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LEAD LEVELS OF WATER SOURCES IN MANILA, PHILIPPINES

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ABSTRACT

Water is very important. People use it for drinking, cooking, bathing, washing clothes, cleaning materials and recreation. It is vital that water must be free from contaminants that may pose health hazards to living things. Heavy metals are among the toxicants in the environment that are not readily degraded such that once introduced, it will stay there indefinitely. Heavy metals, like lead which this study is focused on may cause adverse health effects to children and adults. Literature review have provided evidences that lead may be implicated in the occurrences of several diseases, primary of which may be related to neurological dysfunctions. This study focused on the detection and quantification of Lead (Pb) concentration in tap and deep well water sources from twenty-four residential areas in the City of Manila and water from Baywalk, Roxas Boulevard Manila during summer when recreational activities occur, comparative to the set standard limit. It compared the levels of lead concentration in tap and deep well water. The analysis made use of Flameless Atomic Absorption Spectrophotometry (FAAS). The mean lead concentration for all tap water samples was found as 0.6059 ppm. Mean lead concentration for deep well water samples was 0.4489 ppm, while that for Baywalk was 2.4801 ppm. Samples obtained from tap, deep well and Baywalk water sources, fell above the 0.015ppm imposed by United States Environmental Protection Agency (US EPA) limits. This standard limit is used as basis in the Philippines. Shore soil in Baywalk showed a mean of 3.2229 ppm. The lead in the soil contributes to the lead source in the water and vice versa. As the concentration of lead in Baywalk soil is very high compared to EPA standard limit, coming in contact with it may prove hazardous. Thus, given the results of this study wherein no sample conformed to the US EPA standard, it is recommended that the Manila, Philippines should begin regular surveillance on lead contamination in water sources from representative areas and their correlation on possible toxicological findings in the consumers. Likewise the government must also take environment clean up initiatives and draft policies to help lessen lead burden in Manila.

Keywords: water sources, quantify, strategies for pollution prevention and control

1. INTRODUCTION

In Manila water is sourced from tap and deep well waters. Most residents enjoy the water as recreational medium in Baywalk, Roxas Boulevard, Manila. The quality of such water sources is not regularly tested. This could expose Manila residents to health risks if water sources become contaminated. In the recent years, there have been numerous investigations assessing the presence of water pollutants such as microorganisms (Abu Amr et al., 2008), radionuclides (Karamanis, 2007), synthetic and volatile organic compounds including pesticides (Batista et al., 2002) and herbicides Ding, 2000), and inorganic substances particularly, heavy metals (Yagi, 2007; Lasheen, 2008). This study focused on the detection and quantification of Lead (Pb) concentration in tap and deep well water sources from twenty-four residential areas in the City of Manila and water from Baywalk, Roxas Boulevard Manila. Lead concentration was determined using Flameless Atomic Absorption Spectrophotometer. Due to the use of leaded gasoline by millions of vehicles in Manila since its introduction to the market and the highly urbanized nature of the city of study, lead may be present in high amounts. This heavy metal is among the hazardous chemicals in the environment. It is found in water due the use of lead laden pipes (Knebel, 2000). It may also reach water bodies and natural reservoir run-off and leaching. Lead had been linked to high incidence of several neurological abnormalities in humans after chronic exposure (Cecil, 2008; Bull, 1975). This study will contribute to the limited number of researches in the Philippines on assessment of lead levels from different water sources. Also it will help forewarn the public of the possible heavy metal contamination in water which they use daily. Recommendations on pollution prevention and control may emanate from this study to improve on the present environmental quality. This study has to answer the following problems:

1. What are the lead levels in deep well and tap water in chosen areas in Manila and in Baywalk, Roxas Boulevard, Manila.
2. What water source exhibits higher lead concentration, deep well or tap water?
3. What are the concentrations of lead in Baywalk water during summer?
4. Do lead levels from water sources in Manila fall within set standard limits?

2. OBJECTIVES OF THE STUDY

The study aimed to quantify lead from water sources in Manila, Philippines. It basically intending to answer the below listed objectives:

1. To quantify lead levels from tap and deep well water sources in twenty-four areas in the City of Manila and in Baywalk, Roxas Boulevard, Manila.
2. To compare which water source exhibits higher levels of lead concentration than those imposed by official standards.
3. To identify lead concentrations in Baywalk water during summer where recreational activities usually occur.
4. To propose strategies for pollution prevention and control.

3. OVERVIEW ON THE ACTUAL WATER SITUATION IN MANILA

3.1. Water Supply in Metro Manila

The major source of water supply in Metro Manila comes from Angat-Ipo-La Mesa Dam Raw Water System. The water is then treated at the Balara Treatment Plant which is operated by the Manila Water Company, Inc., and the La Mesa Treatment Plant Water Services, Inc. From the Angat Dam, water flows to the Ipo Dam. From here it goes to three settling basins in Bicti, Norzagaray which are then connected to five Bicti-Novaliches aqueducts. From this portal, most of the water is transported to La Mesa and Balara Treatment Plants (http://www.manilawater.com/about-us/water-supply-system).

3.2. Water treatment process

In the Balara Water Treatment Plant four mechano-chemical processes are used, namely,coagulation/flocculation, sedimentation, filtration and disinfection. Coagulants and coagulant aids are mixed uniformly with water to be treated for bridging or adhesion of individual particles into flocs to occur. This will facilitate settling of the particles. The process is aided by slow, extended mixing to convert minute particles into discrete suspended particles. The flocs are allowed to settle in a sedimentation basin. After the sedimentation phase, water to be treated is passed through a media with several layers of graded sand and anthracite to screen out all foreign particles which did not settle down in the sedimentation basin. Chlorination to disinfect water is utilized at the Balara Treatment Plant. There are three stages of chlorination namely, pre, intermediate and post chlorination. Pre-chlorination is applied to remove odor and taste of water. Intermediate chlorination is for filter aid while the post-chlorination stage is for water disinfection. After these treatments, water is distributed by gravity and pumping (http://www.manilawater.com/about-us/water-supply-system).

3.3. Lead Contamination

Several factors dictate the amount of lead dissolved from the plumbing system, namely, the presence of chloride and dissolved oxygen, pH, temperature, water softness, and standing time of the water. Soft, acidic water is the most plumb solvent Lead that can be leached from water pipes can proceed indefinitely but leaching from soldered joints and brass taps decreases with time. Even in modern day houses, use copper piping with soldered connections can release 210-390 ug/L of lead. This may result to lead intoxication especially among children (http://www.who.int/ water_sanitation_health/dwq/chemicals/lead.pdf). As previously mentioned solder in joints between copper pipes, older faucets, and some types of water meters, are sources of lead. Some of these materials were previously marketed as "lead free" (Schock 1999). From water sources people may be chronically exposed to lead (Sherlock, 1984). In toxicokinetic models, 50% of lead in drinking water is absorbed by children (U.S. EPA 2002). In 1978, United States government officials banned the use of lead in home plumbing systems. Those houses built before 1978 though may still contain lead lined pipes (http:// www.historyofwaterfilters.com). Lead may be leached due to corrosivity (Switzer *et. al.*, 2006). In 2003, residents of the District of Columbia (DC) experienced an abrupt rise in lead levels in drinking water. This was due to a change in water-disinfection treatment in 2001(Tee, 2007) Use of chloramines instead of chlorine as disinfectant increased lead levels in tap water (Schock, 1999).

3.4. Detrimental Effects of Lead

Lead has been associated with neurological abnormalities in children following chronic exposure due to environmental pollution. In a study conducted by Meyer et al., in (1999), stated that the nature and extent of lead poisoning in children in the United States: a report to Congress, 1988) they have found out that thousands of children in the United States have elevated blood lead levels. At blood lead levels of $\geq$70 μg/dL, neurologic problems like seizure, coma, and death may ensue. High levels of lead in blood often correspond with impaired potential intelligence among children in a linear, dose-dependent fashion. This is contrary to its far more subtle effects on other neurologic functions (Goldstein *et. al.*, 1988). During critical early postnatal development, lead may enhance 'synaptic noise' which may permanently disrupt the architecture of cortical processing units through deprivation of high resolution environmental signals. These signals are essential for the refinement of synaptic connections (Johnston, 1998). In prospective longitudinal study, and retrospective studies, lead exposure in children and adolescents was linked to antisocial behavior. Both pre and post natal exposure to lead were also associated with antisocial acts. This may play a measurable role in the epigenesis of behavioral problems independent of the other studied social and biomedical cofactors (Dietrich, 2001). Lead had been a contaminant of water. It makes drinking water unsafe. In the Philippines, both tap and deep well water are used for drinking, cooking and bathing. Filipinos take summer dips in Baywalk water as well. Lead levels in the different water sources must therefore be determined, monitored and lessened if not removed from it. Its continued presence may result to serious impairments or even death to humans.

4. METHODOLOGY

4.1. Research design

Areas with deepwell water in Manila and utilization of Baywalk water for recreational activities during summer were observed and documented for this study. Thus the design of the research is partly descriptive where observation, description and documentation are part of the process (Polit, 2008) Exploration by collection of tap, deepwell and Baywalk water was done. Baywalk soil was also collected. The lead levels were determined using FAAS to investigate the probable deposition of the heavy metal from the environment in Baywalk, tap and deepwell water. The research design employed was descriptive-exploratory.

4.2. Population, locale and sampling procedure

Tap and deep well water samples from various areas in Manila were randomly collected. Twenty four different areas were selected as sampling stations. Baywalk (near US Embassy) water and near shore soil were sampled during summer of 2008.

4.3. Sample preparation and testing

One thousand five hundred milliliter samples for tap and deep well water were stored in pre-washed (with detergent and rinsed with distilled water) and acid-cleaned (diluted nitric acid and freshly distilled water) polyethylene bottles and were acidified immediately to a pH of about 1 with 60 % nitric acid. Digestion was carried out by filtering the samples first with # 2 Whatman filter paper. One hundred mL of the filtrate were collected in a beaker. Five mL of concentrated fuming nitric acid were added to the filtrate and the resulting solution was immediately covered with a watch glass. Samples were heated in a hotplate and evaporated to 50 mL without boiling. When the volume was reduced to half, the sides of the beaker and the watch glass were washed with freshly distilled water and then 3 mL of nitric acid were added to the solution. The samples were heated again and evaporated to around 40 mL. When the samples have cooled down, they were filtered again using #2 Whatman filter paper. The filter paper was washed around the funnel three times and the washings were collected in 50 mL volumetric flask. Samples were diluted to volume using distilled water and transferred to a high density polyethylene container. Samples were stored at 28-30°C then analyzed using Flameless Atomic Absorption Spectroscopy. Lead standards were prepared with the following concentrations: 0.02 ppm, 0.05 ppm, 0.1 ppm, 0.5 ppm and 1 ppm (adapted from Prester *et al.*, 1998). Five grams and five milliliters of the soil and water respectively were digested in 10ml concentrated nitric acid in an open glass container overnight, at room temperature, and the next day at 80 C for 5 hours. It was cooled to room temperature, and the volume was adjusted to 50 ml with distilled water and then analyzed using flameless atomic absorption spectroscopy (Prester *et al.*, 1998).

4.4. Observation procedure

Along major roads in Manila, areas with deepwell water stations were surveyed. Most residential places have water piping systems where tap water was obtained. Recreational activities of Manilenos in Baywalk water were observed during summer of 2008.

4.5. Statistical analysis

Two trials of sample and standard readings were conducted and the average concentration expressed in parts per million was obtained. For the tap, deepwell and Baywalk water lead concentrations, their respective means were obtained for ease of analysis.

5. RESULTS AND DISCUSSION

The presence of lead was detected in all samples taken from tap water and deep well water sources through the FAAS. The samples were taken from 24 chosen different areas (see Table 1).

Table 1: Chosen Sampling Stations in Manila

Sampling Station Number	Type of Water Source	Place of Sampling Station
A	Tap	Baranggay 383 Arlegui St., Quiapo
B	Tap	Remedios St
L	Deep Well	Baranggay 378 Zone 38, Tambunting
M	Deep Well	Baranggay 860 Zone 94 Selya St., Pandacan
C	Tap	Baranggay 378 Zone 38, Tambunting
D	Tap	Baranggay 581 Zone 84 Piña Avenue, Sampaloc
E	Tap	Baranggay 447 Zone 44, Vicente Cruz, Sampaloc
F	Tap	Baranggay 356 Zone 36, Blumentritt
G	Tap	Baranggay 52 Zone 76, Zamora St., Sampaloc
H	Tap	Vito Cruz along Taft Avenue
N	Deep Well	Baranggay 192 Zone 17 Roxas St., cor Blumentritt
O	Deep Well	Baranggay 857 Zone 97 Sta. Ana
P	Deep Well	Baranggay 571 Zone 56 Palawan St., Domingo Santiago, Sampaloc
Q	Deep Well	Baranggay 446 Zone 44 Antipolo St., Sampaloc
R	Deep Well	Baranggay 458 Zone 45 Maceda St., Sampaloc
S	Deep Well	Baranggay 357 Zone 36 T. Mapua, Sta. Cruz
T	Deep Well	Baranggay 608 Sta. Mesa
U	Deep Well	Baranggay 376 Zone 38 Aurora Boulevard
V	Deep Well	Baranggay 188 Zone 17 Barrio Obrero
W	Deep Well	Dimasalang St., Sta. Cruz
X	Deep Well	Baranggay 654 Zone 69 Intramuros
I	Tap	San Marcelino St along Taft Avenue
J	Tap	United Nations Avenue, Ermita
K	Tap	Baranggay 676 Zone 73 Gen. Luna St., Paco

Table 2: Lead Concentrations (ppm) in Tap Water Sources

Station Number	Sampling Stations	Concentration of Lead
A	Quiapo	0.7580
B	Remedios St.	0.3308
C	Tambunting St.	0.9970
D	Piña Ave., Sampaloc	0.2801
E	Vicente Cruz, Sampaloc	0.4466
F	Blumentritt	0.3525
G	Zamora St., Sampaloc	0.9535
H	Vito Cruz	0.9390
I	San Marcelino St., Ermita	0.6856
J	United Nations Avenue	0.4249
K	Paco	0.4973
		0.6059 Mean

Lead concentrations in tap and deep well waters are presented in Tables 2 and Tables 3 respectively. The highest lead concentration (0.9970 ppm) was detected in the tap water sample obtained from Baranggay 378 Zone 38 in Tambunting. Two other tap water samples with high lead levels were from Zamora St. in Sampaloc (0.9535 ppm) and in Vito Cruz (0.9390 ppm). Lowest lead level (0.2801 ppm) was found in the tap water sample from Piña Avenue, Sampaloc. Lead concentration from all tap water samples and the mean lead levels for all tap water samples (0.6059 ppm) were all above the permissible lead limit of 0.015 ppm as stated by US Environmental

Protection Agency Guidelines (http:// www.epa.gov/ OGWDW/lead/ basicinformation.html). Not one tap water sample conformed to the US-EPA standard. Figure 1 shows the bar graph of lead concentrations in water from pipes/tap water sources.

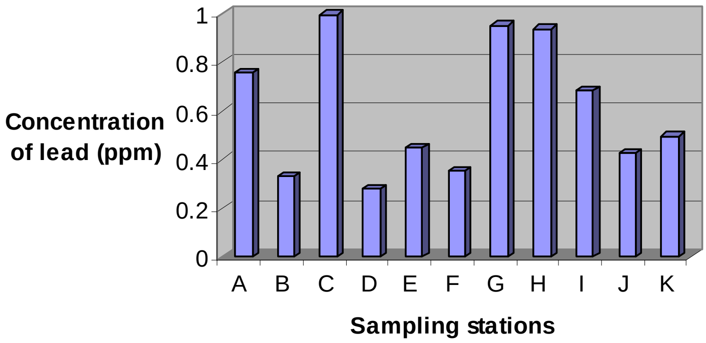

Fig. 1. Lead concentration (ppm) in tap water sources in Manila, Philippines

Analysis of the deep well water sources showed that the sample obtained from Roxas St cor. Blumentritt exhibited the highest lead concentration (0.7725 ppm). The sample that exhibited the lowest concentration was obtained from Baranggay 571 Zone 56 Palawan St., Domingo Santiago, Sampaloc (0.2801 ppm). Mean lead concentration for deep well water samples was 0.4489 ppm. Similar with the samples obtained from tap water sources, not one analyzed sample fell within the US EPA limits. Higher levels of lead were found in tap water samples as compared with those obtained from deep wells. Figure 2 shows the bar graph of lead concentrations in deep well water sources.

Table 3: Lead Concentrations (ppm)in Water from Deep Well Water Sources

Station Number	Sampling Station	Concentration of Lead
L	Tambunting	0.3235
M	Selya St., Pandacan	0.3235
N	Roxas St., cor. Blumentritt	0.7725
O	Sta. Ana	0.3525
P	Palawan St., Domingo Santiago, Sampaloc	0.2801
Q	Antipolo St., Sampaloc	0.4177
R	Maceda St., Sampaloc	0.4828
S	T. Mapua, Sta. Cruz	0.3380
T	Sta. Mesa	0.3959
U	Aurora Boulevard	0.4756
V	Barrio Obrero	0.5553
W	Dimasalang St., Sta. Cruz	0.5697
X	Intramuros	0.5480
		0.4489 Mean

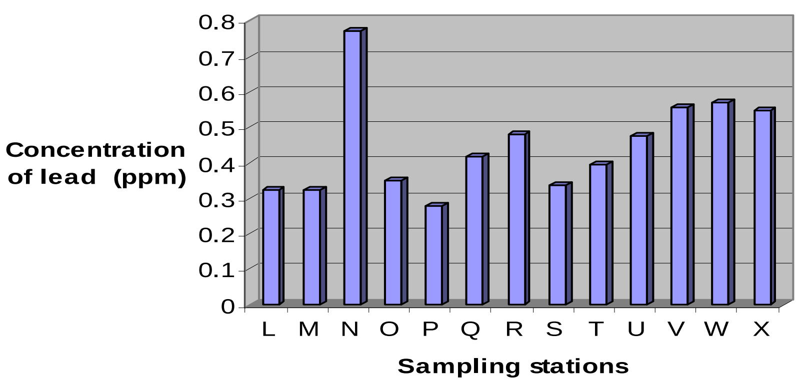

Fig. 2 Lead concentration (ppm) in deepwell water sources in Manila, Philippines

The amount of lead from Baywalk water showed very high concentrations of the heavy metal. During summer, the Baywalk area near the US Embassy is being converted by Manilenos into a beach resort. Both the very young (infants) and the very old would either lounge on the soil near the shore or swim until the middle parts of the Baywalk water. One can swallow water and partly soil from the area. Water and soil attach to one's skin during such leisure activities. Contaminants may enter the body through skin absorption. Because of this, shore soil samples were also analyzed. There is not much difference in lead concentration in the areas were water and soil were sampled. During the time of sampling though, wastes accumulated in the far left side of the Baywalk area were recreational swimming was observed. It may have contributed to the higher concentration of lead from the soil samples taken from there (3.6840 ppm). Mean lead concentration for water samples from Baywalk from both far left and far right, near shore and mid water areas showed 2.4801 ppm of the heavy metal. Table 4 below shows the individual lead concentration of water and soil samples from Baywalk as well as their respective mean lead concentrations. Also figure 3 shows the column graph for the lead concentrations of water and soil samples from the said site.

Table 4 Lead Concentration (ppm) from Baywalk Water and Soil

Baywalk Sampling Station	Sample Type	Lead Concentration
Shore far left	Soil	3.6840
Shore far right	Soil	2.7612
Near shore far left	Water	2.5378
Near shore far right	Water	2.4224
Mid water area left	Water	2.4224
Mid water area right	Water	2.5378
		3.2229 mean for soil 2.4801 mean for water

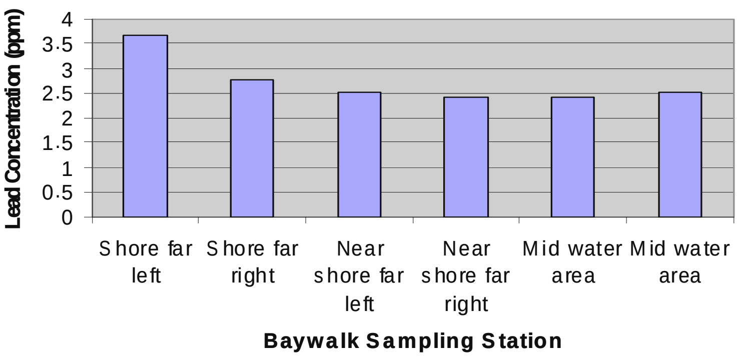

Fig 3. Concentration of lead (ppm) in Baywalk water and soil in Manila, Philippines

In spite of chemical treatments, some heavy metals may still leach from the pipes or deep well sources into the water distribution system through corrosion. These metals may find their way to the tap water that people consume. Although lead does not normally occur in ground or surface waters, its presence may be attributed to the contamination of natural sources by industrial lead mining and smelting and through the use of lead in pipes (Wong et al, 1976) and plumbing systems (Goldberg, 1974; Mahaffey, 1977). PVC pipes also contain lead compounds that can be leached from them and result in high lead concentrations in drinking-water (Levin et al, 1989). There has been increasing concern with the regulation of lead contamination from water sources used in human consumption. Various literature have provided evidences that lead may be implicated in the occurrences of several diseases, primary of which may be related to neurological dysfunctions. Lead in water therefore is a public health concern.

6. CONCLUSIONS

This study showed that water sources in Manila have high lead concentrations. A mean of 0.6059 ppm in tap water sources, 0.4489 ppm in deep well sources and a mean of 2.4801 ppm from Baywalk water. Baywalk soil showed values of 3.6840 and 2.7612 ppm. The tap water sources showed higher lead concentration in relation to deep well water sources. Baywalk water and soil during summer showed very high lead concentrations. Lead in the different water sources in Manila may cause adverse public health effects. The high levels of lead which do not conform to the US EPA standards found in both tap and deep well water sources in various sampling stations in the city of Manila represent an alarming cause of concern for possible lead toxicity in the consumers.

7. RECOMMENDATIONS

Given the results of this study wherein no sample conformed to the US EPA standard, it is recommended that the Manila, Philippines should begin surveillance on lead contamination in water sources from representative area and their correlation on possible toxicological findings in the consumers. Further, surveillance and monitoring must be made regular within another year to see if weather changes would affect lead levels from water sources. Likewise the government must also initiate environment clean up programs and draft policies to help lessen lead burden in Manila. Strict implementation of existing Philippine environmental laws must be adhered to. Planting of trees is proposed as part of phyto remediation. Research initiatives must be started to identify the best plant/s to grow in Manila for efficient absorption and adsorption of lead in the environment. This will hopefully lessen lead levels in the different water sources in Manila. Change of water pipes to non-leaded ones must be started. It is recommended that the representative sample areas in Manila be increased to widen the knowledge regarding lead levels from water sources in the whole place. Further, water and soil samples from Baywalk area are also recommended to be collected during the rainy season in the Philippines to compare it with the data obtained from samples gathered during the dry and hot season as presented.

REFERENCES

[1.] *Abu Amr, S.S., and Yassin, M.M. Microbial contamination of the drinking water distribution system and its impact on human health in Khan Yunis Governorate, Gaza Strip: Seven years of monitoring (2000–2006). Public Health [Online]. 122 (11), pp.1275-1283, 2008. Available at: http://www.sciencedirect.com/ [Accessed 16 January 2009].*

[2.] *Batista, S., Silva, E., Galhardo, S., Viana, P., Cerejeira, J.M. Evaluation of Pesticide Contamination of Ground Water in Two Agricultural Areas of Portugal. International Journal of Environmental and Analytical Chemistry. Vol. 82(8-9) pp. 601-609, 2002.*

[3.] *Bull, J., Stanaszek, P.M., O'Neill, J.J., Lutkenhoff, S.D. Specificity of the effects of lead on brain energy metabolism for substrates donating a cytoplasmic reducing equivalent. Environmental Health Perspective. (12): 89–95, 1975.*

[4.] *Cecil, K.M., Brubaker, C.J., Adler, C.M., Dietrich, K.N., Altaye, M., et al., (2008). Brain Volume in Adults with Childhood Lead Exposure. PloS Medicine. [Online]. 5(5). p. Available at http://medicine.plosjournals.org/archive /1549-1676/5/5/pdf/10.1371_journal.pmed.0050112-S.pdf . [Accessed 16 January 2009].*

[5.] *Dietrich, K.N., Early exposure to lead and juvenile delinquency. Neurotoxicology and Teratology, Vol. 23, 511–518, 2001.*

[6.] *Ding, W.H., Liu, C.H., & Yeh, S.P. Analysis of chlorophenoxy acid herbicides in water by large-volume on-line derivatization and gas chromatography-mass spectrometry. Journal of Chromatography, 896, (1), 27 October, pp. 111-116(6), 2000.*

[7.] *Goldberg, A. Drinking water as a source of lead pollution. Environmental Health Perspectives. 7. pp. 103-105, 1974.*

[8.] *Goldstein, G.W., and Johnston, M.V. Selective vulnerability of the developing brain to lead [Metabolic Disorders and Neurotoxicology]. Current Opinion in Neurology. 11(6) pp. 689-693, 1988.*

[9.] *Karamanis, D., Stamoulis, K., & Loannides, K.G. Natural radionuclides and heavy metals in bottled water in Greece. Desalination, 213. 90-97, 2007.*

[10.] *Knebel, B.J. and Wright, R.T. Environmental Science. USA: Prentice Hall, Inc. 2000.*

[11.] *Lasheen, M.R., El-Kholy, G., Sharaby, C.M., Elsherif, I.Y. & El-Wakeel S.T. Assessment of selected heavy metals in some water treatment plants and household tap water in Cairo, Egypt. Management of Environmental Quality: An International Journal.19 (3), pp. 367-376, 2008.*

[12.] *Mahaffey, K.R. (1977). Quantities of Lead Producing Health Effects in Humans: Sources and Bioavailability. Environmental Health Perspectives. Vol 19. pp. 285-295.*

[13.] *Polit, D.E. and Beck, C.T. (2008). Nursing Research, 8th edition USA: Lippincott Williams and Wilkins.*

[14.] *Prester, L. (1998). Decomposition of Fish Samples for Determination of Mercury. Arh hig rada toksikol, 49 (4), 343-348.*

[15.] *Sherlock, J.C., Ashby, D., Delves, H.T., Forbes, G.I., Moore, M.R., Patterson, W.J., et al. Reduction in exposure to lead from drinking water and its effect on blood lead concentrations. Hum Toxicol 3(5):383–392, 1984.*

[16.] *Schock, M.R. (1999). Internal corrosion and deposition control. In: Water Quality and Treatment: A Handbook of Community Water Supplies (Letterman RD, ed). 5th edition, New York: Mc-Graw-Hill.*

[17.] *Switzer, J.A., Rajasekharan, VV., Boonsalee, S., Kulp, E.A., Bohannon, E.W. (2006). monochloramine disinfectant could lead to elevated Pb levels in drinking water. Environmental Science Technology, 40(10): 3384–3387.*

[18.] *Tee L. Guidotti, Calhoun, T., Davies-Cole, J.O., Knuckles, M.E., Stokes, L., Glymph, C., Lum,G., Moses, M.S., Goldsmith,D.F., & Ragain, L. Elevated Lead in Drinking Water in Washington, DC, 2003–2004: The Public Health Response. Environmental Health Perspective. 115(5): 695–701, 2007.*

[19.] *The nature and extent of lead poisoning in children in the United States: a report to Congress. Atlanta, GA, United States Department of Health and Human Services, 1988.*

[20.] *U.S. EPA (2002). User's Guide for the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) Windows® Version–32 Bit Version. EPA–K–01–005.*

[21.] *Washington, DC: U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response.*

[22.] *Wong, C.S. and Berrang, P. Contamination of tap water by lead pipe and solder. Bulletin of Environmental Contamination and Toxicology. Volume 15, Number 5 / September, pp. 530-534, 1976.*

[23.] *Yaghi, B. Heavy metal levels in tap water in Batina Region, Oman. International Journal of Environment and Pollution. Vol. 31, No.1/2 pp. 219 - 229, 2007.*

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