Exposure of Children to Lead in Drinking Water

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During a case-control investigation of increased lead absorption and lead toxicity in the children of lead battery plant workers and their neighbors in Bennington, Vermont,[1] we found that several children in our control group had increased blood lead levels,[2] with one as high as 55 *mg*/100 ml. Further investigation showed that tap water in that child's house contained lead in a concentration above the U.S. Environmental Protection Agency's (EPA) drinking water standard of 0.05 mg/l,[3] and that in fact the EPA standard was exceeded in approximately one-third of the Bennington homes; the highest value observed was 0.6 mg/l. Drinking water in Bennington, population 15,000, was provided by lead-free, but moderately acidic soft water (pH 5.5-6.5, akalinity 10-20 mg/l, hardness 12-36 mg/l) from a mountain brook.

As a result of these findings, the Center for Disease Control was asked by the Vermont Department of Health to participate in an evaluation of children in Bennington for posssible deleterious effects of exposure to lead in water.

Methods

An epidemiologic study of children 1-12 years old, the age-group most vulnerable to the toxic effects of lead[4] was conducted. Most of the children were drawn from families who had voluntarily submitted tap water samples for lead analysis. Other households were recruited in the same neighborhoods; the total sample consisted of 105 houses with 200 children. To evaluate non-food sources of lead within each house, we measured lead levels in water, paint, and dust. Three tap water samples—an early morning sample representing water remaining in the pipes overnight, a standing grab sample representing water taken immediately after turning on the tap during the day, and a running grab sample representing water collected after 5 minutes of continuous flushing—were collected in 50 ml nitric acid-washed polyethylene bottles. The samples were analyzed for lead at the Vermont Department of Health Laboratory by flameless atomic absorption spectrophotometry.[5] We classified home service pipes according to type of metal by visual and tactile inspection, and we estimated the length of the service pipe from the street to the house.

During May 20-22, 1977, we completed questionnaires on 195 of the 200 children aged 1-12 in the 97 homes for which environmental data had been collected and obtained venous blood samples from 192 children. The questionnaires elicited information on parents' employment, pica, symptoms associated with lead poisoning, documented episodes of lead poisoning, and water consumption. Blood specimens were analyzed for hemoglobin and zinc protoporphyrin (ZPP) as they were collected. Lead levels on all samples and confirmatory erythroyte protoporphyrin (EP) levels on 20 per cent of specimens, including all with elevated lead or ZPP levels, were determined at the Center for Disease Control; blood lead determinations were by modified Delves' cup atomic absorption spectrophotometry.[6]

Results

Lead service lines were definitely identified in 45 of 97 homes, copper lines in 26, and galvanized pipes in 8. The type of pipe could not be determined in 18 homes.* In the houses where lead pipes were found, we observed a gradient in lead concentrations from high to low for the early morning, standing grab, and running grab samples, respectively. Approximately one-half of the homes with lead service lines had lead concentrations in water samples above .05 mg/l; however, approximately one-fourth of the homes without lead service lines had similar findings.

Blood testing showed that nine (4.7 per cent) of 192 children had blood lead levels $\geq$30 μg/100 ml, the level indicative of increased absorption,[2] and two had elevated EP levels; both lead and EP concentrations were elevated in one child. Blood lead levels ranged from 7 to 43 μg/100 ml with an average of 16.1 μg/100 ml. Blood lead levels were highest in young children and decreased with age (Table 1). There was no significant correlation between water lead and blood lead or EP levels. As a way of looking at the EPA drinking water standard, we divided the children into those exposed to home water lead levels above and below .05 mg/l. Those exposed to lead concentrations persistently (after 5 minutes of flow) elevated above the standard did not have mean blood levels which were appreciably higher than the remainder (Table 2). No differences in exposure to lead in dust and paint were found between these two groups. The 10 children with elevated blood lead or EP values came from nine

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*Reasons include: 12-inch crawl spaces and pipe embedded in concrete.

TABLE 1—Concentrations of Lead in Blood and Water and Daily Intake of Lead by Age—Bennington, Vermont, May 1977

Age (Yrs)	Number of Children	Mean* Water Lead (mg/l)	Mean Blood Lead (μg/100 ml)	Estimated Mean** Daily Dose from Water (μg)
1	11	.07	20.8	60
2	22	.08	20.0	60
3	13	.06	15.6	50
4	15	.06	16.1	60
5	16	.09	17.4	60
6	25	.06	14.9	50
7	8	.06	14.0	50
8	16	.08	14.6	70
9	19	.07	13.8	70
10	17	.05	15.0	60
11	13	.07	13.0	70
12	11	.07	13.3	50

*Mean of the means of the early morning, grab, and running grab samples.
**Based on the mean of means of the three samples and home water consumption histories.

TABLE 2—Mean Blood Lead Levels by Water Lead Levels in Flushed Lines Above and Below the EPA Standard, Bennington, Vermont—May 1977

Water Lead Level—Running Grab Sample	N	Blood Lead Level (μg/l)
≥ .05 mg/l	36	16.3
< .05 mg/l	154	15.8
t = .43		

homes, in which the average water lead concentration was .035 mg/l, compared with .048 mg/l for all participants. Only four of 27 water samples from these nine homes had lead concentrations above .05 mg/l.

Discussion

This study corroborates the results of other studies that have demonstrated the presence of increased concentrations of lead in soft, acidic drinking water transported by lead pipes.[7,8] The degree of plumbo-solvency of water is known to be related to pH, temperature, and hardness.[9] As expected, we found that water transported by lead pipes had significantly higher lead values than water transported by copper or galvanized iron pipes; however, since a number of water samples from copper/galvanized iron pipes also had high lead values, visual inspection of pipes appeared to be of limited value in predicting the presence or absence of lead in water. Examiner error in classifying pipes may have contributed to these findings, but we consider that lead in water was more likely due to the presence of buried segments of lead pipe or to leaching of lead from soldered joints, as can occur with 50/50 (tin: lead) solder.[10] Our study showed neither lead-related illness in exposed children nor correlation between water lead and blood lead levels. Mean blood lead levels were similar to those reported for other rural areas.[11]

These negative findings occurred even though the sample size was much larger than that in the 1976 studies by Elwood, et al,[12] and Beattie, et al,[13] which showed correltions between water and blood lead levels. However, water lead levels in this study were lower, and the total intake of lead from all sources (water, food, dust, and paint) may not have been sufficient for bioaccumulation of lead to occur.

The threshold level required for bioaccumulation of lead has been estimated to be 100 μg Pb/day for infants and 300 μg Pb/day for children.[4,14] Thus, even if a child consumed 200 μg Pb/day from food, 2 liters of water with 0.05 mg/l of lead would be required for the threshold to be exceeded in the absence of exposure to non-food lead sources. This observation suggests that lead in water is more likely to cause the bioaccumulation threshold to be exceeded in urban areas where background levels of lead in air and dust are much greater, as are baseline blood lead levels.[11] Inhabitants of semirural areas, such as Bennington, may be able to ingest water with higher lead levels before bioaccumulation and deleterious health effects occur.

We could not determine the minimum concentration of lead in water that would cause a blood lead elevation in Bennington for the reason that the threshold had not been reached and, accordingly, we conclude that the EPA standard is safe and even conservative for a non-polluted semirural area.

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