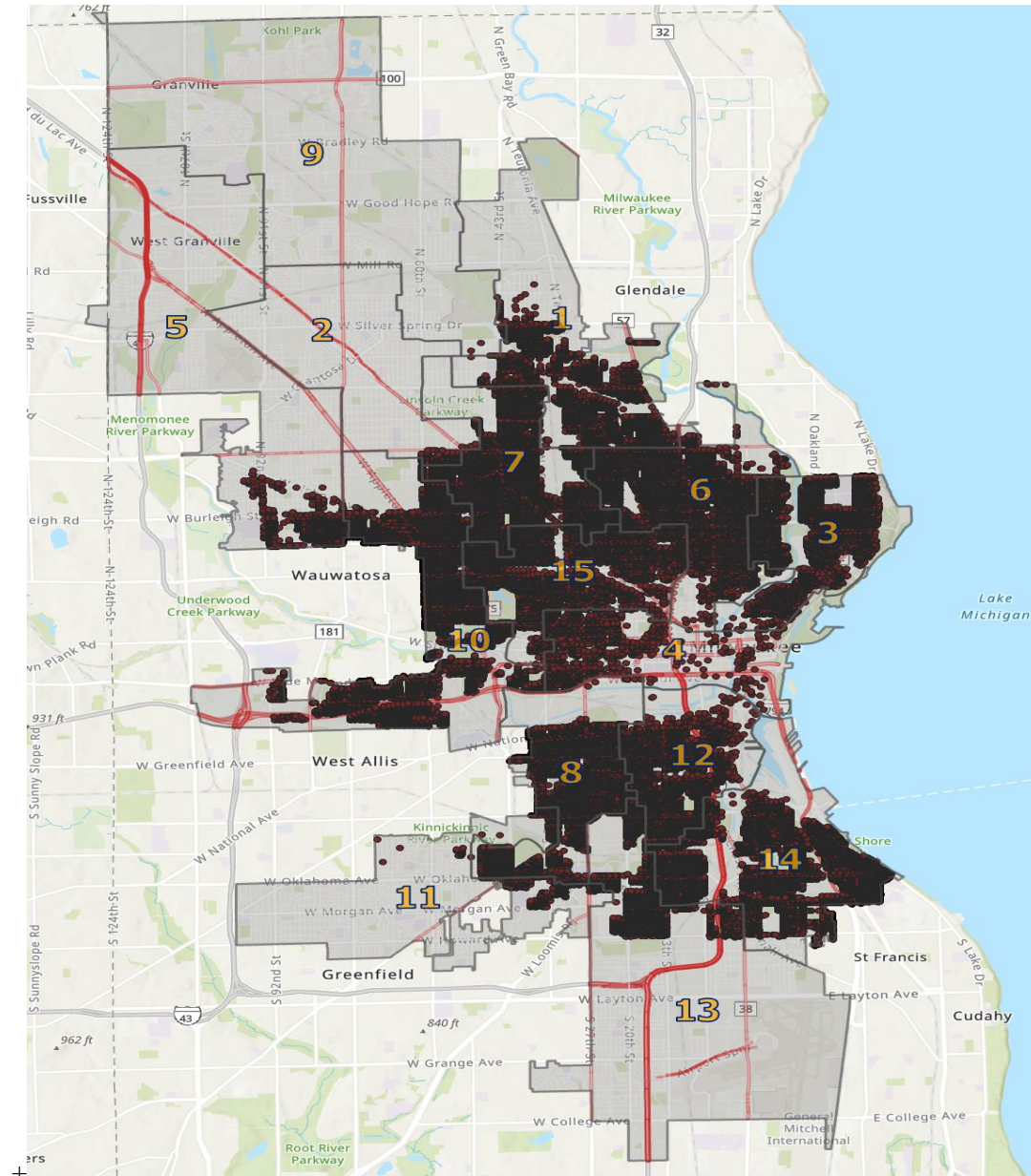
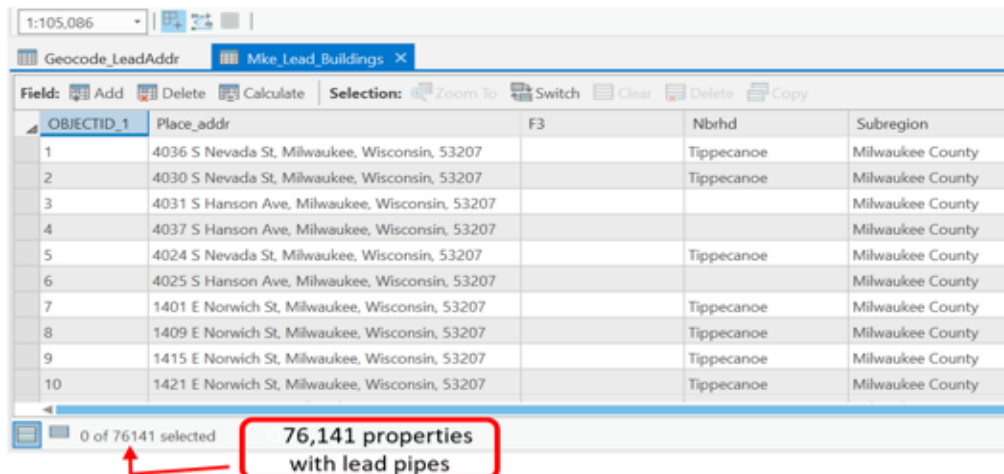


Figure 4. Map of Milwaukee showing points of lead service lines

In total, there are 76,141 properties served with lead service line in Milwaukee (Figure 5). This accounts for approximately half (47%) of the total water service lines owned by the city. Further analysis shows that 93% of these lead service lines serve residential properties, which is a major health concern for the residents of Milwaukee.

The city replaced 621 lead service lines in 2017 and another 882 in 2018. Most of these replaced pipes are paid for by the property owners, which cost \$8,000 per lead service line (Senator LaTonya Johnson). This is a ridiculous amount for low-income households who are trying so hard to keep up with life. The city's lead service line replacement model is not equitable.



OBJECTID_1	Place_addr	F3	Nbrhd	Subregion
1	4036 S Nevada St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
2	4030 S Nevada St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
3	4031 S Hanson Ave, Milwaukee, Wisconsin, 53207			Milwaukee County
4	4037 S Hanson Ave, Milwaukee, Wisconsin, 53207			Milwaukee County
5	4024 S Nevada St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
6	4025 S Hanson Ave, Milwaukee, Wisconsin, 53207			Milwaukee County
7	1401 E Norwich St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
8	1409 E Norwich St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
9	1415 E Norwich St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County
10	1421 E Norwich St, Milwaukee, Wisconsin, 53207		Tippecanoe	Milwaukee County

0 of 76141 selected

76,141 properties with lead pipes

Figure 5. Attribute table of lead affected properties in Milwaukee

The lead service lines are clustered within the core of the city where older homes are most likely seen. The analysis looked at different aldermanic districts in Milwaukee with higher concentration of lead service lines, and the result was not surprising because aldermanic districts with huge minority populations had large clusters of lead service lines. Communities in aldermanic districts 3, 6, 7, 8, 12 and 14 have denser numbers of lead service line (Figure 6). According to the 2015 elevated blood lead report from Milwaukee Health Department, 3.1% of children tested in Milwaukee had blood lead levels at or above 5 micrograms per deciliter ($\mu\text{g/dL}$), which is above

the Centers for Disease Control and Prevention (CDC)’s recommended public health concern “blood lead level of concern”. The majority of the reported cases came from children living in these areas of the city with particularly old homes; they include zip codes from the center of the city and Bay View (53204, 53205, 53206, 53208, 53209, 53210, 53212, 53215, and 53216). These zip codes are geographically located in/across the above-mentioned aldermanic districts with higher concentration of lead service lines. The zip codes have an average of \$29,264 median household income, which is below the median household income (\$38,289) for the entire city (U.S. Census Bureau).

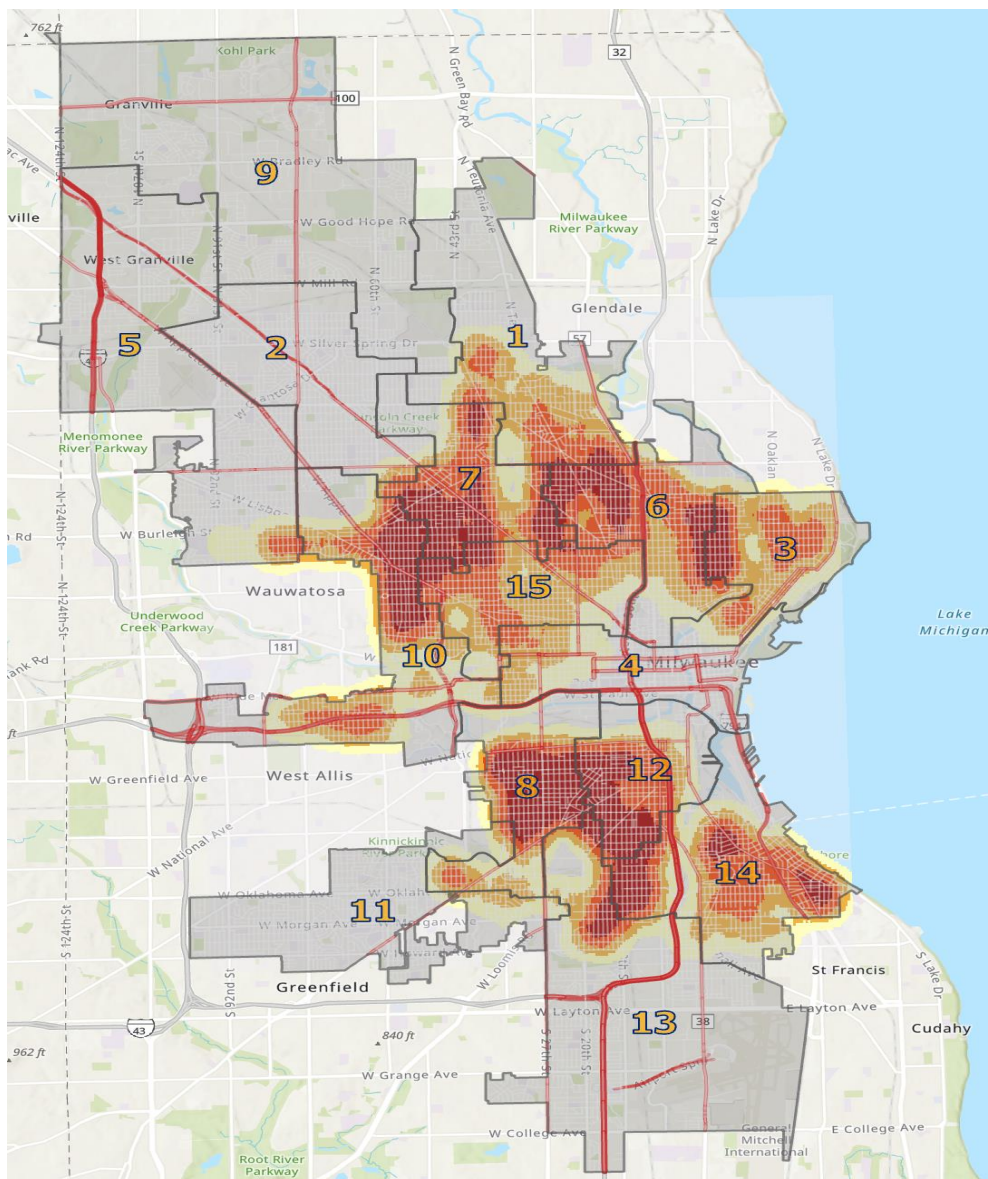


Figure 6. Heat map/point density of lead service lines in Milwaukee

Conclusion

Lead poisoning appears to be more prominent amongst all other heavy metal poisonings. The use of lead has been from time immemorial, and was not too big of a problem until the hazards of lead became known through research that proves the risk and health related problems associated with lead if ingested. As the health crisis in Flint, Michigan shows, drinking water is a significant source of lead in childrens' blood. Inhaling or ingesting lead through water or food is inevitable considering the fact that lead is mostly used all over the world due to its unique physical and chemical properties that make it suitable for a large number of applications. Although safer alternatives may be available, many affected households in Milwaukee cannot afford to change these existing lead service lines, leading to increased toxicity or high rate of lead poisoning in this areas. Children are at a higher risk, particularly at areas with huge proportion of lead service lines in the city of Milwaukee.

In addition, lead prevents enzymes from performing their normal activities. Lead even disrupts the normal DNA transcription process and causes disability in bones. The good news is however, that it can be reversed and the levels of lead can be reduced from the body by a number of techniques used nowadays. The prominent ones among them are chelation therapy, nano-encapsulation, N-acetylcysteine (NAC). A number of antioxidants also help in the removal of lead from the body.

Finally, it is important to note that hot water from a lead service line is likely to contain more lead than cold water. Therefore, it is safer to use cold water for cooking and other domestic uses.

Click on the link to explore the web app built to support this paper.

<http://uwm.maps.arcgis.com/apps/webappviewer/index.html?id=562b60c474f743388edb102cbd47ac23>

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