Lead in Christmas Lights

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Abstract

A recent California proposition led to awareness that lead is a stabilizer in the Polyvinyl Chloride (PVC) jacketing that covers conductors in Christmas lights. The objective of this study is to examine the level of accessible lead in Christmas lights. Following U.S. Environmental Protection Agency (U.S. EPA) Lead Inspectors' procedures, researchers at Cornell University and in Nebraska conducted wipe samples and total lead content samples of newly purchased and older Christmas light sets. Samples were analyzed for lead content. Lead was present in varying amounts on all samples. The amount of lead from the Nebraska samples, normalized to length of strings, was independent of analyzing laboratory, analysis method, age of string, and repeat sampling, both immediately and after extended storage. A later analysis of these same strings by the Cornell team showed diminished quantities. Amounts of surface lead normalized to crude estimates of the area of light string indicated surface concentrations in excess of U.S. EPA clearance level for lead on window sills. Whether exposure to lead in Christmas lights affects blood lead levels in humans is unknown. No standards exist for lead content in this product, and no protocols exist for conducting tests on it. Therefore, consumers may wish to exercise caution to reduce possible exposure.

Introduction

Humans have had a long relationship with lead. Before 1550 BCE, Egyptians used lead-based compounds for external remedies, which, according to Nriagu (1983), suggests an appreciation for lead's toxic properties. In more recent times childhood lead poisoning was recognized as a clinical disorder in the 1920s (Maas, Patch, Pandolfo, Druhan, & Gandy, 2005), and lead was banned as an ingredient in residential paint in 1978 by the Consumer Product Safety Commission (CPSC) (Jacobs et al., 2002). While the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO) have set 10 micrograms (µg) of lead per deciliter (dL) of blood as a "level of concern," Jusko and co-authors (2008) observed impaired intellectual functioning in children under six years of age who had blood lead levels (BLL) as low as 2.1 µg/dL, which suggests that no threshold may exist for negative health problems from lead exposure. Furthermore, while blood lead remains elevated for only a few weeks to months after exposure, it should be noted that its disappearance does not signify elimination. Rather, lower BLLs after exposure indicate relaxation of lead into bones and teeth where it remains stored, contributing to a lifelong accumulated body burden, which sums all individual sources of exposure. This stored lead can be remobilized into the blood by numerous triggers, e.g., various conditions of physiological stress, disease, or "normal" aging (U.S. Environmental Protection Agency [U.S. EPA], 2006).

Despite awareness of the dangers of lead exposure, lead is continually found in products that expose people to high levels of this toxin, including deteriorating paint (Jacobs et al., 2002); jewelry (Maas, Patch, Pandolfo, Druhan, & Gandy, 2005); motor vehicle wheel weights that easily fall from vehicles (Root, 2000); charms on children's tennis shoes (Testerman, 2006); miniblinds (CPSC, 1996); artificial Christmas trees (Maas, Patch, & Pandolfo, 2004); ceramics, folk medicines, hair dyes, cosmetics, and other items (National Safety Council, 2004).

California's Proposition 65, The Safe Drinking Water and Toxic Enforcement Act of 1986, requires the governor to publish a list of chemicals known to cause cancer or reproductive toxicity. At a minimum, this list must be published annually. An environmental advocacy group in California used this act as the basis of a lawsuit that resulted in a warning that now exists on Christmas light packaging. The warning reads: "Handling the coated electrical wire on this product exposes you to lead, a chemical known to the State of California to cause birth defects or other reproductive harm. Wash hands after use."

Lead compounds are used as stabilizers in the polyvinyl chloride (PVC) coating (jacketing) that covers a wire's copper electrical conductors. Stabilizers give PVC resistance to heat, light, and moisture; they can comprise 2%–5% of PVC jacketing in different types of wires, including building wire, telephone wire, appliance cords, power cable, coaxial and antennae cable, electronic and data wire, and magnet wire (Greiner Environmental, Inc., 2002). European directives and lawsuits connected to California's Proposition 65 are stimulating research into alternatives to using lead in PVC jacketing.

In the fall of 2006, consumers began questioning the toxicity levels of Christmas lights through discussions and postings found on online blogs and forums as well as news reports. The purpose of this study is to ad-

TABLE 1

Lead Content of Christmas New Light Wires and Bulbs

Sample ID	Length (m)	Total µg	µg/m
Flame-tip	7.7	41.5	5.4
Rope light	1	<1.2	<1
Star-light sec.1	1	9.29	9.3
Star-light sec. 2	1	4.60	4.6
Star-light bulbs	NA	<1.2	NA
Flame-tip bulbs	NA	3.73	NA

TABLE 2

Lead Content of Older Christmas Lights—Lincoln and Cornell Tests

Length (m)	Total µg 1st Test (Lincoln)	Total µg 2nd Test (Lincoln)	Total µg Retest (Cornell)
5.68	50.9	70.0	6.46
7.62	62.7	58.0	13.7
7.62	62.0	65.0	12.5
7.62	73.0	76.0	16.7
10.0	52.0	54.0	18.4

dress consumer questions by quantifying the amount of lead found in mass-produced Christmas lights and concluding about the relative danger in using these products.

Methods

The Cornell team analyzed wipe samples and total lead content samples of newly purchased Christmas light sets. Three light sets were purchased—a 5.4-meter length of rope lighting, a 6.8-meter length of a star light set, and a 7.7-meter length of a flame-tip light set. These light sets were suspended between two chairs. Distilled water was applied to sterile gauze and the gauze was wiped on the wire for each of the following: a one-meter length of the rope light, two random one-meter lengths of the star light set, and the entire 7.7-meter length of the flame-tip light set. The gauze wipes were sealed in plastic bags, as were several flame-tip and star light bulbs in their sockets. These samples were shipped to a laboratory for analyses that meet quality control requirements of the American Industrial Hygiene Association (AIHA) and the National Environmental Laboratory Accreditation Conference (NELAC). Inductively coupled plasma (ICP) detection was used as the analysis method. Results of these tests are shown in Table 1.

To provide further data for this study, an additional test was conducted. Using a standard wire stripper and wire cutter, the entire 7.7-meter length of the flame-tip was prepared for analysis by first cutting the lights from the wires connecting them and stripping the PVC jacket from the copper conductors. The PVC coating was shipped to the same laboratory as above and analyzed for total lead content. The reported result was 1,200 µg/g.

Additional wipe tests were conducted on six Christmas light sets that had been purchased for home use by the Lincoln, Nebraska, researcher. The exact dates of purchase were unknown. Three identical sets were purchased on the same date in the 1970s, two nonidentical sets in the 1990s, and an additional set within the last three years. The older identical sets had two twisted wires, and all of the more recent ones had three twisted wires. The Nebraska researcher measured the length of each light set using a flexible tape measure. Widths were measured with a caliper. U.S. EPA Lead Inspectors' procedures were used for the wipes (American Society for Testing and Materials [ASTM] wipes, gloved hands; one set of gloves for each wipe). The researcher firmly but lightly wiped the full length of each cord, folded in the wipe, and repeated this as close to a right angle twist as was practicable. No attempt was made to separate the strands and wipe between them. After another fold of the wipe, six socket bases and the plug were wiped.

Wipes were mailed for analysis to three National Lead Laboratory Accreditation Program/AIHA-accredited laboratories in polyethylene 50 mL centrifuge tubes provided by the laboratories along with spiked samples. Wipes were analyzed by three laboratories. Four of the five strings were analyzed by flame ionization (FI) and one of the three identical strings was analyzed by ICP. The five strings initially sampled were stored for eight months in plastic ziplock bags and resampled using the same method. An additional string purchased more recently was sampled at a later date, allowed to dry for one hour, and resampled on the same day, prior to storage. Reanalysis of all the strings was done by the same lab using FI. The residue left in two of the plastic storage bags was also wiped for analysis. Some of these residuals were analyzed by FI, and others by ICP.

Results

Lincoln home light set test results are shown in Table 2. The original five strings of Christmas lights were further retested within a month of the second Lincoln test at Cornell University by Cornell researchers who attempted to use similar procedures. These Cornell retest results are also included in Table 2. Lead content of plastic storage bags and blank samples for the Lincoln samples are reported in Table 3. Spiked samples submitted with the light strings to the labs and results of their tests are shown in Table 4 for both Cornell and Lincoln.

Averages of various subsets of the Lincoln measurements, which highlight the total lead content as affected by the three analyzing laboratories, two methods of analysis (FI and ICP), ages of the strings, the repeat samplings, and these amounts after normalization to the lengths of the strings are summarized in Table 5.

Discussion

The Cornell results appear to be somewhat more variable than the Lincoln ones, although with comparable amounts of total lead. It is not clear whether this variability is characteristic of different varieties of lights selected by the Cornell researcher (the home use sets all contained minibulbs of similar appearance), of their more recent purchase than the home use strings (some of them may have been manufactured using less lead than has been characteristic of past manufacturing practices), or is somehow related to some difference in sampling protocols between the Cornell and Nebraska wiping methods. Also, the Lincoln sampling was done of the entire length of the string, whereas the Cornell sampling was mostly done on segments. It is possible that the lead was not uniformly distributed along the string segments, or that an extended length is required to average variability of the touch as the wipe is moved along it.

The averages of the total lead content of the three identical home use strings shown in Table 5 are statistically indistinguishable from each other in the first sampling in spite of analysis by three different labs and two methods of analysis (FI and ICP). Results of the replicate samplings performed after a several-month delay, all of which were measured by a single lab using FI only, also were indistinguishable from results of the initial set of measurements. The implication is that, for identical strings, the amounts of lead sampled using the wipes was independent of the testing laboratory, the method of analysis, and replicate testing after a storage period.

If the results for total lead are normalized to the length of all six of the cords, the amount of lead/meter appears independent also of the manufacturer, year of purchase, and the number of years of usage of the strings. The immediate remeasurement of the sixth string appears to be somewhat lower than those separated in time by several months, but even that measurement can be included in the same grand average if the single low measurement from the initial measurement from the identical strings is also retained. It was thought that knowledge of the inherent experimental error of these measurements is inadequate to justify throwing out either of the low measurements. The implication is that the amount of available lead in these varied strings is very similar for all of them, regardless of manufacturer, age, and usage of the strings, and similar in repeat samplings.

If the lowered results from the immediate retest of the sixth string are considered comparable to the initial test, as was the case for the five strings in which the retest occurred after a several month time delay, it would appear, considering just the Lincoln measurements, that the available lead is not affected by a rewipe, and thus does not indicate a manufacturing residue that wears off after handling, but is a repeatable source of exposure.

The third sampling of five of the home use strings at Cornell gave significantly lower results than obtained by the second Lincoln sampling, however. These different results obtained for the same strings by the Lincoln and Cornell tests may be explained by several possible reasons. The Cornell tests were conducted after both Lincoln tests. It could be that most of the lead residue was wiped from the surface of the PVC conductor covering during the two initial tests, and sufficient time had not transpired between the second Lincoln and subsequent Cornell sampling to refresh the supply. This likelihood would seem surprising, given the indistinguishability of the Lincoln results of samples first measured after repeated usage over many years, and then again after a few months of storage. Other possibilities are that the Cornell tester had a lighter touch with the wipe, so that most or all of the Cornell strings were undersampled, or that the gauze wipes used by the Cornell worker were less effective in removing lead than the ASTM one. It is also possible that the gauze wipes used in the Cornell retest are less thoroughly digested in the analysis than are the ASTM ones, and thus the lead was underanalyzed. All of these puzzles point to the necessity of developing a standard protocol for testing of this nature, which is reliable in removing all available surface lead and is reproducible between experimenters.

TABLE 3

Blank Samples and Storage Bags*—Lincoln Samples

Sample	Date Measured	Method	µg/sq. ft.
New 1 gal. Glad	10/07	FI	<10
Storage 1 gal. Glad	10/07	FI	14
New 1 gal. Glad	12/07	ICP	<0.31
New 2 gal. Hefty	10/07	FI	<10
New 2 gal. Hefty	12/07	ICP	<0.16
Storage 2 gal. Hefty	12/07	ICP	<0.16
Blank	2/07	FI	<10
Blank	2/07	ICP	<0.5
Blank	10/07	FI	<10
Blank	10/07	FI	<10
Blank	12/07	ICP	>0.31

* FI = Flame Ionization Detection; ICP = Inductively Coupled Plasma Detection.

Conclusion

Lead hazard levels set by the U.S. Department of Housing and Urban Development (HUD) address building components, water, and soil (HUD, 1995). No hazard level exists for Christmas lights. Further, our results in Table 1 are reported in µg/meter, and HUD lead hazard levels are set in µg/ft^2. In order to estimate some comparison between the surface amounts of lead on the strings and that in household dust, a crude estimate of the surface area of the cord was made by using a vernier caliper to determine the span of the braded strings; this measure was doubled and multiplied by the length of the string, a procedure which might be expected to overestimate the sampled surface area. Normalizing the total lead analyzed by this crude area, the surface concentrations of the five home use sets would be somewhat in excess of the 250 µg/ft^2 determined by U.S. EPA to constitute a clearance level for window sills, and would be considerably in excess of the 40 µg/ft^2 required for clearance by floors.

Primary factors of concern for actual exposure hazards include family activities relating to tree decorating. Installing the lights on a tree and in other places inside the home causes exposure that, when followed by hand-to-mouth contact, could result in ingestion. Clearly the degree of transfer to hands could be significant, but would be highly variable with the amount and skill of handling and hygienic precautions. In addition to transfer of the lead to hands during installing and removing light strings, it is possible that lead dust may drop to contaminate the branches of the tree or nearby ornaments. A single dust wipe taken from one section of a tree branch, however, showed undetectable lead by ICP analysis. The plastic bag used to store one of the older identical sets, however, showed lead content elevated above the limit of detectability (14 µg vs. 10 µg).

Additionally, dust could be liberated into the air during handling, where it could be breathed

TABLE 4

Spiked Samples and Their Test Results

Spike Amount	Lab Result
0.75 µg	<1.3 µg
75.0 µg	67.4 µg
211 µg/ft^2	230 µg/ft^2

TABLE 5

Subset Averages of Lincoln Results

Subset Description	*n*	Average (µg)	Average (µg/m)	Σ
Identical strings, initial	3	66	—	6
Identical strings, retest	3	66	—	9
Identical strings, both	6	66	—	7
All strings, initial	6	—	8.1	1
All strings, retest	6	—	8.6	1
All strings, both	12	—	8.4	1

during installation and removal of lights and ornaments. Whether significant amounts of respirable dust are generated during handling is unknown. Measurement of air dust might be estimated by use of a mask, followed by analysis of dust captured by the filter.

With the conclusion from Jusko and coauthors in mind (2008) that no safe threshold exists for lead exposure to children, these results are of concern.

PVC degrades and produces lead dust when it is exposed to sunlight (Block, 2007). Therefore, lights used for exterior trim may generate more dust than those used only inside. The level at which exposures from Christmas lights are significant should be investigated in further research where branches, ornaments, the floor below the tree, hands, and respirable dust are tested in a controlled manner. A key aspect of the exposure risk is whether exposure is greater during initial use of the strings, remains constant, or even increases as the strings age.

The amount of lead measured in the digested PVC jacket from one of the Cornell strings fell well below the 2%–5% commonly used (1,200 µg/g). American manufacturers have been moving away from use of lead as a PVC stabilizer in the last five years (E. Harriman, personal communication, February 14, 2008). The cord measured was one of those purchased most recently. It would also be of interest to know how much variability exists in the amount of lead in jacketing from various manufacturers, and also other light and appliance cords. Since PVC has many uses other than in electrical cords, the amount and accessibility of lead in PVC used in different applications is also of interest, and, like that in Christmas lights, is inadequately reported. It must be reemphasized, however, that such comparisons must be done within a context of protocol development that ensures consistent sampling protocols that are reproducible and reliably comparable between experimenters.

Implications of this research involve both producers and consumers. Producers of Christmas lights, which are handled more extensively than other light cords, could be persuaded to stop using lead as a PVC stabilizer, either through legislation or consumer demands that could be expressed through boycotts. In the near-term, consumers should be alerted to exercise safety precautions during installation, use, and removal of Christmas lights.

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