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Lead Content and Exposure from Children's and Adult's Jewelry Products

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Public health risks associated with exposure to lead have been recognized as a serious issue in the United States and abroad for many years. Though lead poisoning in children was first identified as a clinical disorder in the United States in the 1920s, it did not become a major issue until the 1960s (Lin-Fu 1992). In the late 1980s and early 1990s, researchers discovered that lead can cause irreversible damage to the neurological system at much lower exposure levels than previously believed, with damage occurring most notably in infants and young children (Sciarillo et al. 1992). A recent study by Lanphear et al.(2000) found measurable learning deficits in association with blood lead levels (BLLs) as low as 2.5 μg/dL , while even more recently Canfield et al. (2003) estimated an average IQ difference of 7.4 points between children with BLLs of 1.0 μg/dL and 10.0 μg/dL, suggesting that a disproportionate amount of neurological damage may occur at the lower BLLs.

The health effects of lead exposure on children include well-documented intellectual effects, such as IQ deficits, learning disabilities, and brain damage, as well as behavioral and emotional problems, such as hyperactivity, aggressiveness, and anxious behavior (Burns et al.1999). A study by Kafourou et al.(1997) showed that lead may also affect the growth of children; in the study, decreases in height, head circumference, and chest circumference were found to correspond with increases in lead levels.

Lead has been prohibited or severely restricted in most consumer products, and recent data shows that baseline blood lead levels have been declining for more than 20 years (Mattuck et al. 2001). Nonetheless, there are still approximately 890,000 children living in the United States alone with elevated BLLs (USCPSC 2003). Because of the continuing widespread occurrence of lead poisoning in children, lead-containing products with moderate or low exposure potential are becoming acknowledged as having public health significance.

The purpose of this research was to consider one of these sources of potential lead exposure, metallic low-cost jewelry, including pieces intended specifically for children. Low-cost jewelry has traditionally been made using lead because it gives

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weight to the pieces and is easily manufactured (Urbanowicz 1986). Despite this knowledge, no significant studies into the exposure of individuals to lead through common jewelry items have yet been published, nor do any national restrictions exist in the manufacturing and sale of these items. For this study, 285 pieces of metallic jewelry acquired from various nationwide retail stores located in California were tested for total lead content, and approximately 100 pieces were tested for surface lead transfer from laboratory wiping or actual handling. Considering that the nature of the products often causes them to be in constant contact with a child's skin, and that a child can easily transfer lead to his or her mouth, the risk of lead exposures from these pieces may represent a significant public health issue.

MATERIALS AND METHODS

Jewelry pieces were purchased from a variety of retail stores located in California by the California based non-profit organization, As You Sow, and sent in four shipments under appropriate chain of custody documentation to the Environmental Quality Institute (EQI) laboratory, where all analyses were conducted. A total of 285 jewelry items from 20 different stores were included in this study. The items in the first two shipments appeared to be generally oriented towards children, while the items in the last two shipments were chosen to represent a sample of jewelry intended for both older children and adults. A summary of the jewelry received in all four shipments is given in Table 1.

Table 1. Summary of the jewelry samples.

Type of jewelry	Number of samples received
Anklet	5
Anklet/toe ring	1
Belt	1
Bracelet	59
Bracelet/earring	2
Earrings	19
Hair accessory	5
Keychain	4
Necklace	90
Necklace/earring	5
Necklace/hair accessory	2
Necklace/ring	1
Necklace/toe ring	1
Pendant	53
Pin	1
Ring	33
Toe ring	3

Upon arrival at the EQI laboratory, each individual piece of jewelry was placed in its own plastic bag along with any accompanying tags or packaging and was labeled with an individual identification number. Jewelry analysis for lead content of all four shipments was conducted in an identical manner. A sample was obtained from each piece by clipping a small section of metal off with a pair of handheld pliers. Due to the irregularity of the jewelry items, there was some discretion involved in choosing the section of metal to sample in each case. Most jewelry pieces included a metal setting around a central jewel or stone, and such pieces were always sampled from the edge of the metal setting. Other jewelry pieces were sampled by clipping off a substantial section of metal, while thin wire, non-metal components and paint-covered areas were strictly avoided. Some jewelry pieces contained more than one substantial section of metal, and in these cases multiple samples from the same jewelry piece were taken. Assayed sections of metal varied in weight between roughly 0.10 and 1.0 grams.

Each metal sample was placed in a clean, labeled 500 mL or 1 L plastic bottle to which 20 mL of 50% (v/v) nitric acid (HNO_3) was added; the bottles were then left uncapped to fume for 24 hours. Once samples were dissolved in the acid, 500 mL of deionized water was added to each bottle before it was capped and shaken. Samples were analyzed for lead content using flame atomic absorption spectroscopy (FAAS) following NIOSH method 7082. Lead detection on FAAS has an expected detection limit of about 0.05 mg/L and sensitivity of about 0.5 mg/L (NIOSH 1994). The lower reporting limit for these particular analyses was 0.20 mg/L, which corresponds to a lead content between roughly 0.01% and 0.10% depending on the weight of the original jewelry sample.

After all jewelry lead assays were performed, each of the items was given a careful visual inspection in order to determine whether any type of coating or plating was present that might affect the amount of lead transferred by routine handling of the product. Based on these observations, 97 pieces were selected for the second phase of the research, the surface wipe experiment. Each selected piece had a lead content greater than 3.0% as determined by the metal assay. Of the 97 pieces, 62 were selected because they appeared to have a dull metallic coating suspected to contain lead, while the other 35 samples were chosen because they appeared to be free of any coating or plating.

Each of these pieces was wiped with a laboratory wipe designed for testing lead in dust. All of the pieces were wiped using one side of the wipe for ten seconds, followed by folding and wiping with the other side for an additional ten seconds. Wipes were immediately placed in 50 mL vials for subsequent digestion and analysis. Wipe samples were digested using NIOSH method 7082 with concentrated HNO_3 and 30% H_2O_2. Analysis for total lead was conducted using graphite furnace atomic absorption spectrophotometry (GFAAS) following Standard Method 3113B, 20th Ed, 1998.

RESULTS AND DISCUSSION

Table 2 provides a summary of the metal assay results. The mean percent lead, as well as the percent of pieces within varying ranges of lead content, is shown for each jewelry type. Those lead contents that were reported as less than the lower reporting level (0.02 %) are represented in weight percent as the reported value or less. In some cases, the number of samples tested is greater than the number of samples received due to the fact that some of the jewelry pieces had multiple parts of their surface area tested.

Table 2. Summary of lead assay results for all jewelry pieces.

Type of jewelry	# of jewelry pieces	# of assays	Mean % lead	Percent <3.0% Pb	Percent 3.0-10.0% Pb	Percent 10.0-50.0% Pb	Percent >50.0% Pb
Anklet	5	5	48.7	20.0	0.0	0.0	80.0
Anklet/ toe ring	1	1	44.7	0.0	0.0	100.0	0.0
Belt	1	2	0.02	100.0	0.0	0.0	0.0
Bracelet	59	69	31.8	50.7	4.4	4.4	40.6
Bracelet/ earring	2	3	3.1	33.3	66.7	0.0	0.0
Earrings	19	21	33.9	42.9	4.8	9.5	42.9
Hair accessory	5	7	7.7	85.7	0.0	0.0	14.3
Keychain	4	4	11.8	75.0	0.0	25.0	0.0
Necklace	90	98	24.3	55.1	6.1	8.2	30.6
Necklace/ earring	5	5	43.3	40.0	0.0	0.0	60.0
Necklace/ hair accessory	2	2	61.5	0.0	0.0	0.0	100.0
Necklace/ ring	1	2	0.05	100.0	0.0	0.0	0.0
Necklace/ toe ring	1	1	5.1	0.0	100.0	0.0	0.0
Pendant	53	54	40.7	25.9	9.3	11.1	53.7
Pin	1	1	4.8	0.0	100.0	0.0	0.0
Ring	33	33	38.8	30.3	6.1	12.1	51.5
Toe ring	3	3	0.03	100.0	0.0	0.0	0.0
Overall	**285**	**311**	**30.6**	**45.7**	**6.8**	**8.0**	**39.5**

Clearly, there is a considerable amount of lead being used in the production of most of the sampled jewelry items. Of the total 311 samples tested (including duplicates), 169 contained at least 3.0% lead by weight in at least one portion of the jewelry piece. These 169 samples showed a wide range of lead weight percents, from a low of essentially zero to a maximum of essentially one hundred percent lead. In fact, 123 of the 311 samples were found to contain more than 50.0% lead by weight. Remarkably, 36 of these 123 samples contained more than 75.0% lead.

Previous research on lead exposure has indicated that handling items with much lower lead weight-percent than these jewelry pieces (e.g. 1.0%-8.0%) results in significant transfer of lead to the skin. A handling study conducted on keys with lead contents of 1.4% to 1.9% indicated that as much as 30 μg of lead could be transferred to the skin when handling the key for the first time (Middleton 2000). A similar study testing galvanized plumbing parts (approximately 1.0%-2.0% Pb) for lead exposure involved handling an apple slice after handling the galvanized part to determine the amount of lead transferred to foodstuffs. Results indicated that up to 4 μg of lead could be transferred from the skin to the surface of food items, and thus ingested, after a single hand contact with such parts *(Maas et al. EQI Technical Report #01-087, 2001).* The potential hazard associated with 3.0% to 100.0% lead jewelry items that may be worn on a finger or through the skin is readily apparent in light of these earlier studies.

The content of lead appears to vary with the nature of the particular jewelry item, such as its intended weight and appearance, more so than the place of purchase. Based on the data provided, those items categorized as children's jewelry showed an overall mean lead content of 27.8%, while those pieces intended for all ages had a mean lead content of 35.6%. However, these values are of little application given the wide variability of lead content. A more useful interpretation is the probability of purchasing a high lead-containing jewelry item (one with a lead percentage of 10% or more), which was over 54% in this large California retail store sample.

Upon careful visual inspection, it was observed that about one-half of the 311 jewelry sections appeared to have some type of coating or plating. Visually, these fell into three categories: shiny chrome-colored plastic coatings, shiny chrome-colored metallic platings, and dull grey metallic platings. The presence of plating or coating is of interest because it may affect the amount of lead transferred during routine handling of the pieces. For these experiments, samples with dull grey metallic plating and samples that appeared to have no shiny plastic or metallic platings were tested for the amount of surface lead which would be transferred to a standard laboratory wipe from a moderate amount of wipe contact.
From visual observation of the 311 jewelry pieces included in the study, it was found that one of the most common uses of lead in these products was as dull grey plating, apparently intended to impart an antique pewter type finish to the piece. We identified 90 jewelry pieces of this type of which 62 had been previously found to contain more than 3.0% lead. Each of these 62 pieces was rubbed with a standard laboratory wipe for 20 seconds as described previously.

The results of the wipe experiments on the 62 pieces were placed into one of four categories. The Low Exposure (LE) category (35% of pieces) represents samples which transferred less than 1.0 μg of lead onto the wipe, the Moderate Exposure (ME) category (48% of pieces) represents samples transferring 1.0 to 10.0 μg of lead, the High Exposure (HE) category (11% of pieces) includes samples transferring 10.0 to 50.0 μg of lead, and the Very High Exposure (VHE) category (5% of pieces) represents the samples with more than 50.0 μg of lead on the wipe. The 10 pieces in the HE and VHE categories represent a relatively high lead exposure hazard with transfers in the range of 10 μg to over 90 μg from a single wiping. Using the CPSC's 50% hand-to-mouth transfer rates for a child three and under and a 30% transfer rate for children age 3-7 (CPSC, 1997), these pieces would result in a lead exposure of 5.0 to 45.0 μg per 20 second contact for a young child and a range of exposure from 3.0 to 27.0 μg for a child 3-7 years of age. Forty (i.e. 65%) of the products transferred in excess of 1.0 μg to wipes, which assuming a single daily use, would translate to an estimated lead exposure of greater than 0.5 μg/day (the California Proposition 65 warning level for a consumer product) for a child age 3 or younger per 20 second contact.

In the second phase of the wipe experiments, thirty-five of the jewelry items with more than 3.0% lead which did not appear to have any coating or plating were randomly selected to undergo the same surface wipe procedure. Eight of the pieces (23%) had less than 1.0 μg of lead and thus fell into the Low Exposure (LE) category. These samples transferred measurable amounts of lead to the wipes, but would result in an actual exposure of less than 0.5 μg per contact using the CPSC assumptions described above. It is quite possible that some of these items may have had some type of plating or coating that was not visually observable. The ME category (1.0-10.0 μg) included 16 samples (46%). These pieces would expose a young child to between 0.5 μg and 10 μg of lead per 20 second contact. Nine pieces (26%) were included in the HE category (10.0-50.0 μg). These pieces would most likely represent a significant lead exposure hazard with a range of 11.4 μg to 47.0 μg of lead transferred to the wipe. For a young child, these products translate to an exposure of 5.7 μg to 23.5 μg, and for a child between ages 3 and 7, they translate to an exposure of 3.4 μg to 14.1 μg of lead. Two products (6%) were included in the VHE category because they had more than 50 μg of lead on the wipe. One of these products had 63.6 μg of lead, while the other had almost 7500 μg of lead. This second piece represents an extreme lead exposure hazard; for a child under 3, exposure could be as great as 3750 μg, and for a child between ages 3 and 7, exposure could be up to 2250 μg of lead per 20 second contact.

A summary of both components of the surface wipe experiments is provided in Table 3. The table shows the mean amount of lead in the wipe and percent of samples in each category for each jewelry type represented in the experiment, including non-coated as well as dull grey coated pieces. The results show that the greatest number of the pieces fall into the ME category, with between 1.0 and 10.0 μg of lead, though there are a significant number of pieces in the HE and VHE categories that pose serious health risks.

Table 3. Summary of results from combined dull-coated and non-coated surface wipe experiments by lead exposure category.*

Jewelry Type	Sample size	Mean Pb in wipe (μg)	Percent LE (<1.0μg)	Percent ME (1.0-10.0μg)	Percent HE (10.0-50.0μg)	Percent VHE (>50.0μg)
Anklet/ ring	1	0.06	100.00	0.00	0.00	0.00
Bracelet	24	11.86	33.33	41.67	16.67	8.33
Bracelet/ earring	1	0.15	100.00	0.00	0.00	0.00
Earring	4	2.30	25.00	75.00	0.00	0.00
Necklace	38	5.53	28.95	57.89	10.53	2.63
Pendant	15	7.29	20.00	46.67	33.33	0.00
Ring	14	541.97	35.71	28.57	21.42	14.29

*LE= low exposure, ME= moderate exposure, HE= high exposure, VHE= very high exposure

The jewelry analyses conducted during this research demonstrated that lead is still being used as a major component in the production of many jewelry items. Approximately 40% of the 311 jewelry pieces tested had at least 50.0% lead content, and over 10% of the samples had greater than 75.0% lead. Wipe testing experiments to simulate actual handling showed that a majority of uncoated jewelry items or dull antique plated jewelry items will expose a child to amounts of lead greater than 0.5 μg/day from a relatively small amount of daily hand contact; in fact, roughly 70% of the pieces produced wipes with at least 1.0 μg of lead. One particular piece of jewelry presented an extreme health risk, with estimated exposures of 3750 μg of lead for a child under 3 and 2250 μg for children between the ages of 3 and 7. Although not tested in this research, more intensive handling or direct mouthing activity would obviously result in even greater lead exposures to children. This research clearly shows that lead in low-cost jewelry is a significant threat to public health, and currently these items are being sold directly to the consumer without any form of warning. The results of this study emphasize the necessity of continuing to identify and eliminate unregulated sources of lead exposure from common consumer products.

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