Identifying Lead Dust Contamination Limits Appropriate for Adults and Older Children

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Abstract

This paper proposes a method by which lead dust contamination limits appropriate for adults and older children can be derived from existing childhood standards. The derived limits can be applied whenever the lead dust hazard level established by the Unites States Environmental Protection Agency (EPA) is contemplated for use with populations other than children under six years of age in residential dwellings. The method applies exposure factors that account for differences in behavior between any given target population and the EPA's target population of children aged one to two years. The method employs the behavioral factors of exposure period and ingestion rate because they are intuitive, easily derived, well documented, and do not require the use of complicated biokenetic models.

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On April 4, 2006, the Connecticut Department of Public Health (DPH) issued a Product Advisory and Information Sheet regarding the "Use of Leaded Ceramic Glazes in School Art Classes." This sheet advised Connecticut school districts to determine if leaded ceramic art glazes had been used in the district and, if so, to coordinate with the local health departments to identify and remedy any lead hazards that may have been created by such use. The advisory specified the lead dust *hazard level* established by the United States Environmental Protection Agency (EPA) as the trigger value to initiate decontamination activities and as the clearance standard to determine the efficacy of decontamination activities (Connecticut Department of Public Health. (2006).

Presumably, the DPH selected the EPA hazard level because no other lead dust contamination standard was available. However, the EPA hazard level was developed for residential dwellings occupied by children under six years old (EPA, 2001a), with a specific target population of children aged one to two years. This setting and target population is significantly different than public school art rooms occupied by adults and older children. It is difficult to imagine that any health benefit gained from decontaminating the art rooms to the hazard level established for children from one to two years of age is commensurate with the effort and expense required to achieve this level. This study will show that age and activity appropriate lead dust contamination standards can be readily and reliably derived from the EPA hazard level by applying exposure factors that account for differences in behavior between target populations.

Art Room Lead Contamination Issues

Lead in Ceramic Art Glazes

Ceramic art glazes are used to strengthen and decorate art formed from clay. Modern ceramic art glazes are pre-mixed liquids that contain frit made from finely ground glass. When the glaze is fired in a high-temperature oven called a kiln, the glaze vitrifies into a permanent, impermeable coating over the clay. Various other materials, including lead, are added to the glass frit to improve the performance of the glaze during the firing process or to enhance the color of the finished product. According to Material Safety Data Sheets provide by ceramic glaze manufactures, ceramic frit represents approximately fifty percent of the weight of liquid glazes (American Art Clay Company, Inc., 2005) and, depending upon the formulation, up to 28 percent of that frit can be lead oxide (Duncan Enterprises, 2005).

During the glazing process, lead from the liquid glaze can contaminate surrounding surfaces in several ways. The most direct means of contamination is spillage of the liquid glaze product. When allowed to air dry, the dried glaze is easily crumbled into a fine, talc-like dust that readily spreads throughout the surrounding area. Lead in ceramic art glaze can also volatilize during the firing process, contaminating the inside of the kiln, other objects within the kiln, and, in older kilns without adequate ventilation systems, the spaces surrounding the kilns.

Decontamination Procedures and Costs

The DPH product advisory for leaded ceramic art glazes was issued after a Connecticut school system identified contamination in art rooms that was attributed to lead in ceramic art glazes. The author of this paper assisted two Connecticut school systems with their response to this advisory. Thirteen buildings were evaluated for lead dust contamination, including two high schools, four middle schools, six elementary schools, and a multi-use building that included space used for art instruction. Lead dust contamination levels in excess of the EPA hazard level were identified in all 18 art rooms within the 13 buildings.

Cleanup of the contaminated art rooms was conducted in accordance with standard decontamination techniques. Non-porous items and surfaces within the rooms were decontaminated with HEPA-filtered vacuum cleaners and wet cleaning methods. Porous and other items that could not be decontaminated in this manner were discarded. Decontaminated items and surfaces were sampled before they were returned to service to assure that they were less than the EPA hazard level.

The direct cost of decontaminating all eighteen art rooms, which includes the cost of the industrial hygiene consultant, analytical laboratory, abatement contractor, and hazardous waste disposal, was $199,134, or an average cost of approximately $11,063 per room. Indirect costs are difficult to quantify, partly because not all of the discarded items were immediately replaced, and partly because many of the discarded items had been personally accumulated by the art teachers outside of normal procurement channels.

EPA Lead Dust Standards

EPA Hazard Level for Surface Dust Lead Contamination

The EPA's hazard level for surface dust lead contamination was developed for residential dwellings occupied by children under six years old, with specific interest in a target population of children aged one to two years. Children aged one to two years are the population most susceptible to the adverse effects of lead poisoning because of a high level of hand-to-mouth activity, a rapidly developing central nervous system, and a peaking of the synaptic density of the frontal cortex of the brain (EPA, 1998). Detailed risk analyses supported the conclusion that children aged one to two years exposed to less than forty micrograms of lead dust per square foot of floor area (40 ug/ft^2) are unlikely to develop blood lead levels in excess of 10 micrograms per deciliter (10 ug/dl), the level of concern established by the Centers for Disease Control (EPA, 2001a). Accordingly, 40 ug/ft^2 was established as the EPA's hazard level for lead dust on floors in residential dwellings occupied by children under six years of age.

EPA Dust Standards for Adults

Ideally, lead dust hazard levels for settings other than child-occupied dwellings would be based upon a research and development program comparable to the program that developed the 40 ug/ft^2 hazard level for children under six years of age. Unfortunately, from the passage of the Residential Lead-Based Paint Hazard Reduction Act of 1992 until the publication of the final hazard level in 2001, it took the EPA nearly nine years to develop the final childhood hazard level (EPA, 1995a, 1998a, 2001a). It is unlikely that this level of effort and expense could be justified to develop a hazard level for every other situation of lead contamination.

Though the EPA has not developed a specific lead dust hazard level for adults and older children, it has not been inactive on the subject of adult exposure to lead in soil and dust. However, most of the EPA's work in this area has been under the authority of the Superfund program, which is responsible for identifying and cleaning up uncontrolled hazardous waste sites. As might be expected, the EPA's emphasis at Superfund sites is on the amount of lead in the soil and the means by which that soil – and dust from that soil – may be ingested by adults.

Typical of EPA's work on adult lead exposure is the document, "Recommendations of the Technical Review Work for Lead for an Approach to Assessing Risks Associated with Adult Exposures to Lead in Soil" (EPA, 2003a). This documents provides "a methodology for assessing risks associated with non-residential adult exposures to lead in soil" (p. 1). This methodology is designed as an assessment tool that will provide consistency in the EPA's decision-making process when evaluating the health risks of employees whose place of business is situated on lead contaminated soil.

This is a well thought out methodology that uses relatively simple algorithms and well-defined input variables. However, it is difficult to apply this and most other Superfund methodologies to situations where the lead contamination is in the form of fine dust that is thinly spread over a large surface area. This is because Superfund methodologies use mass-weighted concentrations, where the concentration of lead is expressed in micrograms of lead per gram of soil (ug/g). In contrast, because of the small quantities of dust involved, surface contamination studies typically use area-weighted dust loadings, where the concentration of lead is expressed in micrograms of lead per square foot (ug/ft^2).

EPA is currently working on an "All Ages Lead Model" that will be capable of "simulating multimedia exposures and biokenetics over the entire human lifespan" (EPA, 2001b, p. 2). However, since the All Ages Lead Model will be based upon the current Integrated Exposure, Uptake, and Biokinetic (IEUBK) Model for Lead in Children (EPA 1994), it will likely require mass-weighted input data as does the IEUBK.

It is possible to collect and analyze surface dust samples using methods that provide both mass-weighted lead concentrations and area-weighted lead dust loadings (EPA, 1995b). These methods use a vacuum device to collect surface dust onto filter media enclosed within a plastic sampling cassette. The total amount of dust collected from the surface is calculated by weighing the sample and subtracting the pre-determined weight of the filter media. The mass-weighted lead concentration is calculated by dividing the mass of lead in the sample by the total mass of dust in the sample (ug/g). The area-weighted lead dust loading is calculated by dividing the mass of lead in the sample by the area vacuumed (ug/ft^2).

If mass-weighted concentration is not required, area-weighted lead dust loading can be determined using wipe samples (EPA, 1995b). Wipe samples are collected by wiping a measured area in a specified manner with moistened paper wipes. These samples can be collected quickly and easily, and require none of the specialized field equipment required for vacuum sampling. In the laboratory, the processes required to prepare wipe samples for chemical analysis are simpler and fewer than those required for samples collected by vacuum methods. For these reasons, wipe sampling is more economical than vacuum collection methods and is subject to fewer variations during field collection and laboratory analysis.

The EPA elected to express the childhood lead hazard level as an area-weighted dust loading rather than a mass-weighted concentration so that wipe sampling techniques could be used to quickly and economically evaluate the lead paint hazard in the nation's housing stock (EPA, 1995a). Since the EPA's predilection for wipe samples was formalized in 1995, wipe sampling has become the overwhelming means by which lead dust contamination is measured. A large population of lead risk assessors has become skilled in the collection of these samples, and numerous accredited laboratories provide analytical services at attractive prices. Therefore, even through mass-weighted lead dust concentrations could be used to develop more accurate lead dust limits for adults and older children, the ease and economy of using wipe samples to determine using area-weighted dust loadings favor deriving such limits from the area-weighted EPA childhood hazard level.

Deriving Age and Activity Appropriate Lead Dust Contamination Limits

Exposure Factors

Many factors were considered during the development of the EPA lead dust contamination hazard level for children under six years of age in residential settings. However, in the interest of simplicity and clarity, only two well-documented factors need be considered to derive a lead dust limit that is appropriate for other ages and environments: exposure periods and dust ingestion rates. Once these factors are defined, a hazard level for a given population of interest can be derived mathematically as follows:

$$LDL_{\text{Population of Interest}} = HL_{EPA} \bullet EPF \bullet IRF \qquad \text{(Equation 1)}$$

where:

$LDL_{\text{Population of Interest}}$ = Lead Dust Limit for the Population of Interest (ug/ft^2)

HL_{EPA} = EPA Hazard Level (40 ug/ft^2)

EPF = = Exposure Period Factor (dimensionless)

IRF = = Ingestion Rate Factor (dimensionless)

Exposure Period Factor

The models used by the EPA during the development of the lead dust hazard level assume ongoing exposure to specified contamination levels to provide an average daily lead uptake value (EPA, 1998b). These models assume that the daily uptake value is an average value that is applied for 365 days a year (EPA, 1994). In order to compare exposure periods of different target populations, it is necessary to determine the number of hours per year each population spends on contaminated surfaces. An approach similar to that used by the EPA when setting health-based contamination benchmarks after the World Trade Center disaster can be used to make this determination (EPA, 2003b, Appendix B). This approach uses the default values in the EPA's Standard Operating Procedures (SOPs) for Residential Exposure Assessment (EPA, 1997) to estimate that infants from one to two years of age – the population of interest used to develop the EPA hazard level – spend 12 hours per day in contact with potentially contaminated surfaces.

$EPF = (AET_{EPA\ Infant} / AET_{Population\ of\ Interest})$ (Equation 2)

where:

EPF = Exposure Period Factor (dimensionless)

$AET_{EPA\ Infant}$ = Annual Exposure Time for Infants up to Two Years Old (EPA 1997) (hours per year)

$AET_{Population\ of\ Interest}$ = Annual Exposure Time for the Population of Interest (hours per year)

Solving for art students (180 days per year, 1 hour per day): (Solution 1)

$EPF = (AET_{EPA\ Infant} / AET_{Art\ Students}) = (365 \bullet 12) / (180 \bullet 1) = (4380 / 180) = 24.33$

Solving for adult art teachers (185 days per year, 8 hours per day): (Solution 2)

$EPF = (AET_{EPA\ Infant} / AET_{Art\ Teachers}) = (365 \bullet 12) / (185 \bullet 8) = (4380 / 1480) = 2.96$

Ingestion Rate Factor

Physical and behavioral differences between age groups result in significant differences in the amount of surface dust ingested by each group. Because the target population for lead poisoning regulations is children under six years of age, a great deal of research has been conducted on dust ingestion rates for this population. The results of this research have been embodied in the EPA's IEUBK Model for Lead in Children (EPA, 1994). The EPA used the IBUEK uptake value of 0.135 grams per day for children one to two years old during the risk analysis that was used to develop the EPA lead dust contamination hazard level (EPA, 1998). The oldest age group in the IEUBK model is six to seven years old, but the ingestion rate 0.085 grams per day specified for this age range can be conservatively applied to children from six to eighteen years old. The research on adult dust ingestion rates is not as voluminous as that for children, but enough data are available to allow the EPA Technical Review Workgroup (TRW) for Lead to recommend a value of 0.050 grams per day for adults that are occupationally exposed to indoor dust (EPA 2003a).

$IRF = (IR_{\text{EPA Target Population}} / IR_{\text{Population of Interest}})$ (Equation 3)

where:

IRF	=	Ingestion Rate Factor (dimensionless)
$IR_{\text{EPA Target Population}}$	=	Ingestion Rate for the EPA Target Population (grams per day)
$IR_{\text{Population of Interest}}$	=	Ingestion Rate for the Population of Interest (grams per day)

Solving for art students from six to 18 years old: (Solution 3)

$IRF = (IR_{\text{EPA Target Population}} / IR_{\text{Art Students}}) = (0.135 / 0.085) = 1.59$

Solving for adult art teachers: (Solution 4)

$IRF = (IR_{EPA\ Target\ Population} / IR_{Art\ Teachers}) = (0.135 / 0.050) = 2.70$

Results

Using the exposure factors derived above, an appropriate lead dust contamination limit can be calculated for different scenarios of exposures to adults and children over six years of age. For art rooms contaminated with lead from ceramic art glaze, the following hazard levels can be calculated using equation one and solutions one through four:

$$LDL_{Population\ of\ Interest} = HL_{EPA} \bullet EPF \bullet IRF \qquad \text{(Equation 1)}$$

$$LDL_{Art\ Students\ 6\text{-}18} = 40\ ug/ft^2 \bullet 24.33 \bullet 1.59 = 1{,}547\ ug/ft^2$$

$$LDL_{Adult\ Art\ Teachers} = 40\ ug/ft^2 \bullet 2.96 \bullet 2.70 = 320\ ug/ft^2$$

Because both populations will be using the same room, it is appropriate to select the lower of these two values (320 ug/ft^2) as the lead dust contamination standard appropriate for use in a school art room.

Discussion

The EPA emphasizes that the 40 ug/ft^2 hazard level established in their final rule "applies to pre-1978 target housing and certain child-occupied facilities, and that these standards were not intended to identify potential hazards in other settings" (EPA, 2001, p. 1,211). EPA goes on to warn:

> If one chooses to apply the hazard level to situations beyond the scope of Title X, care must be taken to ensure that the action taken in such settings is appropriate to the circumstances presented in that situation, and that the action is adequate to provide any necessary protection for children exposed. (p. 1,211)

One could argue that applying the EPA's 40 ug/ft^2 hazard level to adults and older children in a classroom setting is appropriate because it is a conservative approach that will provide a high level of confidence that the older population will not be poisoned by lead in surface dust. Implicit in this argument are two assumptions: (a) a higher limit established specifically for adults and older children cannot provide a similar level of health protection, and (b) the money spent to decontaminate classrooms to the childhood lead standards is not diverted from other equally important endeavors. If a higher limit developed specifically adults and older children can provide the same level of health protection for that population as the childhood standard provides for young children, then it is hardly conservative to spend limited education dollars on decontamination efforts that provide no health benefit.

The EPA acknowledged the importance of maintaining credibility when specifying expensive decontamination projects in the preamble to the final rule that promulgated the 40 ug/ft^2 hazard level:

> Thus, if EPA were to choose standards that are too low, the public could be unable to distinguish between trivial risks at the low levels of lead from the more serious risks at higher levels. This could result in clean up for little to no health benefit, or conversely, it could result in almost no clean up because persons would question the credibility of the ‘‘hazard’’ determination. Thus, they may ignore even those high-risk situations that need to be controlled. (EPA, 2001, P. 1,216)

It is possible to agree that hazard limits should be developed for specific situations not considered by the EPA, but to disagree with the method proposed in this paper. Clearly, the best way to develop situation-specific standards would be to replicate the standard development process used by the EPA during the development of the hazard levels for children under six years of age. Unfortunately, the cost of this approach is prohibitive even for the EPA, which has yet to develop lead dust hazard levels for adults and older children.

The exposure factors described in this paper were chosen because they are easily derived, well documented, and represent the two major variables that affect the amount of lead dust ingested by a target population. These factors are also intuitive: It is easy for all parties involved in a lead contamination scenario to understand the differences in behavior and occupancy that will result in different standards for lead dust contamination.

For an art room occupied by adult teachers and by children from six to 18 years old, the exposure factors described in this paper could have been used can be used to establish a surface lead contamination limit of 320 ug/ft^2. If this limit had been applied in lieu of the 40 ug/ft^2 limit specified by the Connecticut DPH, six of the 18 art rooms inspected by the author would not have required decontamination. Furthermore, the scope of the decontamination work in nine of the 12 remaining rooms would have decreased by fifty percent or more. Applying this revised limit would have saved each of the two school systems tens of thousands of dollars that were spent to decontaminate art rooms and replace discarded materials and supplies.

Conclusion

It is possible to derive a lead dust contamination limit appropriate for adults and older children from the EPA hazard level by applying exposure factors that account for age-specific differences in behavioral factors. These exposure factors are simple, well documented and intuitive, and can be used to derive age- and activity-appropriate lead dust limits whenever the lead dust hazard level established by the Unites States Environmental Protection Agency (EPA) is contemplated for use for populations other than children under six years of age in residential dwellings.

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