Lead in drinking water: factors affecting lead concentration, health effects, and is flushing effective.

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Abstract

Background: Lead is a systemic toxin that affects multiple organs and impairs physical and mental development. Although lead is ubiquitous in the environment, majority of exposures to lead is through drinking water. Lead-based plumbing components are the primary reason. Flushing is a lead reduction technique commonly used to reduce lead in drinking water, but the efficacy of the technique has been questioned. The purpose of this research project was to determine if there were significant levels of lead found in the drinking water of 12 buildings (sites) owned and operated by a Health Authority before and after 30-second flush and to determine if flushing is an effective measure to reduce lead concentrations.

Materials and Methods: Lead in drinking water data was provided by Dr. Tom Kosatsky in an Excel spreadsheet. The data contained 184 pre-flush ($\geq$ 8-hour stagnation period) samples paired to 184 post-flush (30-second duration) samples collected at locations within the 12 different sites. The sites were labelled A to L due to confidentiality. This data was then exported to NCSS, and statistical analysis in the forms of a two tailed t-test, one tailed one sample t-test, and repeated measures ANOVA was performed to determine if a statistically significant relationship between flushing and reduced lead concentrations exists.

Results: Out of 368 samples, 28% of stagnation samples contained lead concentrations greater than the MAC (n = 103) whereas, 9% of post 30-second flush samples contained lead concentration greater than the MAC (n = 33). Lead concentrations in the drinking water samples after flushing were significantly reduced below the MAC (p = 0.00000). However, lead concentrations from samples collected at sites A, C, and G were equal to or greater than the MAC. Statistical analysis failed to reject the null hypothesis that post-flush lead concentrations for samples collected at sites A, C, and G is greater to or equal to the MAC (A: p = 0.22708, C: p = 0.06866, and G: p = 0.70589).

Conclusion: Flushing is an effective measure in reducing lead concentrations at the tap to safe levels. However, the effectiveness of flushing and flushing duration is dependent on numerous factors such as the stagnation period, amount of lead-based plumbing supplying the drinking water and building size. Longer stagnation periods, increased lead-based plumbing, and large buildings all require longer flushing times to reduce lead concentrations to below 0.005 mg/L. The results of this can study can aid governments in developing polces that will eliminate existing lead infrastructure in British Columbia and Canada. Flushing is not a long-term solution in reducing lead concentrations at the tap to below 0.005 mg/L.

Literature Review

Introduction

Lead like other heavy metals, such as mercury once ingested is toxic and detrimental to the body (1). The health effects of lead are dependent on the concentration and duration of exposure, however even on the low end of the spectrum, effects are detrimental (2). Canada has a maximum allowable concentration (MAC) for lead at 0.005 mg/L with an emphasis on ALARA (as low as reasonably achievable), as different studies have shown that chronic lead exposure below the MAC has been associated with severe deterioration of kidney function (3). At chronic exposure levels greater than the MAC, severe health effects can occur such as psychosis, dyslexia, birth defects, brain damage and mental retardation (4). Nevertheless, there is no safe exposure level to lead as any amount can cause health effects and children are the most affected due to lead affecting childhood development (4).

Due to the negative health effects, lead has been widely removed from products that were previously a major source of lead such as paints, gasoline, and consumer products (5). However, ingesting lead-contaminated drinking water is now the primary source of lead exposure (5, 6, 7). Lead gets into drinking water when corrosive water flows through old lead piping and dissolves the lead into the water (7).

Sources of Lead Exposure

Lead in drinking water continues to be one the main sources of lead exposure in the developed world (5). Prior to 1975, lead piping and soldering were commonly and widely used materials in the plumbing infrastructure of buildings and houses due to its softness, poor conductibility, and resistance to corrosion (8 ,9). After the adverse health effects of lead were discovered, usage of lead piping and plumbing started to decline in the infrastructure of homes and buildings (8). Despite this, there continue to be reports of high lead concentrations in drinking water. It is estimated that ingesting drinking water accounts for approximately one-fifth of an adult's total lead exposure and half of a child's total lead exposure over a lifetime (7). Researchers found approximately 25% of samples collected after a stagnation period and 10% of samples collected after a 30-second flush exceed the previous MAC for lead in Ontario schools (10). However, another study conducted in 2016, analyzed over 70,000 water samples from schools, daycares, and large buildings and found conflicting results as samples ranged from less than 5e-5 mg/L to a maximum of 13.2 mg/L of lead (11). Many of the high lead concentrations found were due to the presence of old lead plumbing and long stagnation periods whereas lower concentrations of lead were found in newer buildings with newer plumbing systems and had a flush protocol (11). The extreme variation in lead levels show the importance of age, corrosion

amount, and type of lead plumbing components used in the buildings as it greatly affects the level of lead found in drinking water (11). When ingested, the levels of lead from drinking water can cause adverse health effects dependent on the dose, with children being disproportionately affected (7).

Relationship between lead and health effects

Children are the most vulnerable to lead exposure. Majority of lead exposure occurs in the gastrointestinal tract and children absorb lead more efficiently in that region when compared to adults (40% efficiency for children compared to 5% to 15% for adults) (12, 13). Due to this, children are more at risk for lead poisoning (12).

Blood and bone lead level measurements are useful in determining the accumulated concentration of lead in the body (14). Blood and bone lead levels in the Canadian population have been significantly reduced since the 1990s and can be attributed to the stringent regulations and legislations enacted to combat lead exposure (14). The average mean blood lead levels in children living in the United States due to ingestion of lead contaminated drinking water was estimated to be 0.019 mg/L (6). Meanwhile, a recent Canadian study examined blood lead levels of children aged one-to-five and found the average levels to be 0.0135 mg/L (15). Due to the similar results of blood lead levels found between the two study populations, an inference can be made regarding the significance of lead exposure caused by lead-contaminated drinking water in the overall population (15). The findings presented by Ngueta et al are consistent with the results found in the Canadian Health Measures Survey (CHMS) which stated the average blood lead levels of the Canadian population to be 0.012 mg/L (15, 16). There is no safe threshold for lead exposure and evidence has shown that lead follows a dose-response relationship in the severity of health effects (17).

The health effects of lead can vary greatly depending on the level of exposure; it can range from vitamin D deficiency, hypertension, or mental retardation depending on the dose (1). Studies analyzing the relationship between blood lead levels and IQ deficiency in children have shown complementary results. Both Chen et al. and Health Canada suggested a negative relationship between increased blood lead levels and lower IQ scores in children. The study conducted by Chen et al, established a negative correlation of -0.20 suggesting an inverse relationship (18). Whereas a Canadian study also reported a negative relationship by stating that every 0.01 mg/L increase in blood lead level is associated with a one-point drop in IQ score (19). The association between blood lead levels and health outcomes such as IQ deficiency is causal; for others such as hypertension, the association is more controversial.

Hypertension is considered a major risk factor for numerous different cardiovascular diseases (20). Numerous studies have suggested that a dose-response relationship exists between lead concentration and risk of hypertension, albeit the results of these studies are conflicting

(20, 21, 22, 23). Bushnik et al reported a statistically significant association between systolic blood pressure, diastolic blood pressure, and blood lead levels using the study population found in the Canadian Health Measures Survey; however, the association only arose in certain age groups (40 to 54) and only when adjusted for other risk factors of hypertension (22). When accounting for the entire age group of the study population (40 to 79), no statistically significant association between blood lead levels and hypertension of hypertensive and non-hypertensive individuals was observed (22). This likely indicates that other hypertensive risk factors such as obesity played a bigger role than lead levels in hypertension development (22). Although another study consisting of a Brazilian population reported a statistically significant association between the same parameters measured by Bushnik et al, along with increased odds of developing hypertension in the same age range of 40 years and older (21, 22). The variance in results between the two studies could possibly be explained by the discrepancy in the study population size (4450 for Bushnik et al.' study vs 984 for Almeida Lopes et al.' study) or the differences in ethnicity and race of the two study populations; or the differences in experimental methods, as Bushnik et al., was analyzing secondary data while Almeida Lopes et al., was analyzing primary data. It has been shown that blood lead levels and development of certain disease outcomes vary between ethnicities and races, with some ethnicities and races having

higher risk levels (24). Furthermore, the studies conducted by Bushnik et al and Almeida Lopes et al, both used a cross-sectional study design which makes it difficult to determine a causal relationship between lead concentrations and risk of developing hypertension due to analysis of the data being at a singular point in time. However, the results from a multi-year cohort study conducted with a Swedish study population also found an association between increased blood lead levels and hypertension in a cross-sectional analysis similar to the other two studies mentioned above (20). However, after a 16-year follow-up with two-thirds of the study population, no association between blood lead and hypertension was recorded (20). The literature on blood lead and hypertension risk needs to be explored further before establishing a causative link and a definitive dose-relationship between the two. There is no clear association or dose-response relationship between lead and certain health outcomes such as hypertension.

Relationship between plumbing , water quality and lead concentration

Lead is present in household drinking water primarily due to lead-based plumbing fixtures such as pipes and fittings, as well as city service connections (25). The concentration of lead dissolved in drinking water from plumbing is dependent on several factors such as the corrosiveness, the duration of stagnation, and pH of the water (25). Corrosion of lead-based plumbing during the delivery of water from the source to tap is a major contributor to the amount

of lead found in drinking water (26). Knox et al compared the drinking water quality at the tap of homes to the quality of water at the source by analyzing the pH, corrosion controls, and the amount of lead detected (26). The highest amount of lead was found in the first and second samples after a cold-water flush at the tap compared to samples at the source of the water in each region (26). These results are indicative that corrosion of household plumbing during the delivery of water contributed to the significant increases in levels of lead and impacted the water quality (26). However, small variations in pH levels did not affect the concentrations of lead present in the samples taken at the tap suggesting corrosion control did not affect the levels of lead found (26). Similarly, Deshommes et al, found extreme lead concentrations up to 2640 times greater than the MAC after an 8-hour stagnation period along with a sample reaching 186 times greater than the MAC after a 5-minute flush in buildings serviced by lead plumbing and piping along with corrosive water (11). These results suggest that corrosive water, the usage of lead-plumbing, and duration of stagnation all contribute to the amount of lead found in drinking water. Flushing reduces lead concentrations to a certain degree depending on the duration.

Deshommes et al consistently found that flushing times between 30-seconds and 5-minutes greatly reduced lead concentrations below the previous MAC of 0.010 mg/L (11). However, 10% of samples collected in larger buildings after a 30-second flush exceeded the previous MAC (11). Due to the nature of the large buildings, aged-lead plumbing serviced a majority of the taps thus, influencing the lead levels in the samples collected (11). Another study measured the lead concentrations in schools and large buildings built between 1920 and 1960 after a 30-second flush and found 14% of samples exceeded the previous MAC and 22% of samples exceeded the current MAC (27). The higher lead concentrations were attributed to lead plumbing servicing the schools and large buildings as lead plumbing was widely used back in the early 1900s (8, 27). Another study found increased levels of lead in water sampled after a 30-second flush compared to samples collected after a stagnation period in residential homes; however, the association was marginally significant as the researchers reported a p-value of 0.04 (28). Most homes that exhibited high lead concentrations in drinking water were built before the 1950s or serviced by city-water connected via lead plumbing (28). Thus, a building's age and use of lead plumbing influenced lead concentrations in drinking water despite a 30-second flush (28). These findings suggest that the probability of flushing reducing lead levels in drinking water to below the MAC is dependent on whether the building is serviced by lead plumbing or if the building has outdated plumbing infrastructure.

Purpose of this Study

The purpose of this research project was to determine if there are significant levels of lead found in the drinking water of 12 buildings (sites) owned and operated by a Health Authority and to

determine if flushing is an effective measure to reduce lead concentrations.

Materials and Methods

The materials used in the analysis of the secondary data was the Excel file containing the raw data and a Windows 10 PC running the NCSS statistical software. The samples were collected from 12 different sites operated by a Health Authority and labelled A to L to ensure confidentiality. At each respective site, multiple samples were taken pre-and-post flush at different locations within each site, but the number of pre-and-post samples differed per site. The number of samples taken at each site was dependent on building size and how many frequently used taps were available.

The methods for this project involved statistical testing of the secondary data. One paired t-test was conducted to determine if there was a difference in the lead concentration of samples collected after an 8-hour stagnation period (i.e., pre-flush) compared to samples collected after a 30-second flush (i.e., post-flush). Five separate one-sample t-tests were conducted, one comparing pre-flush and one comparing post-flush samples to the MAC; and three one-sample t-tests to determine if post-flush samples collected at sites A, C, and G exceeded the MAC. These tests were used to determine if mean pre-flush lead levels were significantly greater than the MAC and if mean post-flush lead levels were significantly lower than the MAC. A repeated measures ANOVA was conducted to determine if the sites where the pre-and-post samples were collected had any influence on the lead concentrations in each respective sample.

Statistical Analysis

Descriptive Statistics of Real Data

The lead in drinking water data set contains numerical and continuous data as the values in the pre-and-post flush sample populations fell within a range.

Figure 1. Log_{10} Box Plot with Outliers for Pre-Flush and Post-Flush Samples
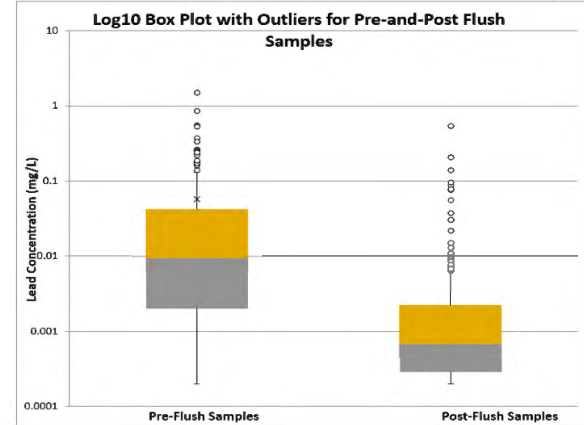
Figure 1 shows a box plot containing potential outliers for both pre-flush and post-flush samples. There was a large number of outliers for both pre-flush samples (n = 22) and post-flush samples (n = 30), see Appendix 2. The researcher decided to the keep the outliers in the data set during statistical analysis due to the abundance as outliers are supposed to be rare. Furthermore, the data is secondary data thus, the researcher can not go back to recollect the water samples to try and reduce outliers. In the literature, lead concentrations in drinking water have been shown to reach the values seen in the outliers.

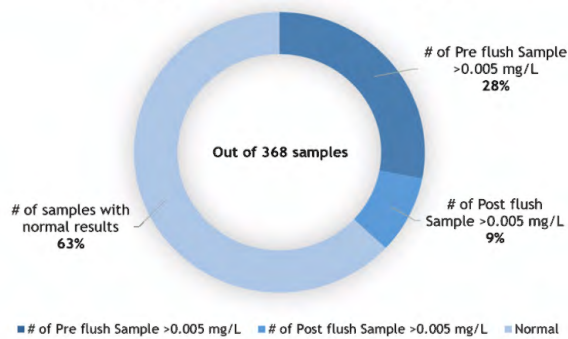**Figure 2. Donut Chart of Drinking Water Lead Testing Results**

Figure 2 shows the percentage out of 368 samples collected that were normal and samples that were below or above the MAC. Samples are considered normal if lead concentrations pre-flush or post-flush were less than 0.005 mg/L. Overall, the majority of samples had lead concentrations less than the MAC (68%). Flushing appeared to work as it reduced the percentage of samples with lead concentrations greater than the MAC by 19% down to 8% of post-flush samples compared to 28% of pre-flush samples being above the MAC. Furthermore, the number of samples with lead concentrations greater than the MAC vary across all 12 sites.

Figure 3. Number of Pre-Flush Samples Greater Than 0.005 mg/L by Site
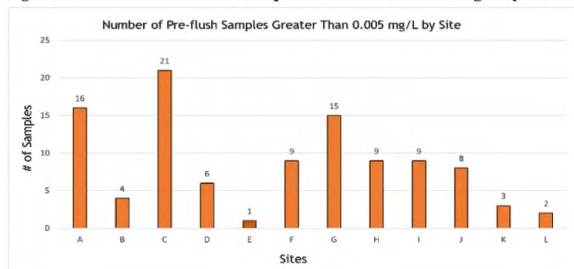

Figure 3 shows the number of pre-flush samples containing lead greater than the MAC at each site. Of the 103 samples, sites A, C, and G had a combined 52 water samples with lead concentrations over the MAC which constituted 50% of total samples. Sites F, H, I, and J had a combined 35 samples with lead concentration over the MAC which constituted 34% of total samples. Whereas, sites B, D, E, K, and L had a combined 16 samples with lead concentrations over the MAC which constituted 16% of total samples. The differences seen could be due the stagnation duration at each site, the buildings age, or the number of plumbing connections.

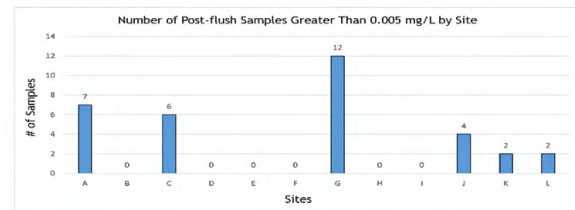**Figure 4. Number of Post-Flush Samples Greater Than 0.005 mg/L by Site**

Figure 4 shows the number of post 30-second flush samples with lead concentrations greater than the MAC across all twelve sites. Similar to figure 3, sites A, C, and G had the most samples with lead concentrations greater than the MAC when compared to the other sites. Out of the 33 samples, sites A, C, and G had 25 samples with lead concentrations over the MAC which constituted 78% of total samples. This could indicate potential sources of lead in the aforementioned sites due to high concentrations even after a 30-second flush.

Inferential Statistics

Secondary data analysis of lead concentration in drinking water was performed using the NCSS software. Table 3 below presents the parameters, results, and conclusion of the paired T-test, one tailed T-tests, and repeated measures ANOVA. A standard alpha value of 0.05 was used for all statistical tests.

Table 3: Results and interpretation of NCSS data analysis.

H$_0$ and H$_a$	Test Used	Result	Conclusion (alpha or beta error, if relevant), power (if provided)
H$_0$: Post-flush lead concentration is greater or equal to pre-flush lead concentrations. H$_a$: Post flush lead concentration is less than pre-flush lead concentration.	Two Tailed T-Test	Wilcoxon Signed-Rank test (p = 0.00000)	With a P value of 0.00000, one would reject H$_0$ and conclude that there is a statistically significant reduction in lead concentration post-flush compared to pre-flush. The power for this test was 99% which suggests that there truly is a difference in lead concentrations post-flush compared to pre-flush.
H$_0$: The mean pre-flush lead concentration is less than or equal to the MAC. H$_a$: The mean pre-flush lead concentrations is greater than the MAC.	One Tailed One Sample T-Test	Wilcoxon Signed-Rank test (p = 0.00000)	With a P value of 0.00000, one would reject H$_0$ and conclude that there are statistically significantly greater lead concentrations in pre-flush samples compared to the MAC. The power for this test was 99% which suggests that there truly is a difference between lead concentrations found in pre-flush samples and the MAC.
H$_0$: The mean post-flush lead concentration is greater than or equal to the MAC. H$_a$: The mean post-flush lead concentration is less than the MAC.	One Tailed One Sample T-Test	Wilcoxon Signed-Rank test (p = 0.00000)	With a P value of 0.00000, one would reject H$_0$ and conclude that there are statistically significantly lower lead concentrations in post-flush samples compared to the MAC. However, the power for this test was 0.17% indicating a potential beta error of 0.99826. This would suggest that mean post-flush lead concentrations are actually higher than the MAC, but with a significant p-value of 0.00000 this level of beta error should not have occurred. Borrowing power from a parametric test where the p-value was insignificant at 0.89932 would not make sense in this scenario and remains unresolved.
H$_0$: The mean post-flush lead concentration for samples collected at Site A is greater than or equal to the MAC. H$_a$: The mean post-flush lead concentration for samples collected at Site A is less than the MAC.	One Tailed One Sample T-Test	Wilcoxon Signed-Rank test (p = 0.22708)	With a P value of 0.22708, one would fail to reject the null hypothesis and conclude that drinking water samples collected at Site A contained lead concentrations equal to or greater than the MAC post-flush. However, with a power of 0.3%, this would indicate a beta error of 99.7%. The beta error can potentially be caused by the small sample size for Site A (n = 22). However, this would indicate that the null hypothesis is indeed false and lead concentrations post-flush are less than the MAC.

H_0: The mean post-flush lead concentration for samples collected at Site C is greater than or equal to the MAC. H_a: The mean post-flush lead concentration for samples collected at Site C is less than the MAC.	One Tailed One Sample T-Test	Wilcoxon Signed-Rank test (p = 0.06866)	With a P value of 0.06866, one would fail to reject the null hypothesis and conclude that drinking water samples collected at Site C contained lead concentrations equal to or greater than the MAC post-flush. However, with a power of 0.071%, this would indicate a beta error of 99.9%. The beta error can potentially be caused by the small sample size for Site C (n = 24). However, this would indicate that the null hypothesis is indeed false and lead concentrations post-flush are less than the MAC.
H_0: The mean post-flush lead concentration for samples collected at Site G is greater than or equal to the MAC. H_a: The mean post-flush lead concentration for samples collected at Site G is less than the MAC.	One Tailed One Sample T-Test	Wilcoxon Signed-Rank test (p = 0.70589)	With a P value of 0.70589, one would fail to reject the null hypothesis and conclude that drinking water samples collected at Site G contained lead concentrations equal to or greater than the MAC post-flush. However, with a power of 0.17%, this would indicate a beta error of 99.8%. The beta error can potentially be caused by the small sample size for Site C (n = 20). However, this would indicate that the null hypothesis is indeed false and lead concentrations post-flush are less than the MAC.
H_0: There is no difference in lead concentrations, site influence, and pre-flush and post-flush conditions. H_a: : This is a difference in lead concentrations, site influence, and pre-flush and post-flush conditions.	Repeated Measures ANOVA	C: Pre_Post (p = 0.000072) A: Site_Name (p = 0.01326) AC: Pre_Post_Sites (p = 0.173739)	With a P value of 0.000072, one would reject H_0 and conclude that there is a statistically significant difference between pre-and-post flushing values. Furthermore, there is also a statistically significant difference in lead concentrations between the 12 sites (A: Site_Name P value = 0.013126), but no statistically significant difference was seen in the interaction between pre-and-post flush values and the sites together (AC: P value = 0.173739). This indicates that the sites where the samples were taken did not have a statistically significant influence on pre-and-post flush lead concentrations but an overall difference in lead concentrations regardless of the pre-or-post flush condition was seen between sites. The Tukey-Kramer post hoc test for pre-and-post conditions reported a 95% confidence that did not contain zero along with a p-value of 0.00003 indicating there is a statistically significant difference between pre-and-post lead conditions. With a power of 93%, 98%, and 72% for A: Site _Name, C: Pre_Post, and AC respectively, it suggests that there truly is a difference in the factors seen above. Although, the power for AC is below the 80% threshold, indicating a potential beta error.

Discussion

Lead concentrations in drinking water after a 30-second flush were significantly lower than after an 8-hour stagnation period. Out of 368 samples, 28% of stagnation samples contained lead concentrations greater than the MAC (n = 103) whereas, 9% of post 30-second flush samples contained lead concentration greater than the MAC (n = 33). There was a statistically significant reduction of lead concentrations in drinking water samples post-flush compared to pre-flush (p = 0.00000). Both pre-flush and post-flush samples had lead concentrations higher and lower than the MAC, respectively (p = 0.00000 and p = 0.00000, respectively). The literature has shown lead concentrations to be higher after a stagnation period and lower after a flushing period and the result of this study concur with those results (28). The stagnation period refers to when water in plumbing is not moving or flowing appears to greatly influence lead concentration which is seen in the results where 28% of samples collected immediately after stagnation had lead concentrations greater than the MAC. Numerous studies have cited that longer stagnation times of six plus hours allow for greater amounts of lead to diffuse into the water from lead soldered joints and brass faucets (29, 30). Flushing has been the primary and most effective method of reducing lead concentrations in drinking water with the duration of flushing time being reliant on the type of plumbing servicing the home (30). Often, the recommended flushing time ranges from 30-seconds for buildings primarily containing brass

fittings or lead-soldered joints to 2-minutes for buildings serviced by partial lead service lines (28, 30). The results of this study agree with the literature as after a 30-second flush, lead concentrations were significantly reduced to levels below the MAC (p = 0.00000). However, certain sites (A,C, and G) had water samples that showed no to little reduced concentrations of lead after flushing. Reasons for this are unknown as details of the buildings are unavailable; however, the literature has shown that short flushing periods in areas serviced by lead serviced lines have actually increased levels of lead compared to first draw (28). However, majority of cities in British Columbia do not use lead service lines to deliver water from source to tap (31, 32, 33). Another reason for the increased lead concentrations for samples collected in sites A, C, and G could be building size which determines how long water stays stagnant due to vast plumbing infrastructure as well as plumbing materials used in the buildings; mainly lead-based fixtures, fittings, and pipes. Building size influences the amount of lead in drinking water, one study found that larger buildings had lead concentrations greater than the MAC even after flushing due to longer stagnation periods which allowed for greater diffusion of lead into the water (11). This is troubling as many large buildings are institutions such as schools, hospitals, or daycares and lead affects children's development the greatest (11). Privately owned buildings serviced by city lines and city water have been shown to have increased lead

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concentrations after flushing as these buildings may be old and contain lead plumbing materials (34). The reason being longer stagnation times allow for greater concentrations of lead in drinking water due to diffusion and short flushing periods carries the majority of the lead in the water out the tap during the initial flush (28). One solution to reduce lead concentrations and flushing duration long term is to upgrade the plumbing infrastructure of old buildings to non-lead components, but this option is expensive. One less expensive option is to install a point of use water treatment system at taps with historically high concentrations of lead or install a point of entry water treatment system if building size is adequate. The results of this study are valid as it reflects trends seen in the literature and can be extrapolated to other private-side buildings.

Limitations

The main limitation of this study was the nature of the data given to the student. The secondary data and the confidentiality agreement limited details in regard to the sites where the samples were collected, how the samples were collected, details about the sites and locations, and if the primary researchers faced any limitations during their analysis. Another major limitation of this study was that the researcher was not capable of collecting water samples at the same locations as the secondary data in order to ensure consistency and reliability of the results due to time and budget constraints. Recommendations to relieve these limitations includes: the researcher collecting the samples

themselves, contacting Dr. Kosatsky for details regarding the methods used to collect the water samples, and the researcher having open access to all information.

Knowledge Translation

The results of this study can be incorporated into flushing guidelines that can be developed by health authorities and or cities. This would ensure individuals are flushing for the appropriate amount of time after prolonged stagnation periods such as first thing in the morning. This might be especially useful for residents leaving in areas still fully serviced or partially serviced by lead service lines, as flushing times are dependent on the type of service line. Furthermore, specific flushing times can be incorporated into the documents to better help individuals identify which times are best, dependent on their plumbing infrastructure. Health authorities can use the results and develop an educational tool for schools to use flushing as a method to reduce potential lead concentrations, especially in the mornings after overnight stagnation. Although, it may be a challenge, the results of this study can be used to implement or vary policies in regard to replacement of lead plumbing in buildings such as elementary schools and daycares. The literature shows schools are at risk for increased lead concentrations at the taps due to the age of buildings, complexity, and materials of the plumbing, and long stagnation periods. Children are the most at risk for adverse health effects as lead affects development thus

policies and programs aimed at schools to change plumbing infrastructure are important.

Future Studies

Future research studies that could be done from this project are:

- Personally, collecting and analyzing water samples for lead levels in large and small buildings and comparing the results to determine if there are any differences in lead concentrations between building size.
- Determine if different flush times influence lead concentrations in drinking water.
- Compare different flushing times to different stagnation times in order to determine if a difference in lead concentrations is related to flushing times vs stagnation times.

Conclusion

Excess concentrations of lead in drinking water are still prevalent in developed countries. This study was set out to determine if lead concentrations in drinking water samples collected at buildings owned by a health authority exceeded the MAC and if flushing reduced the lead concentrations to below the MAC. Statistical testing results showed that flushing does reduce lead concentrations to below the MAC, but also showed that flushing may not work 100% of the time. The practical significance of this study is that it reinforces that flushing is effective in reducing lead concentrations, but also shows it is not a long-term solution in reducing lead concentrations. New policies and guidelines targeting plumbing infrastructure and stagnation

which are the main causes of excess lead concentrations can be informed via this study.

Competing Interest

The authors declare that they have no competing interests while conducting this study.

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