Lead Content of Foodstuffs

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The lead content of a number of foodstuffs, particularly baby fruit juices and milk, is reported. Samples were analyzed in quadruplicate by using an automated Delves cup atomic absorption procedure. A large proportion of the products examined contained significant amounts of lead. Of 256 metal cans examined, the contents of 62% contained a lead level of 100 μg/l. or more, 37% contained 200 μg/l. or more and 12% contained 400 μg/l. lead or more. Of products in glass and aluminum containers, only 1% had lead levels in excess of 200 μg/l. Lead levels of contents also correlate with the seam length/volume ratio of the leaded seam can. A survey of bulk milk showed a mean lead level of 40 μg/l. for 270 samples; for canned evaporated milk the mean level was 202 μg/l. These data indicate a potential health hazard.

Introduction

Lead poisoning is an important public health problem. At present, over 250,000 children per year in the United States are screened for undue absorption of lead. Screening is concentrated in decaying urban areas, where children have access to chipped and peeling paint containing up to approximately 20% lead. Since the Industrial Revolution and particularly since the mass introduction of automobiles around 1950, environmental lead levels have markedly increased. Lead is found in drinking water, canned fruit, vegetation growing beside roads, toothpaste, air particulates, dirt, pencils, cigarette ash, newsprint, putty, and numerous other materials in everyday use (*1*).

In December 1972 we carried out a limited survey of the lead content of a number of foodstuffs and found significant levels in some canned fruit juices. This prompted a more thorough survey of the lead content of canned and bottled fruit juices, canned and bulk milk products, beverages, and some canned fruits. Our findings are reported below. A further survey of canned milk products carried out in September 1973 is also included.

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Experimental Procedures

Samples

All nondairy foodstuffs were purchased in Albany County, New York, during May 1973, with the exception of a small amount of canned goods processed for institutional use (obtained from the New York State Department of Mental Hygiene). Bulk milk samples were obtained from a large number of processing plants at various locations in upper New York State, and canned milk products were purchased in Albany County during September 1973.

Instrumentation

The instrumental system has been described in a previous communication from this laboratory (*2*). Briefly, it comprises a

single-beam atomic absorption spectrometer built up from a hollow cathode lamp with dc power supply, a burner-Delves cup injector, an $f/3.5$ monochromator, a photomultiplier, a photon counter, an interface, and a computer. Insertion of the cup into the flame triggers a delay. The system then measures the intensity of transmitted radiation for 200 successive 30-msec periods before, during, and after the absorption peak. Intensity data are converted to absorbance, and the integrated absorbance for the transient lead atomization process is computed. The peak absorbance value is also measured and printed out.

The following instrumental settings were used: slit height 15 mm, slit width 150 μm, lamp current 8 mA, wavelength 217.0 nm. A slightly fuel-rich air–acetylene flame was used, with the cup lip ca. 2 mm below the entrance hole in the ceramic absorption tube.

The instrument is initially calibrated with standards made up from spiked milk. This matrix was chosen because, unlike aqueous lead standards, it gives sharp peaks for the lead-specific absorption. The measurement time base can be identical for the standards and the samples, since they both contain organic matter which enhances the rate of vaporization from the cups into the flame gases. Standards of 800, 600, 400, 200, and 0 μg/l. of added lead were used for all calibration. The milk used for these standards had been previously found to contain only low lead levels by a solvent-extraction macroprocedure.

The computer program allows the operator to select a calibration procedure in which four sets of five standards are introduced into the system. The data from these standards are used to construct a least-squares calibration line. If the data points give a good coefficient of correlation ($R \geq 0.98$) to the calculated curve, the instrument is ready for analysis of unknown samples. A correlation coefficient <0.98 causes the system to ask for recalibration before samples can be run.

Samples are run in quadruplicate; the average integrated absorbance is calculated; and the lead concentration, taken from the calibration curve, is stored by the computer. The total analysis time for one sample with four replicates is about 1 min.

Sample Preparation

For samples (juices, milk, etc.) which were sufficiently liquid to be pipetted with an Eppendorf after shaking, 50-μl portions were diluted with 4 parts of deionized water, and 50-μl aliquots were pipetted into nickel Delves cups. These solutions were dried at 140° C for 15 min and then introduced into the automated flame spectrometer. For more viscous products (purees, baby food, tomato paste, etc.), a twofold dilution with equal amounts of deionized water preceded this treatment to facilitate precise pipetting. For fruit samples, pickled produce, and other products where a solid was packed in a syrup or other fluid, no attempt was made to homogenize the solid; only the fluid was analyzed.

Samples were also drawn from cans of viscous tomato paste as follows. A long-needled Cornwall syringe of 5 ml capacity was inserted to the bottom of the can in the appropriate sample area. (The can had been handled carefully prior to sampling to ensure that the contents did not mix or move.) A 1-ml sample was taken out as the syringe was withdrawn; this was assumed to prevent the contents from mixing due to turbulence within the can. The sample was then diluted with 2 ml of deionized water and prepared as above.

Soldered can seams were analyzed for lead content by cutting a 1-cm portion of the seam length and dissolving the same in 25 ml of concentrated nitric acid making the solution finally to 100 ml with deionized water. This solution after a further 100-fold dilution was sprayed directly into an air–acetylene flame in the normal manner to determine the lead level by conventional atomic absorption spectrometry.

Results

Lead Content in Foodstuffs

Figure 1 shows the distribution of lead lev-

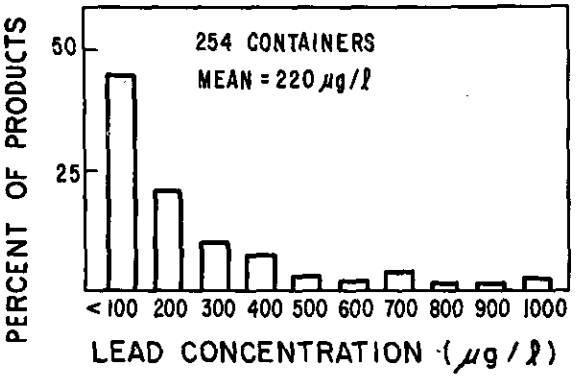

FIGURE 1. Distribution of lead in food products.

els in a group of 254 different containers of which 205 were metal cans. In Figure 2 the distribution for the metal cans with soldered seams is compared to that for bottled products. A comparison of the same product in different containers was possible in only a few cases, and since we could not determine whether the contents came from the same factory and batch, a parallel comparison is not presented. However, the mean lead concentration of the canned products (167 μg/l.) is obviously higher than that of the bottled products (42 μg/l.), suggesting the effect of packaging on the lead level of food products.

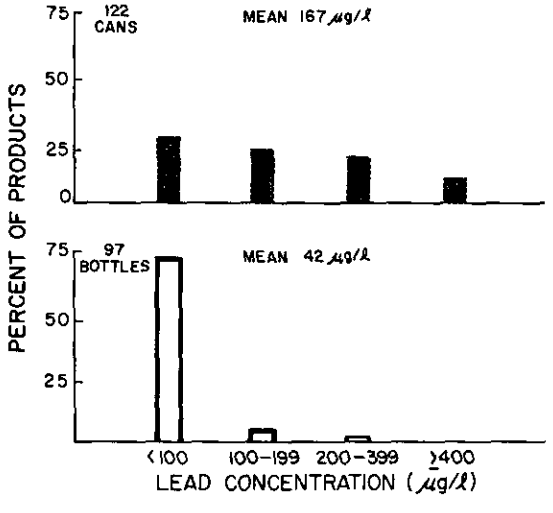

FIGURE 2. Distribution of lead in canned and bottled products.

Baby Foods

Food products marketed as baby foods are generally packaged in small cans or bottles of 4–5 fl oz capacity. A group of 86 canned foods and 35 bottled products were analyzed. The results (Fig. 3) show a mean lead level for the canned foods of 202 μg/l., with 37% of the cans having lead levels above 200 μg/l. In contrast, the bottled products (mainly puree dinners) had a mean lead concentration of 35 μg/l., with only 1 (220 μg/l.) in excess of 100 μg/l.

Of the canned baby foods analyzed, a large proportion were fruit juices and fruit juice mixtures, all pH 2.7–3.9. This acidity, combined with a high seam/volume ratio, would explain the high lead contents. The seams of these cans, in common with those of the

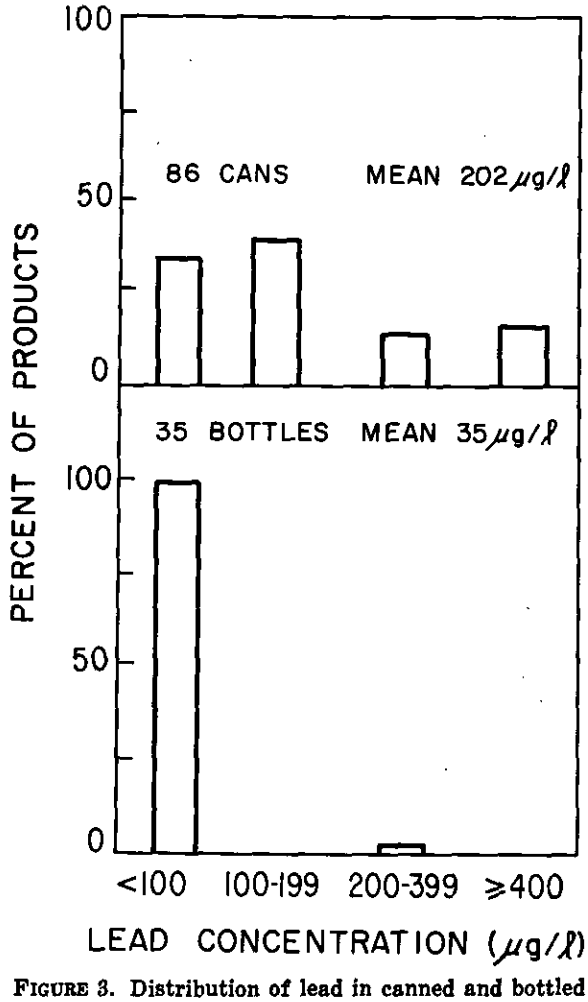

FIGURE 3. Distribution of lead in canned and bottled baby products.

regular 12- and 16-oz cans, showed lead levels of 35–80 mg/cm.

Effect of Soldered Seams and Lacquering

Of the 205 metal cans included in the Figure 1 data, all except 12 had soldered seams. (The others either had welded seams or were fabricated from aluminum.) Of the 193 soldered-seam cans, 35% appeared to have had their inner surfaces lacquered at some stage of manufacture. In several instances the lacquer was discolored at the seam and appeared blistered, as if the lacquer had been sprayed on the metal prior to soldering. In nearly all cases of lacquering, some areas of solder were exposed to the contents of the can, especially at each end of the seams, where the solder had run while molten.

To determine if the higher lead levels in canned goods might be a result of leaching of lead from the seam, we studied the distribution of lead in the contents of a series of cans of viscous tomato paste. The results for five 8-oz cans of tomato paste, sampled in five positions across a diameter passing through the seam, are shown in Figure 4. In all cases, position 1 (nearest the seam) shows a higher lead level than the opposite side of the can. Evidently the can contents were leaching lead from the soldered seam. This is especially likely with the tomato paste, which is highly acidic (pH $\approx$4.0). Figure 5 shows the data from the same cans after they had been stored open at room temperature for 24 hr. The lead distribution is even more indicative of leaching from the seam, and the lead levels (up to 5000 μg/l.) are becoming extremely high.

If lead is entering the can contents via the seam, there should be a relationship between the seam length/can volume ratio and the lead level of the contents. The data from three groups of cans selected for seam length/volume ratios of 1.25, 0.75–1.25, and $<$0.75 confirm this assumption (Fig. 6). In the group with a high seam length/volume ratio, significantly more cans fall within the higher lead levels. In the group with low seam length/volume ratios, the majority are $<$100 μg/l.

A breakdown of the data by container type (Table 1) indicates that 33% of the canned products had lead levels greater than

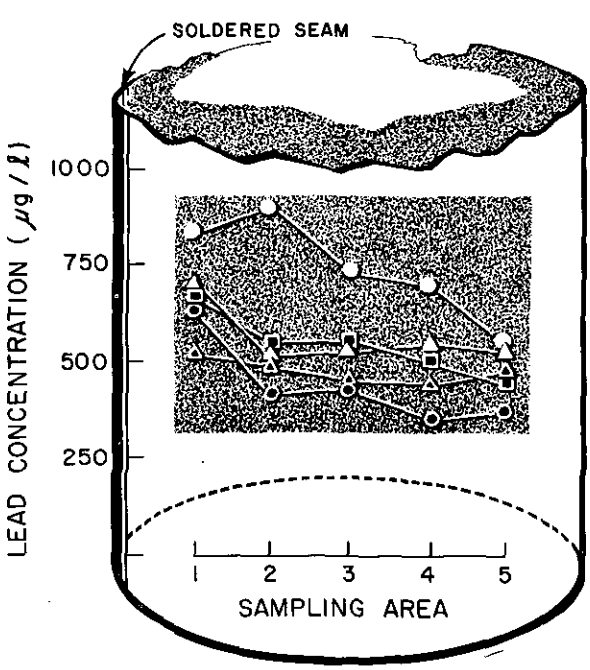

FIGURE 4. Lead distribution in single cans of tomato paste. Symbols represent five different cans.

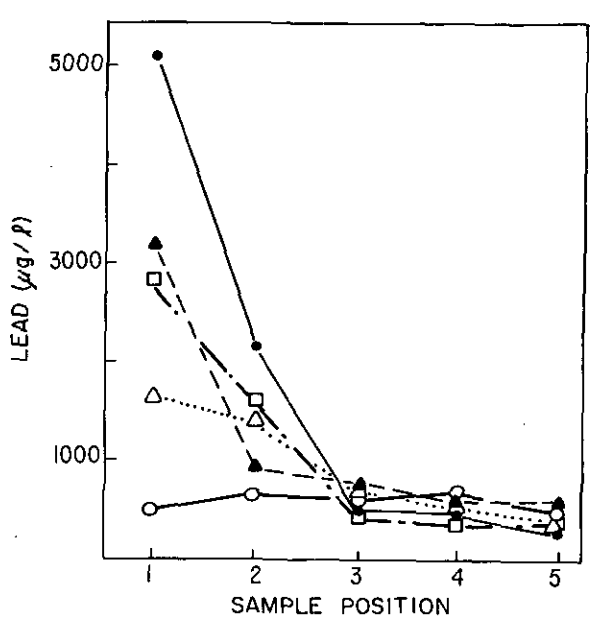

FIGURE 5. Lead distribution in single cans of tomato paste (second day after purchase, cans kept at room temperature overnight). Symbols represent five different cans.

Table 1. Distribution of lead levels in various containers.

Lead concn, μg/l.	Metal cans: Not lacquered	Lacquered	Unknown	Total	Other types of containers	Total, all types
<100	21	24	35	80	43	123
100–199	19	17	21	57	5	62
200	5	10	14	29	0	29
300	1	5	6	12	1	13
400	2	2	3	7	0	7
500	0	7	1	8	0	8
600	0	2	2	4	0	4
700	0	2	2	4	0	4
800	0	2	0	2	0	2
900	0	0	1	1	0	1
1000	0	0	1	1	0	1
Totals	48	71	86	205	49	254
% above 200 μg/l				33	1	
% above 300 μg/l				19	1	

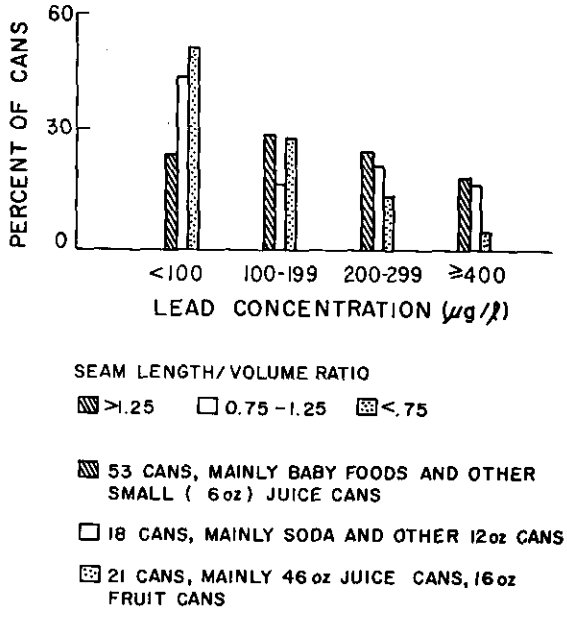

FIGURE 6. Effect of seam length/volume ratio on the lead level of can contents.

200 μg/l. This level is four times the permitted lead level in potable water, as set by the U.S. Public Health Service. Several of the cans with levels >500 μg/l. were small cans of baby fruit juice. Other types of container (bottles, cartons, etc.) showed only 1% above the 200 μg/l. level.

Lead in Milk

For a survey of lead levels in bulk fresh milk, 270 samples were obtained and analyzed in quadruplicate. The distribution (Fig. 7) indicates an average lead level of 40 μg/l., with no samples greater than 200 μg/l. The lead levels in cows' milk may result from environmental contamination of feed and grass, especially if pasture is located near main highways.

In addition to bulk fresh milk, 51 soldered seam cans of evaporated milk were analyzed. Moreover, the tops and bottoms had been soldered, and the hole used to fill each can had a solder button as a seal! Lead concentrations ranged from 10 μg/l. up to 820 μg/l. The mean lead level was 202 μg/l., and 55% of the cans had concentrations >200 μg/l. These results are significantly higher than those obtained by Lamm and Rosen in a similar survey of canned milk products (*3*).

Discussion

Considerable quantities of lead were found in two classes of foodstuffs: canned baby fruit juices and canned milk products. Lead in fruit juices probably presents the greater health hazard, since there is evidence that

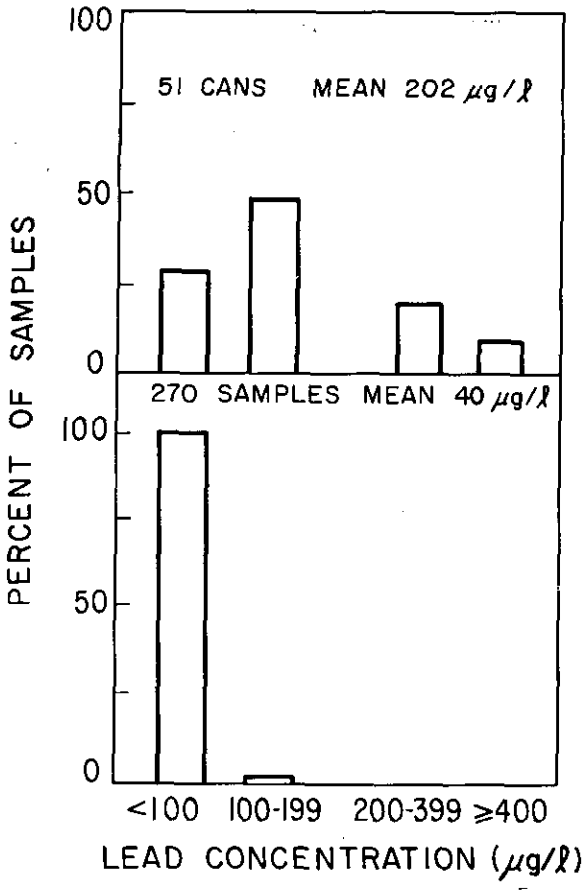

FIGURE 7. Distribution of lead in bulk and canned milk.

calcium has a "protective" effect against lead toxicity (*4*).

These lead sources may make a considerable contribution to the lead body burden for a young child. For example, if a child is fed canned products averaging 300 μg lead/l. (50% above the mean lead level found in this study), it would require 1 liter per day to meet the maximum daily permissible intake (MDPI) recommended by an *ad hoc* committee of the Department of Health, Education and Welfare (*5*). It would take only 0.33–0.67 l./day to exceed the MDPI recommended by Barltrop (93–180 μg/day) (*6*) and only 0.17 l./day to exceed the World Health Organization MDPI for a 10-kg child (5 μg/kg body weight/day (*7*). These calculations probably understate the health hazard, since (a) they omit contributions from other lead sources, including paint, dirt, and air particulates; (b) children ingest these lead sources at a much earlier age than with paint ingestion; and (c) there is some evidence that very young children absorb lead more efficiently than older children (*8*).

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