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LEAD IN RESIDENTIAL DRINKING WATER: RISK ASSESSMENT

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INTRODUCTION

Drinking water quality issues have required considerable attention in recent years because of the widespread publicity concerning contamination of drinking water by synthetic organic chemicals and heavy metals such as lead'.

Several published reports have suggested that D.C. public water supply system might have lead problems. The water supply system in Washington D.C is as old as the City itself. In 1987, D.C health officials stated that an estimated 71000 houses and apartment buildings receive their tap water through lead pipes[2]. The D.C. public works engineers also reported in 1988 that they had found more than 28,000 homes that are connected to public water mains with lead lines[3]. Recent studies conducted by the U.S. Army Corps of engineers showed high levels of lead concentration (ranging from 2ppb to 72ppb) in the water[4]. Lead is leached into tap water as a by-product of galvanic corrosion of lead, and alloy solder joints, faucet fixtures or pipes in household and institutional plumbing. Replacing the city's lead pipes has not been an easy task because of the age of the system, the high cost involved and lack of accurate documentation for identification.

This research is a follow up of a previous project entitled "Lead Concentration Profile and Impact Analysis of Drinking Water in the District of Columbia" and analyzed lead concentration levels in tap water and water fountains on Howard University main campus at Georgia Avenue and the University of the District of Columbia campus at Van Ness.

OBJECTIVES OF THE STUDY

This study was designed to achieve the following goals: (1) to determine the lead concentration levels in residential drinking water; (2) to assess the probable risk associated with exposure to high lead levels in the drinking water.

METHODOLOGY

Approximately 204 D.C. residents volunteered to participate in this research. Each research participant was provided with acid-washed Nalgene sample bottles with detailed instructions on how to take two tap water samples. Sampling of each residence included a one-liter "first draw" sample taken either first thing in the morning or anytime when water had not been used for at least six hours previously and a "purge line" sample taken after running the tap at full rate for exactly 60 seconds following the first draw sample.

All samples were sent to the civil engineering Bioengineering laboratory at Howard University for lead analysis. Upon arrival, the samples were acidified to a pH of < 2.0 by the addition of reagent grade concentrated nitric acid. Samples were then held for a minimum of 28 hours to ensure complete dissolution and desorption of any precipitated or surface adsorbed lead.

LEAD ANALYSIS

Graphite furnace atomic absorption spectrophotometer (GFAAS), model 3030, was used to determine the levels of lead in the samples. The samples were analyzed without any prior preparation (since the samples were analyzed for total lead). A 20-ml. aliquot of the preserved sample was measured and mixed with a matrix modifier, composed of $NH_4H_2P0_4$ and Mg $(N0_3)_2$. The purpose of the matrix modifier used was to prevent the lead metal in the sample, when injected or pipette into the graphite tube from volatilizing before atomization of the instrument is reached.

QUALITY ASSURANCE/QUALITY CONTROL RESULTS

To validate the results obtained from each lead analysis, solution with known concentration was injected periodically during the test, and the readings obtained were compared to the known value. Results were rejected when the readings obtained were found to be more or less than the mean + 12 % coefficient of variation (CV).

LEAD RISK ASSESSMENT

The United States Environmental Protection Agency (USEPA) classified lead as a group B2 (probable) human carcinogen, with a non-carcinogenic effect. The risk of lead in drinking water was assessed by analyzing lead content from samples collected from residential tap water. Parameters such as age, body weight, exposure duration, and rate of consumption were assumed.

Lead is considered as a non-carcinogen (with a threshold effect). The probable risk associated with the ingestion of lead is assessed by determining the no-observed-adverse-effect level (NOAEL), the acceptable daily intake (ADI) or reference dose (M), and the Hazard Index (HI) [5]. The mathematical formulas used for NOAEL, ADI or RfD, and HI estimations are as follows:

$$\mathbf{DWEL = [NOAEL \underline{\ * BW]} / IR}$$

Where,

DWEL	=	Drinking water equivalent level (ppb)
NOAEL	=	No-Observed-Adverse-Effect-level (mg/kg/day)

BW = Body weight (kg)

IR = Intake rate (L/day)

RfD, = NOAEL

Where,
RfD; = Reference dose (mg/kg/day)

$$E, = [CW * IR * FI * ABS_S * EF * ED] / [BW * AT]$$

Where,
CW = Concentration of lead measured from samples (ppb)

IR = Intake rate, (Vday)

FI = Fraction ingested

ABS_S = Bioavailability/gastrointestinal absorption factor, (%)

EF = Exposure frequency, (days/yr)

ED = Exposure duration, (Years)

BW = Body weight, (Kg)

AT = Average time of exposure (for non-carcinogen), (ED * 365 days/years)

Risk, Hazard Index (HI) = E, / RfD,

RESULTS AND DISCUSSIONS

Table 1 shows the distribution of residences surveyed according to the city quadrants (NW, NE, SW and SE). Most of the respondents;(116) were located in the Northwest quadrant and the least respondents were from Southwest and

Southeast, (17). The finding may be explained by the fact that, although residents volunteered to participate in the project, they did not make the samples available for collection at the appointed time.

Table 2, demonstrates the number of first draw and second draw samples that exceed the EPA action level of 15 parts per billion (ppb). The number of first draw samples that exceeded 15ppb was 28 i.e. 13.78% of the total first draw samples of 204.

The EPA Lead and Copper Rule, promulgated in June 1991, requires national monitoring for lead in residential tap water by all large systems and set an "Action Level" of 15ppb. Under the rule if more than 10% of these residences exhibit first draw lead levels in excess of 15ppb, then the water system is considered to have exceeded the "Action Level". The results shown in table 2 indicate that the D.C. water system's lead levels exceed the therefore should take steps to reduce consumer's risk of exposure to lead by providing corrosion control treatment[s]. Table 3 shows the distribution of first draw residential lead levels per quadrant. Northwest had 20 samples (17.24%) that exceeded the action level, Northeast had 4 samples (5.63%). These samples were too small to have any meaningful statistical value.

Table 4 shows the total average lead level concentration for each quadrant of the city. The average lead concentration calculation from residential samples for the first draw was 27.45ppb. This lead level was used to compute the hazard index (HI). The probable risk associated with the ingestion of drinking water with this level of lead and assumed parameters (age, body weight, exposure duration and rate of consumption) used for the no-observed-adverse-effect-level (NOAL), the acceptable daily intake (ADI) or reference dose (RfD) and hazard index (HI) are stated above.

The primary thrust of this study was to assess any probable risk that might be associated with levels of lead that might exceed the EPA action level of 15ppb. Lead is considered as a non-carcinogen hazard. Determining the NOAEL, ADI or RfD and the HI assesses the non-carcinogenic effects of lead. In accordance with the U.S. EPA guidelines on the interpretation of hazard indices for any given chemical, there may be potential for adverse effect if the hazard index exceeds unity. For HI values greater than unity (i.e. HI > 1), the higher the value, the greater is the likelihood of adverse non-carcinogenic health impact.

The calculated risks obtained are as follows: the probable risks computed for children less than 6 years old for 3 years exposure duration is about 1.83 times greater than the EPA unity of 1; for children between the ages of 6 and 9 years of age for 71/2 years' exposure duration is 1.82 greater; for those from 9 to 12 years old with 10 1/2 years' exposure is 1.81 greater; from 12 to 18 years old with exposure duration of 15 years is 1.81 greater; and for adults 70 years old with 30 years exposure duration is 1.81 times greater (see Table 5).

While these lead values do not present ant immediate health crisis, they cannot be ignored because any amount of lead consumed in water can an important source to children and adults. Absorbed lead bio-accumulates in the bones. The major sources of lead exposure today are lead-based paint, lead in dusts and soils and lead in drinking water. The body combines lead absorbed from all sources into one dose. CDC Scientists estimate that drinking water lead constitutes about 20 percent of these multiple source of exposure to humans.

The National Research Council (NRC) reported that lead in drinking water affects different groups of people in different ways. For example, lead-contaminated water can be used in infant formula and beverages for older children and can be consumed directly. The report adds that tap water lead can be ingested in food cooked in lead-contaminated water. Lead in tap water is much more bioavailable than lead in food, because it is often consumed during semi fasting (between meals) or after fasting (overnight) conditions'. Moore et al. and other researchers have stated that there were marked reduction in blood lead concentrations of water consumers in

Glasgow and Ayr, Scotland, after water-treatment steps to reduce corrosively have been instituted. This is a convincing evidence that water lead has an impact on blood lead concentration (Moore, 1981; Moore, Richards, 1985; Sherlock, 1984) [9'0.,,]

CONCLUSION

The significance of these findings is that the D.C. drinking water supply system could have an adverse health impact on the exposed population. It is important to note, however, that because of the various limitations and uncertainties, the result of a risk assessment cannot be considered an absolutely accurate determination of risks. It is used only as an estimate of risks based on current level of knowledge coupled with several assumptions. They are, however, useful for setting a yardstick and decision-making tool for prioritization of problems. But once a baseline risk assessment determines that a chemical presents unacceptable risks to the population, decisions must be made regarding the choice of remedial alternatives, in this case, purging the water before use, reducing finished water corrosively and removing lead-containing pipes or and removing lead-containing pipes or "goosenecks" over time.

Elyse Roger '2 states that probably the most important aspect of risk reduction is cost. She adds that unfortunately, it is an aspect that is discussed reluctantly, for a variety of reasons. Sometimes people don't want to know the price because they feel the issue is "above dollar value", other times cost is ignored because those who are examining the risk-reduction issue are not involved with the expense.

Appendices

Table 1. Distribution of Homes Surveyed according to quadrants.

Quadrants	Number of homes sampled (n)
North West	116
North East	71
South West & South East	17
Total	204

Table 2. Residential lead concentration above Action level (15ppb).

Draw	Number of samples	Percent of samples greater than 15ppb (n')
First Draw	28	13.73
Second Draw (1 minute purge)	18	8.82

Table 3. First Draw Residential Lead level per quadrant.

Quadrants	Number of samples	Percent greater than 15ppb
North West	20	17.24
North East	4	5.63
South West & South East	4	23.08
Total	28	13.73

Table 4. Average Lead Concentration from samples with lead levels greater than 15ppb (First and Second Draws).

Quadrants	Average Lead Concentration, ppb	
	First Draw	Second Draw
North West	29.56	23.23
North East	19.74	24.68
South West & South East	23.59	30.76
Total (n=204)	27.45	24.63

Table 5. Risk calculation

Parameters Used:

EPA Lead Action level is 15ppb

Average Lead concentration calculated from samples with lead levels greater than 15ppb (First Draw) is 27.45uub

Parameters	Child				Adult
Age Range (Yrs)	0-6	6-9	9-12	12-18	70
Consumption rate (L/day)	1.4	1.5	2.0	2.0	2.0
Body weight (Kg)	12	16	20	70	70
Exposure Duration (Yrs))	3	7.5	10.5	15	30
Exposure Frequency (days/yr)	365	365	365	365	365
NOAEL (mg/kg/day)	1.75	1.41	1.50	0.43	0.43
RFD (mg/kg/day)	1.75	1.41	1.50	0.43	0.43
Exposure level (mg/kg/day)	3.20	2.57	2.75	0.78	0.78
Risk, Hazard Index (HI)	1.83	1.82	1.83	1.81	1.81

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