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Airborne Exposure Concentrations During Asbestos Abatement of Ceiling and Wall Plaster

J. H. Lange,[1] K. W. Thomulka[2]

[1] Envirosafe Training and Consultants, Inc., Post Office Box 114022, Pittsburgh, PA 15239, USA
[2] University of the Sciences in Philadelphia, 600 South 43rd Street, Philadelphia, PA 19104, USA

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Removal/abatement of asbestos-containing materials (ACM) in the United States and other countries throughout the world has become a common environmental industry (Lange et al. 1996). Criteria and standards for abatement in the US are mostly a result of regulations promulgated by various governmental agencies (Health Effects Institute – Asbestos Research 1991, Lange et al. 1996a, Lange and Thomulka 2000). Few studies have been published on exposure to workers and effectiveness of engineering controls/work practices (methods) for this industry (Lange and Thomulka 2000, 2000a, Lange 2001). A lack of information in the literature on controlling exposure has hampered refinement of regulations (Lange and Thomulka 2000). Current regulatory strategies appear to encourage employment of anecdotal information and do not allow flexibility for testing, evaluation of controls and implementation of effective methods, especially as applied to specific scenarios (Lange, 2001). These requirements tend to legislate scientific criteria, particularly as related to controls, and can be identified as legislating science or regulating of scientific conditions (Lange 2001, Wong 2001). A few published studies provide information on effectiveness of methods under varying scenarios, including protection of workers and requirements of personal protective equipment (PPE), including respirators (Lange and Thomulka 2000, 2000a). Exposure data from abatement projects will be important for estimating future disease rates and will provide information on design of controls for other types of hazardous substances (Esmen and Corn 1998, Lange 2001).

This study collected air samples during removal of plaster that was ACM from a rotunda of a school building. Data presented provide an estimate of exposure to workers from this building material when using negative pressure and wet methods as engineering controls/work practices.

MATERIALS AND METHODS

Air samples were collected during abatement of plaster from ceiling and walls of a school. Personal, area, negative air machine (NAM,) and excursion limit (EL) samples were collected (Lange and Thomulka 2000). Personal and EL samples were collected from the breathing zone of

Correspondence to: J. H. Lange

workers (occupational sample) (US Occupational Safety and Health Administration - OSHA 1996). Area samples were collected from within 10 to 20 feet of the location where abatement was being undertaken. Samples at NAMs were collected at the intake (in front of filter, inside work area) and from the NAM nearest abatement work.

Plaster, by polarized light microscopy, was reported to be 10-15% asbestos (chrysotile). Floor area, in square feet, of the work or abatement location was approximately 5,000. Plaster was on walls as a troweled on material and on ceiling attached to wire mesh. Some over-spray of ACM existed on the ceiling deck and beams. Removal was conducted by breaking the plaster, scraping with a metal scraper, wire brushing, and cutting mesh pieces. Wet methods were employed by using a garden hose to moisten the ACM. Water was liberally applied to plaster on walls and the ground. All materials to be removed were well saturated with water. NAMs with HEPA filters were employed to achieve at least 4 air exchanges per hour. Plaster was placed in two plastic disposal bags (each 6 mil thick) after removal (OSHA 1996). Some bagging did not occur until approximately 24 hours after removal. Operations involved removal of plaster then bagging of materials on the ground. Wire mesh was cut from the ceiling using tin snips and this material, which has pieces of plaster attached to mesh, was wrapped in polyethylene sheeting (plastic). Plaster was approximately one inch thick and was painted.

Asbestos abatement activities in general were conducted following requirements of the OSHA (OSHA 1996). Workers performing abatement were trained as required by OSHA and Pennsylvania Department of Labor and Industry (PADLI) (OSHA 1996, PADLI 1991). This project was located in Pennsylvania and was conducted during summer, 2001. There were three to eight workers on-site per day and this phase of the project had an approximate duration of 15 days.

Air samples were collected using personal sample pumps with 25 mm diameter electrically conductive extension cowl cassettes containing mixed cellulose ester membrane filters (Lange and Thomulka 2000). All samples were open face and in a downward position (OSHA 1996). Flow rate was 2 lpm (nominal) (Lange and Thomulka 2000). Filter analysis was performed using phase contract microscopy (NIOSH 7400 method) (OSHA 1996). Samples with a reported value below the limit of detection (<) by the laboratory were included in calculations at one-half this value (Oehlert et al. 1995, Lange 2001).

Air sample data were summarized by measures of central tendency (Lange and Thomulka, 2000). Summary air sample data were also reported as a time-weighted average (TWA) (8-hours average) and task-length average (TLA) (Lange 2001). Confidence interval (CI) for arithmetic mean (AM) was determined using a statistical procedure for non-normal populations (Daniel 1991). Personal, area and NAM samples were compared to each other using the Binomial Sign Test (Sheskin 1997). Outliers (non-transformed) were identified using the Grubbs Test (Taylor 1990). Distribution was evaluated using the Shapiro-Wilk Test. Calculation of within-worker exposure for personal samples was performed as previously described (Lange and Thomulka 2000). All statistical calculations were performed at 95%.

Risk of overexposure, using non-transformed data, was determined using a graphic method (Leidel et al. 1977). Probability of exceeding the OSHA permissible exposure limit (PEL) (0.1 f/cc-TWA) was determined for at least 5% of the mean average exposure concentration.

RESULTS AND DISCUSSION

Summary data for air samples are shown in tables 1 and 2. No sample value exceeded the PEL or EL (1.0 f/cc-30 minutes a day). Personal and area samples were non-normally distributed, while NAM samples exhibited a normal distribution. Geometric standard deviations (GSD) support finding of non-normally distributed air-sampling data. Previous studies (Nayebzadeh et al. 1999, Lange and Thomulka 2000) have suggested that environmental measurements, including asbestos air samples, are best represented in a logarithmic form. The highest value for personal samples was an outlier when non-transformed, but was not an outlier when transformed (ln) (Lange 2001a). There were no outliers (transformed and non-transformed) for either area or NAM samples. Area samples had the highest summary concentration followed by personal then NAM. TWA exposure is smaller than non-TWA (TLA). This difference is likely a result of the larger values influencing arithmetic summation.

Table 1. Summary statistics for all air samples, in f/cc+.

Type of Sample	Number of Samples	AM	GM	SD	GSD	Range
Personal	12	0.008 (0.004)	0.007	0.007	1.8	<0.006-0.031
EL	3	0.045	0.045	ND	ND	0.045
NAM	10	0.009 (0.001)	0.008	0.004	1.5	0.008-0.013
Area	10	0.019 (0.012)	0.013	0.019	2.4	0.0009-0.069

+Area, personal and NAM samples were each collected for time period of 1 to 3 hours with usually more than one sample collected per day; () represents CI at 95%. GM=geometric mean, SD=standard deviation

When data were statistically compared using values at the limit of detection, no comparison was statistically different at 5% (personal v.

Table 2. TLA and TWA (f/cc) exposures for personal, area and NAM measurements.

	TWA	TLA	Time (hours)+
Day A (Pers)	0.004	0.008	7.1
Day B (Pers)	0.009	0.013	5.4
Day C (Pers)	0.004	0.008	4.0
Day D (Pers)	0.007	0.007	8.0
Day A (Area)	0.012	0.013	7.6
Day B (Area)	0.007	0.010	5.6
Day C (Area)	0.006	0.013	4.0
Day A (NAM)	0.006	0.009	7.5
Day B (NAM)	0.007	0.010	5.4
Day C (NAM)	0.004	0.008	4.0

Pers – personal samples, area – area samples, NAM – samples at negative air machine, TLA was calculated using actual time of collection, TWA was calculated using 8 hours. + Total time for sampling on that day. AM of TWA for personal, area and NAM are 0.006, 0.008, and 0.005, respectively.

NAM p=0.27, personal v. area p=0.07, area v. NAM p=>0.1). When values at the detection limit were employed at one-half the concentration all comparisons against personal samples were statistically different (personal v. NAM p=<0.05,>0.01 [p=0.047], personal v. area p=0.02, area v. NAM p=>0.1). These comparisons demonstrate importance of how exposure values are included in summary statistics. All EL values were reported as <0.045 f/cc.

Likelihood of overexposure is less than 5% using TWA data. This is supported by upper CIs for all summary non-TWA and TWA values and that no single value exceed the PEL. None of the EL values exceeded its exposure limit standard and all three values were below the reported detection limit. Thus, likelihood of exposure to workers above the PEL and EL during this work is low.

Table 3 represents both within measurements and summary description for TWA exposure. These data suggest there is similarity of exposure to worker A from day-to-day. Variability, as represented by GSD, (e.g. wet methods, work practices and engineering controls) is lower than most previous exposure studies (Lange and Thomulka 2000). This low variability is attributed to effective control methods.

Final clearance samples were collected as required by US Environmental Protection Agency using transmission electron microscopy and met the clearance criteria.

Table 3. Summary data for within measurements using TWA data.

	Number of Samples	AM	GM	SD	GSD	Range
Worker A	4	0.006(0.002)	0.006	0.002	1.5	0.004-0.009

() represents CI.

Previous investigations (Lange 2001) have examined engineering controls (e.g. NAM) and work practices (e.g. wet methods), collectively referred to as methods, and have suggested these methods are useful in reducing exposure concentrations when ACM is in a friable state. Based on this investigation, it is suggested that when these practices are employed for friable ACM the likelihood of exposure to workers is low. This supports employment of methods for friable ACM abatement (Lange and Thomulka 2000, 2001, Lange 2001). Since risk of disease (occupational), public health protection and the environment are the primary purposes of regulations, requirements for preventative methods should be based on exposure levels and not observational or visual methods and categorization of the material (ACM) (Lange 2001).

Other studies (Lange 2001, 2001a, Lange and Thomulka 2001) have shown that abatement of non-friable materials, such as floor tile and window caulking, do not result in exposure levels that would be identified as being of any health importance regardless of what methods are employed. This supports the suggestion that regulatory criteria should be based on levels of hazard from an activity and not on its categorical definition. It appears that criteria for abatement of asbestos are based on regulatory definitions (legislating of science) and not the it's potential of health effects (Lange 2001, Lange and Thomulka 2001, Wong 2001).

This is one of the few studies that report higher exposure levels from area samples than personal samples (Lange et al. 1996). Previous investigations have attempted to evaluate a relationship between area and personal samples with little success (Esmen and Hall 2000, Lange et al. 1996). Most consider that personal samples will always be higher than area samples (Lange et al. 1996), although under some scenarios this may not be true. Based on the data collected in this investigation, when effective methods are employed and levels of exposure are below established standards, either area or personal samples are suggested to provide a valuable measurement of exposure and/or anticipated exposure. This study provides a good example for employment of area and personal measurements as estimators of exposure to workers.

Under some circumstances, although such events have not been clearly identified, area sampling may be used in lieu of personal measurements.

If area samples have a higher or similar statistical concentration of exposure when compared to personal measurements (breathing zone), then area samples may be useful as a measure of personal exposure. It is also likely that area measurement as a representative of occupational exposure is applicable when methods historically maintain exposure levels below the PEL. Thus, it is suggested that area samples be included as part of a monitoring program in combination with established methods that have resulted in exposure levels below the PEL as determined by personal measurements (Lange et al. 1996). This does not eliminate personal sampling requirements, but allows use of historical occupational exposures for supplementing and supporting area samples. Thus, area samples may be incorporated into projects through several scenarios. However, OSHA regulations for all substances, except cotton dust, describe samples as being collected from the breathing zone (personal) as the method of estimating worker (occupational) exposure (OSHA 1996).

Exposure data presented here provides historical information related to methods employed. It has been suggested (Lange 2001) that method(s) and not percentage of asbestos in a material be categorized by historical and objective exposure data. Low exposure levels during abatement of ACM that is traditionally considered "highly" friable support this conclusion (Lange and Thomulka 2000a). Additional research is needed for evaluation of any relationship between area and personal measurements and employment of area samples alone as a measure of occupational exposure.

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