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# Personal Sample Measurements of Airborne Lead During Abatement Procedures

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Lead has been shown to be an environmental and occupational toxicant with multiple target organs (Amdur et al. 1991) and is regulated by various occupational and environmental agencies at all governmental levels (US Department of Housing and Urban Development - HUD, 1995; Lange and Thomulka, 1995). Current awareness of hazards associated with lead has resulted in an explosion of regulations and is creating a new environmental industry (Lange et al. 1994; Lange and Thomulka, 1995). When conducting lead abatement or related activities associated with lead-containing substances (LCS) the US Occupational Safety and Health Administration (OSHA) requires that personal samples be obtained to establish anticipated exposure levels associated with the type of work being performed (OSHA, 1993). Several publications have reported exposure levels for lead (OSHA, 1993; HUD, 1995); although the number of reports currently available is limited. OSHA regulations provide that for some activities a designated exposure concentration is established and require specific types of personal protective equipment (PPE) to be employed until the anticipated exposure level is determined (OSHA, 1993). Upon establishment of the exposure level an appropriate modification, including reduction, in PPE is permitted. The OSHA permissible exposure limit (PEL) and action level for airborne lead are 50 ug/m3 and 30 ug/m3, respectively (OSHA, 1993).

This study provides data on personal sampling that were collected during a lead abatement project. These data provide an estimation of anticipated exposure, effectiveness of engineering controls and applicability of work practices for similar projects in the future (OSHA, 1993; HUD, 1995).

## MATERIALS AND METHODS

This study was conducted to determine the personal exposure concentration of airborne lead associated with abatement of lead-based paint (LBP) from a three story building and basement in the northeastern region of the United States. Work

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was performed during the summer of 1995. All workers performing abatement at this location had received training related to lead abatement, as required by the OSHA Lead Construction Standard (OSHA, 1993).

Abatement practices employed were hand scrape, large area removal (e.g. whole pieces of building components that could be cut-out or disassembled) and gross removal of building components (e.g. walls that contained LBP) (HUD, 1995). All abatement procedures employed wet methods as a control to prevent release of airborne dust and debris. This usually involved light misting the surface or material before beginning abatement activities and maintaining it in a "lightly moist or wet" condition. Light wet misting of air in work area locations, in addition to wet methods, was also performed to reduce airborne dust. LBP was associated with building interior surfaces (i.e. walls, ceiling, baseboards, trim, windows, and doors) and was reported to have a concentration range from <0.5% to 28.3% as determined by paint chip (bulk) sampling and analysis with flame atomic absorption spectroscopy. Walls and ceilings were constructed from either plaster or dry wall materials with all other building components consisting of wood and metal. Abatement was part of the demolition of this building and was performed to eliminate all LBP before other activities were conducted.

All LBP, paint chips, lead-contaminated components, lead containing building materials, and lead-containing debris, dust and residue were placed in 6 mill bags (lead waste disposal bags) or applicability wrapped inside the work area before being deposited in a dumpster that was located outside the building. Critical barriers that consisted of at least one layer of polyethylene plastic were established for all openings to the outside environment (e.g. doors) and as applicable for internal openings (e.g. doors into stairwells) to prevent migration of contaminants. All critical barriers were sealed using duct tape and spray glue. The entire building was considered one abatement unit, with no other contractor occupying the area. Work was started on the third floor and proceeded to the basement with each floor being sealed from the others with polyethylene plastic to prevent any migration of contaminants to other floors. To prevent release of lead dust and debris, a three stage decontamination chamber was established for each floor and was used for personnel and materials along with negative air pressure inside the regulated area (work area) (HUD, 1995). After a floor was completed, the entry/exit location was sealed with at least one layer of polyethylene plastic to prevent any recontamination into the area. This decontamination chamber was then moved to the next floor. Polyethylene plastic used was 6 mill in thickness and was also used in the construction of the decontamination chamber (HUD, 1995). Negative pressure was established using HEPA filtration negative air machines (NAM) with a rate of approximately four exchanges per hour. NAM exhaust were either released to the outside environment or to one of the other floors. Cleaning was performed using HEPA vacuum devices. No wet cleaning was conducted. Pre-cleaning was not performed before establishment of critical barriers, implementation of engineering controls or abatement.

All sample collection was performed by an on-site independent monitor using personal sample collection techniques (Lange et al. 1996). Air sample pumps employed were for low flow measurements and were attached to the worker by their belt. Air draw from the cassette to the pump was through polyethylene tubing. All samples were collected closed face on a 37 mm mixed cellulose ester filter (0.8 um nominal pore size) and were analyzed by flame atomic absorption spectroscopy for lead following the 7105 method (National Institute for Occupational Safety and Health, 1984). The sample detection limit for lead was established at 1.0 ug/m3. These samples were collected from the breathing zone (10 cm from the nose or mouth) of abatement workers at a nominal flow rate of 2 lpm (OSHA, 1993; Lange et al. 1996). Flow rate was determined using a calibrated rotameter (Lange et al. 1996). Results were reported, for airborne lead, as a time-weighted average (TWA) in ug/m3 (Leidel et al. 1977; OSHA, 1993).

Summary exposure data for all samples collected are reported by statistics of location (arithmetic - AM and geometric means - GM) and variability (statistics of dispersion - standard deviation - SD, geometric standard deviation - GSD and range) (Leidel et al. 1977; Gilbert, 1987; Daniel, 1991; Lange et al. 1996). GSD was determined by two different calculation methods, one employed common logarithms (base 10- log10) and the other natural logarithms (in) as described by Leidel et al. (1977). Data that were reported below the limit of detection (censored) were included in calculations for outliers, variability and statistics of location at the limit of detection value (1.0 ug/m3) (Gilbert, 1987; Perkins et al. 1990; Lange et al. 1996). Evaluation of outliers was conducted using a procedure described by Grubbs (1950). Outliers were evaluated using data that were non-transformed and transformed (Lange et al. 1996). Transformation of data was performed using both common logarithms and natural logarithms (Leidel et al. 1977). Determination of sample data distribution was conducted using the Shapiro-Wilk test (Shapiro and Wilk, 1965). Confidence intervals (CI), at 95%, for the AM (as determined by non-transformed measurements) using these data with and without the outlier value were determined by a technique for non-normal populations (Daniel, 1991).

All sample data reported were collected during time periods which work (abatement of LBP) and/or cleaning were performed; thus, none of these data represent other non-abatement activities (e.g. setup). There were approximately three workers a day at the site, with one of these workers selected at random for personal sampling by the on-site monitoring technician. All work was conducted during a single shift. This project had abatement conducted for a duration of 15 (working) days. None of the workers, laboratory personnel or on-site monitoring technician was informed that these data were to be used as part of a study on airborne lead levels. Final clearance was performed by wipe samples from the floor with a maximum passing load value of 200 ug/ft2 (HUD, 1995).

## RESULTS AND DISCUSSION

Summary data for personal air sample results are shown in table 1. These data suggest that all exposures were below both the OSHA action limit and PEL for airborne lead. Based on these data alone, workers performing abatement of LBP as part of demolition activities would not be required by the OSHA Lead Construction regulation to use PPE or complete either medical surveillance or biological monitoring (OSHA, 1993). These data can be considered an initial negative determination for airborne lead levels as related to the work practices employed (OSHA, 1993). However, caution must be exhibited since each project may have some differences in activities and site conditions, involve other hazardous substances (e.g. asbestos) of concern and may not be an occupational homogeneous population (Gardiner, 1995). All factors of interest must be considered when establishing medical surveillance, respirator and other PPE requirements, which may be beyond concerns for airborne lead concentrations alone (Lange et al. 1996; Lange, 1993; 1992). Appropriate training is required for any worker performing abatement of LBP, regardless of exposure level (OSHA, 1993).

Calculation of GSD using both log10 and in methods provided identical values. These data support the use of either method for determining the GSD as previously reported (Leidel et al. 1977).

The arithmetic mean is larger than the geometric mean for this sample population. This difference suggests that these data are non-normally distributed (Lange et al. 1996). Non-normally of this distribution, for all measurements (n=l5), is further supported by the Shapiro-Wilk test at both 5% and 1% for non-transformed data. When these data are transformed using ln a normal distributed was determined at both a 5% and 1% level. However, evaluation of these data using log10 resulted in a transformation that exhibits a normal distribution at 5% but was not normally distributed at 1%.

A GSD of 2.1 suggest a relative high variation for all data and is also suggestive of a non-normal distribution (Leidel et al. 1977). This variation will not allow an assumption of normality for a distribution without resulting in appreciable errors (Perkins et al. 1990). Previous studies (Leidel et al. 1977; Lange et al. 1996) have suggested that occupational airborne contaminant concentrations, collected as personal and area measurements, are non-normally distributed and have a distribution that is better represented in a logrithmetic form. The non-normality at 1% for data transformed with log 10 is likely due to the small sample size.

The highest exposure concentration value observed in this study (15.5 ug/m3) is an outlier at the 5% level, but not at 2.5% when evaluating these data as non-transformed. This high value was not an outlier when evaluated after transformation with in and log10. No other concentration value, including those

Table 1. Summary data for airborne lead concentrations+

| Number of Samples | Arithmetic Mean | Geometric Mean | Standard Deviation | Geometric Standard Deviation | Range |
|---|---|---|---|---|---|
| 15 | 2.9 | 1.9 | 3.7 | 2.1 | <1.0 -15.5 |
| 14* | 2.0 | 1.6 | 1.5 | 1.6 | <1.0 - 5.8 |

+all values are reported, for airborne lead, as ug/m3 of air.
*summary data were determined without inclusion of the single outlier

that were censored as a result of being below the detection limit (<1.0 ug/m3), was an outlier when evaluating these data as either non-transformed or transformed using log 10 or ln. Seven measurements were below the described limit of detection. It is likely that these values below the detection limit, although for calculation methods were all censored, have some influence on summary descriptive data. However, since the highest value reported is an outlier at 5%. for non-transformed calculations, these non-detect data values, when censored, probably have some importance when evaluating these data in relation to the action limit for lead.

The actual influence of the highest concentration appears to be minimal for the statistics of location, although this single elevated concentration appears to have a strong influence on the statistics of dispersion. The next highest value was 5.8 ug/m3. This influence on the statistics of dispersion by the highest exposure concentration is supported by the arithmetic CI for these data of +/- 4.1. The upper concentration, based on this CI datum, is well below the action limit, suggesting that even with this outlier value exposure to workers performing these activities will be well within safe limits, as described by OSHA. If the highest exposure concentration is excluded from these data as an outlier, a more normalized distribution begins to appear as indicated by a GSD of 1.6 (Table 1). Leidel et al. (1977) reported that a GSD of 1.4 “roughly approximate normal distribution shapes,” The arithmetic CI is also dramatically reduced to +/- 0.8 when excluding the outlier. Comparison of data with and without the single outlier demonstrates the dramatic difference that exists in summary statistics when outliers are removed (Lange et al. 1996). The small sample size and large number of censored exposure concentrations in this study must also be considered when evaluating these data (Perkins et al. 1990; Lange et al. 1996).

The variability seen in measurements and comparison of GM and AM suggest that there is a considerable difference for summary endpoints. Previous studies have suggested that AM is a better summary value for occupational exposure and epidemiological studies, especially for evaluation of chronic diseases (Seixas et al. 1988; Lange et al. 1996). However, it is also important to provide summary descriptors that best reflect the non-normally of the distribution such as GM and GSD. The median value is also an important summary endpoint, especially for data sets that are non-normally distributed and do not have an excessively large number of values below detection limits. In addition, it has been suggested that the range of measurements and presence of outliers also be provided (Lange et al. 1996). Inclusion of these various types of summary data in reports provide the greatest degree of information for evaluating exposure from different work practices, comparison of data and future epidemiological studies, as well as measures of exposure variability (Lange et al. 1996).

The large variability (GSD) reported for all measurements in this study suggest that one or even a few personal exposure measurements may not provide sufficient information for predicting subsequent exposures (Gardiner, 1995; Leidel et al. 1977). Observed variability maybe due, in part, to the population not being homogeneous (Gardiner, 1995); although, Leidel et al. (1977) suggested that industrial exposure measurements rarely have a GSD that is less than 1.2. HUD (1995) reported that GSD for various categories of lead abatement had a range of 2.2 to 7.6. Thus, this study reports a lower variation without categorization of population groups than that found by HUD for single classified activities. An unpublished study (Lange, 1996 - unpublished) of personal airborne concentrations for a lead demolition project, with similar activities as described in this investigation, found a GSD of 5.2, which is dramatically different from these results. However, in this unpublished study the contractor also conducted prohibited practices (e.g. dry sanding), LBP was at a higher concentration (range <0.5 to 54.2 % lead) and daily cleanup was not always effectively performed. A likely explanation for the less variability in this investigation is due to a lower concentration of LBP, good work practices and implementation of engineering controls. The confidence coefficient (probability) of exceeding the actual daily employee exposure (for TWA of the action level) based on these data measurements using graphic methods (Leidel et al. 1977) is less than 5%. Thus, even with the variability reflected in the GSD, an average concentration of 2.9 ug/m3 in comparison to the action level creates a scenario that it was highly unlikely during this project that any worker had exposure levels to airborne lead (TWA) exceeding 30 ug/m3.

Personal air monitoring (exposure) data collected as part of this study suggest that work practices and engineering controls employed for abatement of LBP as part of this demolition project were effective in maintaining a low exposure concentration. Certainly not all LBP projects are identical, with other practices applicable, while these practices themselves are not necessarily suited to all projects. Therefore, professional judgment must be used in selecting the appropriate work practices for any project.

Final clearance wipe samples were collected from each floor All wipe samples were below the established criterion for passing and no re-cleaning or re-sampling were required.

This study provides data on exposure concentrations that may be anticipated during LBP abatement of buildings materials (LCS). These low concentrations of airborne lead, a smaller variability as compared to previous reports and the highest exposure value observed not exceeding the action level support applicability of engineering controls and work practices employed during this abatement. Summary data for occupational exposure concentrations should be provided using various descriptors (Lange et al. 1996). Data of this nature will allow development of a historical record that can be used in the future for establishing requirements of PPE and medical surveillance when instituting a similar type of abatement for lead. Studies reporting exposure from different LBP work activities are warranted.

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