The Pennsylvania State University
The Graduate School

Lead Contaminated Water in Newark, New Jersey: Risk Assessment

A Paper in

Environmental Engineering

By

Mitchell C. Harbold

Submitted in Partial Fulfillment
of The Requirements
for the Degree of

Master of Environmental Engineering

May 2017

Abstract

This preliminary risk assessment analyzes the lead water contamination in the Newark, New Jersey School Districts. Over 17,000 children were tested in more than 30 different locations in the Newark School District. This risk assessment calculated a hazard quotient for the 90th percentile concentration/body weight burden recorded above the federal lead action level of 15 ppb (0.0193 mg/kg), the average body weight burden (0.06429 mg/kg), the highest body weight burden (0.193 mg/kg) and lowest body weight burden (0.0161mg/kg) recorded by testing done by the state. The average and highest concentration resulted in a hazard quotient greater than 0.2, which is a cause for concern. Once a hazard quotient was calculated the severity of the risk was assessed and potential preventative measures were evaluated.

MASTER'S SIGNATORY PAGE

Name of Student Mitchell Harbold Penn State ID 9 3501 0346

Penn State email address mKH5480@psu.edu Permanent email address mKH5480@psu.edu

Major Environmental Engineering Graduation semester and year Spring 2017

I hereby certify that I have obtained the necessary permission for copyrighted material included in my thesis and choose that the document be placed in the eTD archives with the following status:

X 1. **OPEN ACCESS** — Allows free worldwide access to the entire work beginning immediately after degree conferral. Appropriate for the majority of thesis submissions in fulfilling the requirement for making the work available to the public.

___ 2. **RESTRICTED (PENN STATE ACCESS ONLY) FOR A PERIOD OF TWO YEARS*** — Access restricted to individuals having a valid Penn State Access Account. Allows restricted access of the entire work beginning immediately after degree conferral. At the end of the two-year period, the status will automatically change to Open Access. *Intended for use by authors in cases where prior public release of the work may compromise its acceptance for publication*

___ 3. **RESTRICTED FOR A PERIOD OF TWO YEARS FOR PATENT DEVELOPMENT** — Restricts the entire work for patent and/or proprietary purposes. At the end of the two-year period, the status will automatically change to Open Access. Selection of this option requires that an invention disclosure (ID) be filed with the Office of Technology Management (OTM) prior to submission of the final thesis and confirmed by OTM and Office of Theses and Dissertations. Confirmed ___

[signature] 5/11/17

Signature of Student Date

FACULTY APPROVAL

(a minimum of three signatures required, including dept. head or chair of graduate program)

We ***accept and approve*** the thesis of the student named above and agree to distribution as indicated.

Signature [signature] Date 5/11/2017
Print name here Shirley E. Clark

Signature [signature] Date 5/10/2017
Print name here Yuefeng Xie

Signature ___ Date ___
Print name here ___

Signature ___ Date ___
Print name here ___

Head or Chair of Graduate Program

Signature [signature] Date 5/11/2017
Print name here Shirley E. Clark

*Requests for a two-year extension can be made by contacting the Office of Theses and Dissertations (gradthesis@psu.edu) 30 days prior to the expiration of the restriction.

Table of Contents

Chapter 1: Introduction

The Environmental Protection Agency (EPA) regulates over 90 contaminants in drinking water. When EPA decides which contaminants to regulate, they look at three main points. The contaminant may cause a negative health effect in the public or in a specific vulnerable subgroup such as children; the contaminant is known to occur or could occur in a public water system at a sufficiently high concentration to cause concerns about public health; and the regulation of the contaminant will provide a greater opportunity to reduce the health risk for the public served by the water system. However, if the EPA's science evaluation does not support that the contaminant meets the threshold for regulation, they may develop a health advisory to inform the public of the potential health hazards and will set an advisory limit that is not enforceable at the federal level (1).

1.1 History Of Lead Exposure to Humans

One of the most important contaminants EPA regulates is lead. Lead was one of the first documented chemicals with known adverse health effects. Lead was discovered as early as 4,000 BC. The Romans for over 400 years mined 60,000 tonnes of lead a year and used the lead compounds for glazing pottery and cooking utensils, and a majority of the lead went toward piping for water systems (2). Over the course of history, lead has been thought to cause many deaths through various routes of exposure. In the 18th century lead poisoning was a major concern when it came to drinking rum because of the rum manufacturing process. During the rum making process, the still had a component called the worm, which was made of lead. During the process, the temperatures were very high, causing lead to leach into the rum. Additionally, during the 18th and early 19th centuries, lead was commonly and illegally added to cheap wine to act as a sweetener. When the Industrial Revolution started in the 19th century, lead poisoning became more common in the workplace. Also during this period, the use of lead-based paints increased, resulting in children having an increased exposure to lead. The United States did not ban the use of lead-based paints until 1971 (2). Although lead poisoning can happen through many routes of exposure as demonstrated above, this risk assessment will look at lead leaching into the water from the piping system as the route of exposure.

1.2 Legislation Addressing Lead in Drinking Water

Section 1417 of the Safe Drinking Water Act (SDWA) states that the following materials must be lead free to protect the public from significant lead leaching during water distribution: wetted surfaces of the pipe, the pipe fittings, plumbing fittings, fixtures, solder and flux. Lead free does not mean that there is no lead, but that the lead is kept to a level that is considered safe. In 2011 congress passed the Reduction of Lead in Drinking Water Act (RLDWA), which revised the meaning of lead free for the materials stated above from 8% lead content to a weighted average of 0.25% (3). The reason why pipe manufactured before 1986 is prohibited is because lead free earlier was defined as solder and flux having less than 2% lead content and pipes having less than 8% lead content.

The weighted average lead content of a product looks at the wetted surface component of the pipe, pipefittings, plumbing fittings, fixtures, solder and flux and is calculated by the following formula:

$$WLC = \sum_{c=1}^{n} \left(LC_c \times \left[\frac{WSA_c}{WSA_t} \right] \right)$$

where;

WLC	=	weighted average lead content of product
LC_c	=	maximum lead content of the c^{th} component
WSA_c	=	wetted surface area of the c^{th} component
WSA_t	=	total wetted surface area of all components
n	=	number of wetted components in product

Figure 1. Equation used to calculate the weighted average lead content of a product (4).

The percent of lead in the component times the ratio of the wetted surface area component equals the total wetted surface area of the entire product. The weighted percent of lead for each component is then added to make up the weighted average lead content of the product (3). This means that if the product exceeds a WLC of 0.25%, it cannot be used for plumbing intended for drinking water use.

Chapter 2: Water Quality and Lead Leaching

Water that has high acidity or alkalinity or low mineral content will corrode lead pipes and fixtures, causing lead to enter the water. There are many factors that affect the way lead enters the drinking water, including temperature of the water, amount of wear and tear on the pipes, amount of protective scales and coating in the pipe, and how long the water sits in the pipes. The wear and tear on the pipes along with the amount of protective scale in the pipes are heavily affected by whether corrosion inhibitors are used.

2.1 Chemical Corrosion Inhibition

Dissolved oxygen in water will react with lead exposed pipes causing soluble lead to enter the drinking water. For this to happen, two reactions must occur. The first reaction is an oxidation reaction. When lead oxidizes, it loses electrons and forms Pb^{2+} ions which are soluble in water.

$$2\ Pb_{(s)} \rightarrow 2\ Pb^{2+}_{(aq)} + 4e^-$$

The reduction reaction results in oxygen gaining electrons as shown below:

$$4e^- + 2H_2O_{(l)} + O_{2\ (aq)} \rightarrow 4\ OH^-_{(aq)}$$

The full redox reaction shown below shows how lead leaches into the drinking water in the presence of dissolved oxygen. While lead hydroxide is shown as a solid in the reaction, it is in the water column and not against the pipe as part of the scale.

$$2\ Pb_{(s)} + O_{2\ (g)} + 2\ H_2O_{(l)} \rightarrow 2\ Pb(OH)_{2\ (s)}$$

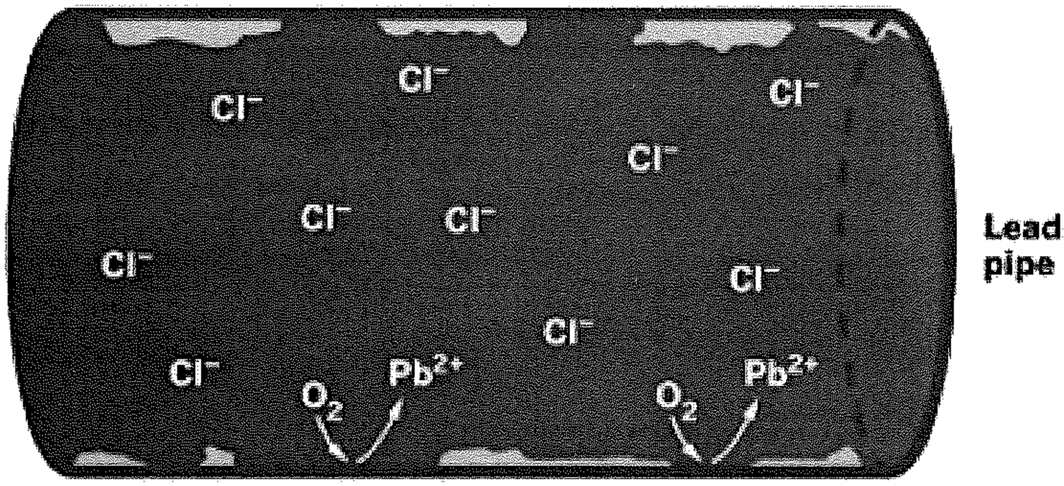

Figure 2. Lead leaching into water when a phosphate inhibitor is unable to be used (5).

Corrosion inhibitors are chemicals, usually phosphate-based, that prevent degradation of the lead pipe surface. Phosphate corrosion inhibitors are usually orthophosphates and help maintain a mineral passivation layer on the inside of the piping system (Figure 2). The negatively charged polyatomic ions help create lead (II) phosphate ($Pb_3(PO_4)_2$) which forms an insoluble, mineral like crust on the inside of the pipes.

$$3Pb^{+2} + 2PO_4^{-3} \rightarrow Pb_3(PO_4)_2$$

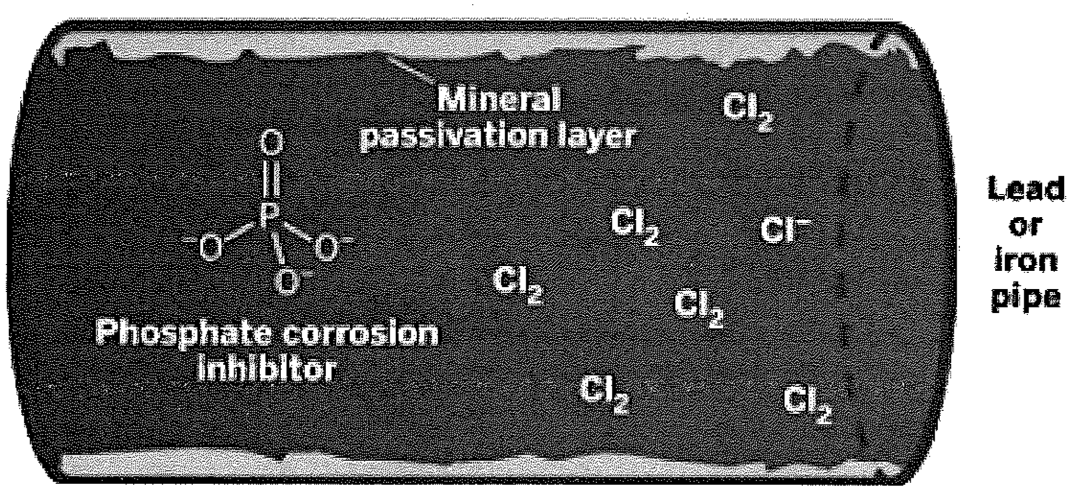

Figure 3. The mineral layer in a pipe when a phosphate inhibitor added (5).

2.2 Non-Chemical Measures to Reduce Lead Exposure in Drinking Water

There are several preventative measures that could be taken when it comes to decreasing the chances of lead exposure. If the system has not been used for several hours, the pipes can be flushed for 30 seconds to 2 minutes, depending on how long water has been residing in the pipes (6). Using cold water for eating and drinking will help decrease the lead concentration in the water because higher temperature water corrodes the pipes faster. Certain water filters and treatment devices could also help in limiting the exposure. Most new piping systems are being constructed with PVC and CPVC because they are lightweight and chemical, corrosion and rust resistant. Copper and stainless steel are also used in place of lead piping but costlier than using PVC or CPVC.

Chapter 3: Risk Assessment Based on Elevated Lead Levels in Newark

In February and March of 2016, reports of elevated lead levels in children and in the drinking water of schools were reported. Over 17,000 children at 30 different locations around Newark were tested for their blood lead levels. The state Department of Health and Department of Environmental Protection led the testing (7).

The objective of this preliminary risk assessment is to evaluate the risk of lead exposure to young children ages pre-kindergarten to 5^{th} grade in the Newark, New Jersey surrounding school districts. Calculating a risk factor/hazard quotient associated with the exposure of lead through water to young children will help us identify how serious the risk is and whether a child exposed to these lead levels could experience delays in cognitive development during critical stages of life.

Chapter 4: Risk Assessment

A risk occurs when there is a hazard and when an endpoint organism, such as a child, can be exposed to that hazard. There is no risk if either there is no hazard or there is no exposure to that hazard. A risk assessment is a method to evaluate the size of the risk and to determine how people or animals or fish or other endpoint organisms could be negatively affected. A risk assessment is organized into four sections: Hazard Identification, Dose-Response, Exposure Assessment, and Risk Characterization.

4.1 Hazard Identification

When it comes to carrying out a risk assessment, physical/chemical properties and toxicology effects are used to determine whether there is a potential hazard.

4.1.1 Physical and Chemical Properties

Lead is a naturally occurring silvery-gray metal in the environment. The origin of the name "lead" comes from the Anglo-Saxon word for metal. It is a chemical element in the carbon group and has an element symbol of Pb on the periodic table. It has an atomic weight of 207.2, a melting point and boiling point of 327.46 °C and 1750 °C respectively. The atomic number of lead is 82, which represents the number of protons located in the nucleus of the atom. Lead is a solid at room temperature (20°C) and one of the softest and most malleable elements on the periodic table (1). It has been used for many years in the industrial industry for a wide array of processes. Some of the common uses of lead include cable coverings, ammunition, shields used to protect patients during x-rays, and inside storage batteries. Historically lead was used for plumbing. Even though lead does not dissolve in water under normal conditions, due to other elements and deterioration of the pipes, lead can leach into the water and create a cause for concern (8).

4.1.2 Toxicology Effects

Lead has an estimated half-life of 28-36 days in the human body and travels as Pb^{2+} once it has entered the blood stream (1); therefore, continued ingestion or inhalation of lead can result in the accumulation of lead in the body.

The health challenge of lead is that it has the ability to imitate and inhibit the functions of calcium. Once lead has entered the bloodstream, it likely will be distributed to three main components of the body – blood, soft tissue (kidneys, liver, brain), and mineralized tissue (bones and teeth). Lead can also produce harmful effects on the peripheral nervous system (PNS), central nervous system (CNS), and blood cells, plus it can affect the metabolism of calcium and vitamin D.

Out of these body systems, the PNS and CNS are the most sensitive when it comes to lead poisoning. Neurons are responsible for the transmission of signals from one location to the next. Dendrites receive the input signal and then pass it on to the rest of the neuron. The axon works as a relay center for these signals. When an action potential takes place due to a depolarization on the surface of the synaptic terminal, the neuron releases the neurotransmitter to the synapse. A calcium ion is used to help convert an electrical impulse into a chemical signal. When depolarization of the presynaptic membrane occurs, it causes a reaction with the calcium ion, which makes the ion travel through a voltage-gated channel and into the neuron. This then triggers the releasing of the neurotransmitter into the synaptic cleft by exocytosis. Once the neurotransmitter is released it enters the dendrite by way of diffusion.

Since lead and calcium enter through the same channel, they are considered to be competitive inhibitors to each other. Not only can lead cause a disruption in neuron transmission but it can also cause unregulated release of dopamine, acetylcholine, and gama-aminobutyric acid (GABA). Dopamine contributes to controlled movement and emotional responses. Acetylcholine assists in transducing nerve impulses to muscular contractions. GABA is an amino acid but is classified as a neurotransmitter, which regulates secretion of growth hormones.

There are two major factors that play into the growth deficiencies in children when poisoned by lead. The first major factor is how lead can block neurotransmitters while the active potential is happening, which then results in decreased pruning. Pruning is what helps shape the brain in early childhood development. Having an increase in neural activity brought on by lead poisoning can cause the brain to experience inhibited growth resulting in permanent effects on synaptic anatomy and function of the brain. Second is how lead and calcium have a natural liking for Calmodulin Protein Kinase II (CPKII) and Kinase C. Lead however has a stronger natural liking, causing it to activate the kinases at lower concentrations and for longer durations. Lead does not activate them the same way calcium does, and causes an interference in the effects of CPK II and kinase C, resulting in learning disabilities and behavioral deficits in children. When lead enters the CNS, it can result in increased permeability of the Blood Brain Barrier (BBB), which will end up leading to a buildup of fluid in body tissues and cavities. Lead allows larger molecules to pass through the BBB by poisoning the astrocyte component and this can lead to neurological development of a child to be altered. The poisoning of lead in the body can result in learning disabilities, high blood pressure, or even death. Many symptoms of lead poisoning are misdiagnosed and when they are noticed it is too late, the damage done is irreparable (9)

4.2 Dose Response

A study was done to examine the long-term effects of children being exposed to low levels of lead during childhood growth. They reexamined 132 of the 270 young adults who were evaluated originally in first or second grade. The tests used to evaluate neurobehavioral functions included California Verbal Learning Test, Boston Naming Test, Rey-Osterreith Complex Figure Test, Word-Identification Test, self-reports of delinquency, and review of school records (10). The mean length of follow-up was 11.1 years and results showed that associations reported earlier between lead and children's academic progress and development continued into young adulthood. Table 1 shows the test results along with the correlating dentin lead levels and it is clear that as lead levels increased, test scores worsened. Reading scores, reading grade equivalent and vocabulary scores worsened substantially as dentin lead levels increased. Number of days for being absent also increased heavily as lead levels increased.

Table 1. Results in young adults according to lead concentrations in childhood (10).

OUTCOME VARIABLE	LEAD CONCENTRATION			
	LOWEST (<5.9 ppm)	LOW (6.0 8.2 ppm)	HIGH (8.3 22.2 ppm)	HIGHEST (>22.2 ppm)
No. of subjects	30	31	30	31
Reading score (words read correctly)	143.8	142.7	140.2	135.2
Reading grade equivalent (grade level)	12.2	11.9	11.2	10.1
Highest grade achieved (grade level)	11.7	11.9	11.5	11.3
Class standing (percentile)	0.60	0.59	0.48	0.45
Absence from school (no. of days/ semester)	12.0	12.0	17.9	20.8
Vocabulary (words correct)	18.0	16.4	17.6	14.6
Grammatical reasoning (no. incorrect)	13.1	13.0	12.8	15.8
Hand–eye coordination†	5.1	5.4	5.5	6.2
Reaction time (msec)				
Preferred hand	246.6	255.5	267.3	275.1
Nonpreferred hand	241.2	238.2	258.4	261.2
Finger tapping (no./10 sec)	46.6	47.2	45.9	43.5

4.3 Route of Exposure

When it comes to children being exposed to lead, the two most common ways are inhalation and ingestion. Exposure to lead can come from imported products such as toys, spices, and cosmetics; exposure can also occur through water being pumped through lead pipes and through contaminated soil and air. The route of exposure that will be of interest in this risk assessment will be ingestion of contaminated drinking water. It has been shown that the drinking water in 30 Newark area resulted positively for lead concentrations greater than the SDWA action level of 15 μg/L. Using this route of exposure, a series of calculations have been developed to analyze the risk of encountering lead and the chances a child could experience development issues due to lead poisoning.

Figure 1 shows the location of the schools in Newark, New Jersey where the lead level in school drinking fountains exceeded 15 ppb. Table 2 lists the specific test results (11).

Figure 1. Map with the location of schools in Newark that reported elevated (over 15 ppb) blood lead levels (11).

4.4 Risk Characterization

Risk calculations are separated by whether the endpoint of concern is cancer or not. Since this risk assessment focuses on lead as a neural development inhibitor in children, the non-carcinogen calculation will be used. This calculation is based on a hazard quotient (HQ). The HQ is a ratio of exposure at a location to a single chemical over a specified period to the daily exposure level at which no adverse health effects are likely to occur. If the HQ is greater than 0.2, there is a potential risk to human health in that area (11). Even though children are exposed to lead in several ways, this risk assessment will calculate the HQ solely on the route of exposure of water ingestion.

Table 2. Specific schools in the Newark School District with lead levels above 15 ppb (11).

School	Number of tests with a level >15 ppb	Individual results ppb			
George Washington Carver (including Bruce Street and KIPP Seek Academy)	1	118			
Ivy Hill	2	131	149		
Branch Brook	3	133	168	194	
Wilson Avenue	2	133	193		
Early Childhood School - Central at Berliner	4	15.6	23.3	22	16
Cleveland	1	158			
14th Avenue School	1	16.1			
Early Childhood School - West at Old Speedway	1	16.4			
13th Avenue	1	16.5			
Mount Vernon	1	16.5			
Luis Munoz Marin	1	17.5			
Quitman Street	2	17	30.7		
Abington Avenue	2	18.8	126		
Louise Spencer (includes Miller Street)	4	20	22	71	134
Weequahic (includes Eagle Academy for Young Men & Girls Academy of Newark)	2	22.8	29.4		
South 17th Street	2	24.5	28.4		
Hawthorne Avenue	1	25			
South Street	1	26			
Benjamin Franklin	1	33			
Ridge Street Annex (Grades K-1)	1	38.8			
Roberto Clemente	1	45.8			

4.4.1 Calculation of the Hazard Quotient

The first calculation done used the 90th percentile concentration of lead in the drinking water reported as a body burden in a child, which was 0.0193 mg/kg. The exposure is based on a child attending school 5 days a week for 36 weeks. A water ingestion rate of 0.8 L/day and body weight of 32.9 kg was used (12). An absorption factor of 1 was used because it is the standard for preliminary risk assessments (12). Once the dose by water ingestion is calculated, the HQ is then calculated by taking the water ingestion dose divided by the tolerable daily intake, which for lead is 0.0036 mg/kg-day (12). Below show the calculation formulas used for each dosage level:

$$Dose_{WaterIngestion} = \frac{(C_W \times IR_W \times AF_{GIT} \times D_{Days} \times D_{Weeks})}{BW \times 365}$$

$$Dose_{WaterIngestion} = \frac{(0.0193 \frac{mg}{kg} \times 0.8 \frac{L}{day} \times 1 \times 5\, days \times 36\, weeks)}{32.9\, kg \times 365}$$

$$Dose_{WaterIngestion} = .000231 \frac{mg}{kg-day}$$

$$Hazard\ Quotient = \frac{Dose_{WaterIngestion}}{TDI}$$

$$Hazard\ Quotient = \frac{.000231 \frac{mg}{kg-day}}{0.0036 \frac{mg}{kg-day}}$$

$$Hazard\ Quotient = .064287$$

The HQ for the 90th percentile is 0.064287. Although this is about 0.14 below the threshold to cause a risk to human health, this is only taking into consideration exposure through the route of water consumption. The water ingestion rate for children is 0.8 L/day, which could be slightly low. During this stage of life, it is important to stay hydrated, which could result in more exposure and increase in the HQ ratio. Children also tend to be very active and require additional hydration.

A calculation was also done for the highest, lowest and average recorded lead concentration levels in the water at the schools using the same calculation method used above. The values used for the highest, lowest and average concentrations were reported values that were over the 15 ppb and reported by a newspaper. The highest lead water concentration was recorded at the Branch Brook School where the concentration was 194 ppb. This resulted in a HQ value of 0.646208. This result is significantly higher than 0.2, causing a great concern that the surrounding public is at risk for adverse health effects because of lead. The lowest recorded level over 15 ppb was 16.1 ppb, which resulted in a HQ value of 0.054294, which is still a potential concern because that is only taking into consideration water ingestion. The average concentration for the schools that tested positive for over 15 ppb was 64.29 ppb. This average was the average of the reported lead levels that were above 15 ppb. This resulted in an HQ value of 0.214148. Table 2 summarizes the results of the calculations for the 90th percentile, average, highest and lowest concentrations.

Table 2. Hazard Quotient results at various lead concentration levels.

Lead Water Concentration (ppb)	Concentration of Lead in Drinking Water (mg/kg)	Hazard Quotient
19.3	0.0193	0.064287
64.29	0.06429	0.214148*
194	0.194	0.646208*

Lead Water Concentration (ppb)	Concentration of Lead in Drinking Water (mg/kg)	Hazard Quotient
16.1	0.0163	0.054294

*States there is a cause for concern.

4.4.2 Discussion of Risk Characterization Results

Based on the exposure and the HQ calculated for two of the dosage levels there is a cause for concern when it comes to lead contaminated drinking water in several schools in the Newark, New Jersey school district. There is a concern at the schools reporting high lead concentrations because even at the lowest dose recorded, the HQ factor was close to 0.2 and only the route of contaminated school water was assessed. When kids return home, they may still be drinking contaminated water since they live in the surrounding area with similar ages of construction and materials, giving them even more contact time with contaminated water. While the water supplier's tests show that the water in the systems pipes is below the action level, many older buildings still have lead piping and/or solder. With chances of also encountering lead from lead-based paints at home, and from soil and inhalation while playing outside, it is possible that children are exposed at overall levels that would results in an HQ factor exceeding 0.2.

Chapter 5: Potential Preventive Measures

The North Jersey Water Supply Commission and Passaic Valley Water Commission (PVWC) supply the Newark area with water. The PVWC has three open water reservoirs for finished water that comes from the Little Falls Water Treatment Plant. However, since these are uncovered reservoirs, they are exposed to bacteriological and chemical elements that linger in the surrounding environment. Even though the water is of exceptional quality, this puts the finished treated water at risk. Because of this, the water withdrawn from this area must be re-chlorinated before distribution. Because they are uncovered, the water company cannot add a phosphate-based corrosion inhibitor to reduce lead leaching into the water as it sits in the piping. They are unable to add this inhibitor because it will promote algae growth in the presence of sunlight when the water sits in the open water reservoirs.

The Little Falls Water Treatment process uses four means of achieving high levels of disinfection and removal. There are two particle removal systems, high rate sand-ballasted and filtration with granular activated carbon and sand. There also are two chemical disinfection systems, primary with ozone and secondary with chlorination. Over the past decade, the system has undergone $80 million in upgrades, which included the high-rate sedimentation and the ozone disinfection systems.

Knowing how the water is treated and the types of chemicals used can help in developing a plan to lower the chances of lead leaching into the drinking water. One of the most effective but also most expensive fixes would be for PVWC to construct a covered water reservoir for finished water. The plan would be to drain three reservoirs on

Garret Mountain and replace them with concrete tanks with cost estimations being around $135 million (13). This would allow them to add the phosphate-based inhibitor and prevent the chances of lead leaching into the water. At low levels the orthophosphates will react with the lead leaching into the water. It will also react with the copper and hardness ions to form an insoluble coating on the inside of the pipes. Most of these orthophosphates work best under alkaline conditions (14).

It was stated by the executive director of PVWC, Joseph Bella, that the water itself is not contaminated from the reservoir but it becomes contaminated when lead leaches from the pipes (15). The PVWC will spend up to $5.5 million to replace the 800 remaining lead pipes in their system to help reduce the high levels of lead in the drinking water (16). The pipes that are being replaced connect the water main to a residential curb therefore this does not include any lead pipes on residential property. A no-interest loan will be available for residence that wish to have their pipes replaced for $4,000 (16).

Currently there are no federal or state regulations for when it comes to regularly testing water at the faucets or drinking fountains at schools in New Jersey. New York has established a new state law that requires schools to collect samples every 5 years at a minimum after initial testing or at times determined by the commissioner of health. The water taken for testing must be cold and have been sitting in the pipes for at least 8 hours but no longer than 18 hours (17). If New Jersey could draft and implement similar legislation, it could be beneficial to document that they are guaranteeing safe drinking water for children during critical life stages.

The Newark Public Schools Superintendent Chris Cerf along with Environmental Justice Organizer Kim Gaddy, NJ Clean Water Council Daniel Van Abs, Managing

Director Chris Sturm, and Ironbound Community Corp. Ivelisse Mincey, held a meeting in April 2016 to address the steps they will be taking to address the lead water problem in New Jersey. Newark cannot afford the costs associated with some of the prevention ideas discussed but they cannot afford to not address the growing concerns of lead in drinking water. Currently school districts are either implementing a flushing protocol or supplying bottled water. These two preventative measures are only putting a bandage on a widespread and large problem. Flushing the water system of schools is a risky temporary solution because of human error. Whoever oversees flushing the system could forget to do it some days or they may not flush it long enough. Providing bottled water to all the schools cost nearly $75,000 a year and has other indirect costs associated with it (18).

The best solution that the school districts are looking at pursuing includes replacing all the piping in the schools' water systems. There are two paths of funding to address the question of who would be paying for these infrastructure upgrades. These two pathways include school district money (tax payers), and then state and federal grants for severely underprivileged areas. To help pay for this, consumers would also be experiencing an increase in their water bills. How substantial of an increase will be unknown until cost estimations are complete. Even if it is a minimal increase, this is going to put underprivileged families under even more strain when it comes to their financial situation. Between 20-22 percent of the water supply is lost through leaks in the piping system, so replacing the piping will help the system be more efficient and will cut down long term life-cycle costs and most importantly they will be supplying lead free water to the schools. The current plan of action that is in place is happening in stages.

The first stage was to stop the access to lead contaminated water in schools, which has been completed. The next stage is working with engineers, EPA and other specialists to develop plans and estimations for the cost to replace the piping system. Once a plan and cost analysis is completed they will hold public seminars to allow the public to voice their opinions on the conceptual ideas developed (18).

Chapter 6: Conclusion

Since this risk assessment only looked at the route of exposure being through water ingestion and half of the doses analyzed resulted in an HQ greater than 0.2, there is a great concern for risk when it comes to children having lead poisoning in the Newark School District. We can conclude from this risk assessment that actions need to be taken to remediate this contamination and preventative measures need to be established to prevent another contamination from happening. After completing this risk assessment, the best options to prevent this from happening include constructing covered reservoirs, allowing the water supply companies the ability to add phosphate inhibitors and prevent corrosion of the pipes and drafting and implementing a piece of legislation that requires regular testing of water outlets in schools. Having regularly scheduled tests will allow for earlier detection of lead and help minimize the opportunity for children to encounter lead contaminated water.

References

1. EPA"How EPA Regulates Drinking Water Contaminants." EPA. Environmental Protection Agency, 11 May 2016. Web. 06 Mar. 2017.

2. Hernberg, Sven. "Lead poisoning in a historical perspective." American Journal of Industrial Medicine 38.3 (2000): 244-54. Web.

3. EPA"Use of Lead Free Pipes, Fittings, Fixtures, Solder and Flux for Drinking Water." EPA. Environmental Protection Agency, 27 Jan. 2017. Web. 06 Apr. 2017.

4. "Pollution Prevention and Green Technology." Office of Pollution Prevention and Green Technology. N.p., n.d. Web. 06 Apr. 2017.

5. Torrice, Michael. "How Lead Ended Up In Flint's Tap Water." CEN RSS. N.p., n.d. Web. 06 Apr. 2017.

6. "Basic Information about Lead in Drinking Water." EPA. Environmental Protection Agency, 20 Mar. 2017. Web. 10 Apr. 2017.

7. Dan Ivers | NJ Advance Media for NJ.com. "17,000 Newark children to be tested for lead poisoning." NJ.com. N.p., 15 Mar. 2016. Web. 09 Apr. 2017.

8. "Lead - Element Information, Properties and Uses | Periodic Table." Lead – Element Information, Properties and Uses | Periodic Table. N.p., n.d. Web. 05 July 2016.

9. Patel, Anjali. "How Does Lead Effect the Nervous System?" How Does Lead Effect the Nervous System? N.p., n.d. Web. 05 July 2016.

10. "The Long-Term Effects of Exposure to Low Doses of Lead in Childhood." New England Journal of Medicine 324.6 (1991): 415-18. Web.

11. Jessica Mazzola | NJ Advance Media for NJ.com. "Which Newark schools have elevated lead levels? (MAP)." NJ.com. N.p., 10 Mar. 2016. Web. 26 Apr. 2017.

12. Hazard Quotient Risk Calculation Tool. N.p., n.d. Web. 14 Apr. 2017.

13. Cowen, Richard. "Passaic Valley Water Commission seeking alternatives to covering reservoirs, will hold public forums." NorthJersey.com. N.p., n.d. Web. 08 Mar. 2017.

14. The Phosphate Forum of the Americas. N.d. The Use of Phosphates For Potable Water Treatment. 04 Mar. 2017.

15. Katz, Maggie. "PVWC: Lead found in water." NorthJersey.com. N.p., n.d. Web. 26 Apr. 2017.

16. Fallon, Scott. "Water utility plans to replace remaining lead pipes." North Jersey. N.p., 18 Jan. 2017. Web. 26 Apr. 2017.

17. "Schools' water to be tested under new state law." Nysut. N.p., n.d. Web. 06 Mar. 2017.

18. "LISTEN: "Safe Water/Safe Cities" Panel Discussion." WNYC. N.p., n.d. Web. 06 Mar. 2017.