Lead in Drinking Water Investigation of a Corrosive Water Supply

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Abstract

An investigation of a corrosive water supply in Morris County, New Jersey was conducted because corrosive reservoir water appeared to be leaching lead out of solder in household plumbing systems. Of the homes served by the reservoir, 25% had water lead levels that exceeded federal standards. Water sampling techniques were compared. Running grab samples showed a mean lead level of 0.018 mg/l. First flush samples averaged 0.053 mg/l. Composite samples taken in homes with elevated first flush lead levels had a mean water lead level of 0.054 mg/l. Running grab samples appear to be of limited value in evaluating lead levels in delivered water that is corrosive.

Excessive lead levels in drinking water can be the result of corrosive water dissolving this metal from lead service pipes and from the lead:tin solder used to join copper pipes in household plumbing (5-7,9,10,14,22). A corrosive, or aggressive water is generally one that is soft, low in alkalinity and with low pH. It is usually identified by a negative Langelier Index(11). As corrosion by-products, elevated lead levels in drinking water have been associated with physiological effects. Several researchers have reported increased blood lead levels associated with high water lead levels (12,13,18,23). Other workers have reported cases of lead poisoning that were traced to corrosive domestic water supplies leaching lead out of lead plumbing components(2,7,8). Beattie, et al(3), in a study in Scotland, reported an association between mental retardation and grossly elevated water lead levels. Although there is disagreement over the contribution of water lead to total body burden of lead, it is clear that excessive lead levels in drinking water must be identified and eliminated.

The Maximum Contaminant Level (MCL) for lead in drinking water is 0.05 mg/l as specified in the National Interim Primary Drinking Water Regulations(19). The MCL is intended to protect the health of the consumer and is to be measured at the tap(19,21). However, taking a water sample for lead at the consumer's tap may result in readings that are exceedingly high or misleadingly low, depending on the sampling method and the corrosivity of the water. Our experience with one water-lead problem indicates that other water systems may unknowingly be delivering water with lead levels that exceed the MCL. This possibility exists because currently used sampling methods, when employed to monitor corrosive waters, can yield false negative results.

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Background

The community of Morris Township is situated in Morris County, New Jersey and is rural-residential in nature. Approximately 16,000 of the Township's 20,000 residents are served by a regional water authority, which also serves four other municipalities. Approximately 85% of the authority's raw water is supplied by wells, and the remaining 15% (1.5 MGD) is supplied by a 385 million-gallon reservoir. The pH of the reservoir's raw water ranges from 5.7 to 6.9. The mean hardness is 32 mg/l as $CaCO_3$ and the mean alkalinity is 19 mg/l. The Langelier Index of the distributed water ranges from -0.5 to -3.4. Approximately 10,000 people are served exclusively by the reservoir. Treatment of the reservoir water consists of pH adjustment by the use of hydrated lime, and disinfection by gaseous chlorine.

In June 1981, high turbidity levels in the reservoir water caused numerous customer complaints to the water authority and to the local health department. In response to the complaints, the local health department took samples of the reservoir water at consumer taps and found lead levels that exceeded the MCL of 0.05 mg/l (maximum = 0.26 mg/l). The state regulatory agency and the water authority were informed of the results. Samples of the raw reservoir water were negative for lead. Samples of the delivered reservoir water, taken as follow-up by the water authority, showed lead levels below the MCL. Comparison of the sampling methods revealed that the health department had taken standing grab samples and first flush samples; whereas, the water authority had run the tap water for several minutes prior to taking their samples.

A review of the literature indicated several studies(2,3,8,12,23) showing stronger relationships between "first flush" water lead levels and blood lead levels. Consequently, both the water authority and health department began analyzing "first flush" samples. The results indicated that, in some homes, lead was being leached out of plumbing systems into solution by the corrosive water. Additional testing was done to evaluate the sampling methods, and blood lead testing was made available for children in the reservoir service area.

Methods

Fron June through November, 135 water samples were taken from 99 locations in the reservoir service area and analyzed. Samples were collected in 250 ml acid-washed bottles with 1 ml of nitric acid as preservative. Samples were analyzed for lead at two laboratories by atomic absorption spectrophotometry in accordance with approved techniques(17, 20). Blanks were run on sampling containers and lab glassware to determine if they were a source of contamination. All blanks proved negative. Duplicate analyses were run on all water samples that exceeded the MCL. Visual and tactile inspection of home service pipes showed no lead service pipes in the homes sampled by the health department. A check of water authority records showed no lead service pipes in Morris Township. Four types of water samples were taken:

1. *First flush samples* were taken the first thing in the morning, and represented water that had been standing in the plumbing system overnight.
2. *Standing grab samples* were taken during the day, without allowing the water to run first. They represented water in contact with plumbing for an unknown length of time.
3. *Running grab samples* were taken after the tap water had been allowed to run to waste for several minutes.
4. *Composite samples* were a mixture of 100 ml aliquots which were taken immediately before one would use the water for drinking or cooking.

First flush and composite samples were taken by homeowners after receiving verbal and written instructions from the health department or water authority. The composite samples were taken in ten homes where prior first flush samples exceeded the MCL for lead.

Results

Results of the sampling, shown in Table 1, indicated that 32% of the first flush samples showed lead levels in excess of 0.05 mg/l with some samples exceeding the MCL by a factor of 5. The composite samples demonstrated that some homes in the reservoir service area had water lead levels that consistently exceeded the MCL. Of the 99 homes tested, 25 had one or more water samples that exceeded 0.05 mg/l.

Blood lead tests were conducted for 52 randomly-selected children (ages 1-13) who regularly consumed distributed reservoir water. Capillary samples were collected by public health nurses from the local health department using collection techniques approved by the New Jersey State Department of Health. Analysis for blood lead and erythrocyte protoporphyrin (EP) were conducted by the New Jersey State Department of Health. Blood lead results showed that all 52 children had blood lead levels below the 30 μg/dl level established by the Center for Disease Control(4) as being indicative of an elevated blood lead level. Six of the children (12%) had EP levels equal to or above the 50 μg/dl level established by CDC as being elevated. The mean blood lead level was 14 μg/dl and the mean EP was 32 μg/dl. Range of blood lead was 8-23 μg/dl. Range of EP was 10-140 μg/dl. Children who lived in homes with water lead levels above 0.05 mg/l averaged 14 μg/dl blood lead. Children who lived in homes with water lead levels below 0.05 mg/l also averaged 14 μg/dl blood lead.

The water authority sent notices out to its customers in the reservoir service area advising them to flush their plumbing systems out in the morning prior to use. In addition, the pH of the water was raised from about 6.1 to 7.9 by lime addition. In January, the water authority began replacing the reservoir water with well water purchased from another nearby water authority.

Discussion

The results of our investigation showed that the excessive lead in the drinking water did not, in this case, contribute sufficiently to total body burden to raise blood level levels above the maximum safe level that is currently accepted for children. Our results are consistent with those cited by Morse, et al(14), in which the inhabitants of a semirural area were exposed to elevated water lead levels. Although our sample size was smaller, the mean blood lead level in Morris Township (14 μg/dl) was slightly lower that noted in the Bennington, Vermont sample (16.1 μg/dl). This may be attributable to the fact that no lead pipes were found in the Morris Township investigation, and the degree and consistency of water lead exposure may have been less than that found in Bennington.

Our investigation also pointed out the difficulty and differences in sampling and evaluating corrosive water supplies for lead. As we discovered in

Table 1
Concentrations of Water Lead by Four Sampling Methods—Morris Township, New Jersey, 1981

Sampling method	Number of samples	Range, water lead (mg/1)	Mean, water lead (mg/1)	Number samples $>$0.05 mg/l	Per cent samples $>$0.05 mg/l
First flush	91	$<$0.02-0.260	0.053	29	32
Standing grab	18	$<$0.01-0.081	0.022	1	6
Running grab	16	$<$0.01-0.039	0.018	0	0
Composite	10[a]	0.01-0.10	0.054	4	40
TOTAL	135[b]	$<$0.01-0.260	0.044	34[c]	25

a. Composite samples from 10 homes with first flush water lead levels $>$ 0.05 mg/l
b. Samples taken at 99 different locations
c. 25 locations had water lead levels $>$ 0.05 mg/l

our investigation, the problem of identifying excessive lead levels in drinking water can be caused by sampling technique. In New Jersey and elsewhere, it is standard practice to let water run for several minutes before collecting a sample from a consumer's tap(1,15,17). This practice, when used to sample a corrosive water supply, can yield misleading results and may lead to unjustified conclusions about the quality of the water.

Other investigators have documented the shortcomings of the commonly-used running water sample when applied to corrosive waters. Worth, et al(23), in an extensive study in Boston, noted that standing water lead samples were more strongly related to blood lead than were running water lead samples. Karalekas, et al(9) as part of the Boston study, noted that a higher percentage of composite water samples exceeded the MCL for lead when compared with running water samples. Moore, et al(12), also found that first flush water lead samples were more strongly related to blood lead levels. Pocock (16) notes the deficiency of running grab samples and suggests the use of the geometric mean of five repeated first draw samples. In a report of three cases of lead poisoning by water (8), Jolliff et al, reported on an implicated water supply that had running water lead levels of 0.03 mg/l yet that had a standing water lead level of 0.4 mg/l, greatly exceeding today's standard of 0.05 mg/l.

We conclude that there are serious deficiencies in the evaluation of corrosive water supplies by the traditional running water sample. In the absence of regulatory recommendations, we advise the use of first flush samples. Should first flush samples show lead levels in excess of 0.05 mg/l, we recommend the use of follow-up composite samples to assess consumer exposure to water lead. We advise the evaluation of lead levels in all potentially corrosive water supplies, even though lead service pipes or lead plumbing is not used or reportedly not used. We also recommend that priority be given to evaluating corrosive waters in urban areas in light of higher background lead exposure for urban children. We further recommend that immediate study be directed towards the development of sampling methods that can be used specifically for corrosive waters and that will represent actual consumer exposure to the metals that are by-products of corrosion.

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