Journal of Environmental Management 91 (2010) 1429–1436

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

# Emissions concerns during renovation in the healthcare setting: Asbestos abatement of floor tile and mastic in medical facilities

William P. Racine*

*Environmental Support Network, Inc., 5376 Fulton Drive, NW, Canton, OH 44718, USA*

ARTICLE INFO

*Article history:*
Received 27 July 2009
Received in revised form
5 January 2010
Accepted 7 February 2010
Available online 25 March 2010

*Keywords:*
Asbestos
Asbestos abatement
Environmental remediation
Asbestos-containing materials
Renovation
Healthcare facilities renovation
Floor tile
Floor tile removal
Mastic
Mastic removal

ABSTRACT

Healthcare facilities undergoing renovation have specific concerns that are exacerbated when the restoration requires asbestos abatement of aged floor tile and mastic. The current state of the art for removal of these materials involves manual removal of floor tile and chemical stripping of mastic. Utilization of these stripping chemicals is a concern for facilities whose perception is based on a safe, caring, and healthy environment. In this study, wet grinding is evaluated as an alternative to chemical stripping of asbestos-containing floor tile mastic. This study endeavors to answer the question; what is the difference between these two methodologies in terms of their operational efficacy and suitability in the healthcare setting. Wet grinding and chemical stripping are evaluated in a side-by-side comparison using a mixed methods approach. The data shows that the methodologies are statistically similar in terms of their cost and emissions data. The data indicates that the benefits associated with the wet grinding method offer advantages that are not present using the chemical stripping method. This study also demonstrates that wet grinding is a viable alternative to chemical stripping especially in healthcare facilities.



## 1. Introduction

Asbestos abatement is a trade that requires specific skills. It necessitates technical capabilities for control of dust, particulates, fibers, and vapor emissions using technical acumen, elaborate engineering control measures, and diligent work practices. Nowhere is the expertise of this trade more challenged than in the healthcare setting.

A large chain of medical treatment facilities required the removal of asbestos-containing floor tile and floor tile adhesive, called mastic, from two of its operating facilities in Ohio. The removal of approximately 5000 square feet of these materials in each facility provided a rare opportunity for a practical comparison of two different techniques of asbestos abatement. The consistency of the work area sizes and the uniformity of asbestos-containing materials allowed for the evaluation of these techniques of abatement in a side-by-side comparison.

The assessment of these two techniques evolved from a particular set of circumstances. In the first facility, the traditional asbestos abatement methodology was used. This included the chemical stripping of mastic using the so-called, “no-odor” mastic removal technique. It should be noted that a residual odor is present after completion of the work, notwithstanding the nomenclature or contention of the manufacturer. The utilization of this methodology caused many employees and patients to display various symptoms including migraine headaches, sore throats, dry sinus passages, and a variety of allergic-type responses. This condition was untenable to the owner such that an alternative methodology was researched. The wet grinding methodology was considered a viable alternative because no chemical stripping agent is necessary for the removal of the mastic, and hence, absolutely no odor. This abatement technique was implemented at the second facility.

These two techniques were evaluated relative to their costs, fiber and odor emission curtailment, suitability to various stakeholders, and effectiveness of removal. The study question is: what is the difference between these two methodologies in terms of their operational efficacy and suitability in the healthcare setting. This study used a mixed methods approach. The objective of this study was to substantiate the validity of an alternative abatement

* Tel.: +1 330 494 0905; fax: +1 330 494 1650.
*E-mail address:* williamracine@ymail.com

0301-4797/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jenvman.2010.02.027

technology in buildings such as operating medical centers where asbestos, dust, and odor emissions are of paramount concern during renovation.

## 2. Background

Asbestos became a regulated material in 1972 in the United States based upon data, at that time, which indicated its hazard potential. When asbestos-containing materials are disturbed, the mineral cleaves along brittle, fibrous striations and the fibers become airborne. These asbestos fibers were determined to be inhalation hazards because the fiber lodged in the alveoli and caused scarring called asbestosis (Murphy et al., 1976). Linkages to other diseases were also documented including lung cancer and mesothelioma (Newhouse et al., 1972). The association between these diseases was supported by independent researchers in other countries at that time (Newhouse et al., 1972; Bohling and Hain, 1973; Elmes and Simpson, 1971; Stumphius, 1971; Rubion et al., 1972; Selikoff, 1976). The Environmental Protection Agency (EPA) and other agencies developed regulations in response to this and other clinical data.

Asbestos abatement of floor tile and mastic in non-school buildings is regulated by the EPA as codified in 40 CFR Part 61 of the National Emissions Standards for Hazardous Air Pollutants (NESHAP) (EPA, 1973). NESHAP requires emission control techniques, intact removal of floor tile using non-mechanical wet methods, and applying nonabrasive techniques to remove the mastic from the underlying substrate. Abrasive techniques are considered regulated because a non-friable asbestos-containing material is subjected to grinding, and thus made friable. EPA uses the term friable to mean, "any material containing more than one percent asbestos that, when dry, can be crumbled, pulverized, or reduced to powder by hand pressure" (EPA, 1973, Sec. 61.141). These techniques must be implemented using elaborate containment techniques. This suggests that certain mastic removal actions allow fibers to be more readily released and therefore propagate a greater inhalation hazard.

Other governmental agencies also have regulations for removal of asbestos-containing floor tile and mastic including the Occupational Safety and Health Administration (OSHA). Grinding of asbestos-containing flooring material, including mastics, is prohibited under OSHA 29 CFR 1910.1001(k)(7)(i) unless full containment is utilized. Breaking up floor tile or sanding, grinding, or abrading the mastic has long been anathema to these regulatory agencies.

Removal of floor tile and floor tile mastic has implications to owners of healthcare facilities. Dust, particulate matter, and odors caused by asbestos abatement challenge the control mechanisms necessary to keep the facility dust and odor-free, safe, and unimpaired by the renovation activity. Moreover, the perception of safeguarding the health of patients, employees, and visitors is of the utmost concern to owners in the healthcare setting. These buildings routinely house sensitive populations such as immuno-compromised patients, children, and those undergoing treatment and surgery.

Because of the above, this study endeavored to compare two different methodologies for floor tile and mastic removal in the healthcare setting. These methodologies are compared relative to the cost of their regulatory burden, fiber emission, perceived odor emission, and general stakeholder satisfaction. The following data is intended to show an impartial comparison of two asbestos abatement operations relative to these variables.

## 3. Literature review

OSHA documented that an increased exposure to asbestos fibers positively correlated to an increase of some cancers (OSHA, 1986a) and published its estimate of cancer mortalities relative to asbestos exposure (OSHA, 1986b). OSHA's research assumed that all fiber sizes and exposures present the same clinical danger of an increased disease incidence. However, other researchers differed in this presumption. These differences are based on data presented after OSHA's promulgation of legislation.

Davis (1986) presented evidence that longer fibers, those not usually associated with floor tile and mastic removal, present a greater risk than do smaller fibers (i.e.: $<5$ μm). This is consistent with studies conducted by Berry (1999), Berman and Crump (2004), and Bernstein and Hoskins (2006) who documented this in peer-reviewed publications and technical documents to the EPA. Others contend that any exposure of asbestos-containing materials is equally important in the discussion of the health effects of asbestos.

The research continued specifically with regard to exposure scenarios during floor tile and mastic abatement. Kominsky et al. (1995) indicated that low speed, 175–1000 revolutions per minute (rpm), buffing of floor tile produced emissions 11 times greater than the baseline or background concentration. However, even on floor tiles in poor condition, the process did not exceed the OSHA Permissible Exposure Limit (PEL) (Kominsky et al., 1995). Ferris (n.d.) conducted air-monitoring studies during actual floor tile and mastic removal operations at 40 locations across the United States. She determined that none of the traditional removal activities indicated an exceedance over the OSHA PEL of 0.1 fibers per cubic centimeter (f/cc) of air. Moreover, it appears that there exists much data that stipulates that the emissions produced during mechanical removal actions are below the PEL (Kominsky et al., 1995; Lange and Thomulka, 2000; Lange, 2001).

Recently, the debate focused on whether chrysotile asbestos, which is usually found in floor tile, has the same hazard potential as other forms of asbestos. Hodgson and Darnton (2000) suggest that it may be relevant that historic animal experiments, many of which were the basis for decision making of chrysotile asbestos exposure hazards, were made using excessive concentrations. They suggest that uncertainty exists because of the relationship between the exposure and the outcome. Berry (1999) and Levin et al. (2000) conducted research in humans that indicates chrysotile asbestos fibers, which clear the respiratory tract in months, have less effect than amphibolic asbestos, which clears in years.

The underlying supposition inherent in the historic literature is that linear effect exists between exposure and disease. Hodgson and Darnton present evidence suggesting that this may not be the case.

> "Uncertainty about the slopes of exposure–response lines has an increasing impact with increasing distance from the observed range. Also the strength of qualitative arguments such as those advanced in the HSE review (Meldrum, 1996), in favor of a threshold for the lung cancer effect increase as exposure falls" (Hodgson and Darnton, 2000, p. 584).

This implies that presenting risk estimates based upon different exposure scenarios might not be adequate to address different kinds of uncertainty relative to fiber type and disease outcome.

Recent studies suggest that the duration of exposure is important to disease outcome. Short duration exposures to chrysotile asbestos fibers may not be as carcinogenic as previously thought. Bernstein and Hoskins (2006) concluded that low exposures to pure chrysotile asbestos do not present a detectable risk to health and that the risk of an adverse outcome may even be low if high exposures were experienced over a short duration. This is consistent with Ferris's (n.d.) study where, at the maximum reading in her study (0.03 f/cc), the risk was less than 1 lifetime cancer death per 1000 people and this activity should not be considered a significant threat (Ferris, n.d.). OSHA's definition of a significant threat is a risk of death in excess of 1 per 1000 workers in a 45-year

lifespan (OSHA, 1994). Further, a 39-year longitudinal study by Sichletidis et al. (2009) reported that exposure to chrysotile asbestos was not associated with a statistically significant increase in lung cancer or mesothelioma. The suggestion is that short duration exposures to chrysotile asbestos fibers should not be regulated similar to other friable asbestos abatement actions.

The debate over the hazard associated with certain asbestos abatement practices such as floor tile and mastic removal continues. While Camplin (2003) suggests that asbestos has been pushed to the back burner in recent years by other emerging issues such as mold, terrorism, and emergency preparedness, the need to safely manage these practices continues to be important to both EPA and OSHA. Owners of buildings where floor tile and mastic removal is regulated by these agencies face the quandary of how best to implement abatement operations so as to minimize the risk to stakeholders, assure regulatory compliance, and achieve an efficient and cost-effective project. This study set out to compare two different asbestos abatement techniques to aid owners and contractors in achieving these objectives.

## 4. Description of the abatement methods

### 4.1. Alternative A: the chemical stripping methodology

The traditional methodology for removal of asbestos-containing floor tile and floor tile mastic has been used for decades. In this operation, the asbestos abatement contractor typically removes the movable furniture and materials from a room or group of rooms. Then, polyethylene plastic sheeting is taped to the walls from the floor to a height of approximately 48″. The purpose of this is to protect the wall covering from dirt, dust, and splashing. The contractor then covers any remaining appurtenances and seals all means of air ingress and egress into the area thus creating a containment zone. Because of the potential for asbestos emission, air filtration devices are positioned in or near the area so that any emission within the abatement area flows across high-efficiency particulate air (HEPA) filters before being discharged into the environment thus trapping any errant fibers.

Once the containment zone is erected, the contractor assures that the work environment is under negative pressure. Then, the contractor mists the floor with amended water to decrease the dust load and uses spud bars to lift the floor tile off the floor. The floor tile is then placed into disposal bags and loaded into a dumpster for delivery to an appropriately licensed landfill. Following this, the contractor liberally spreads a chemical mastic removal liquid onto the floor, waits for a period of time, and uses a low-speed buffer (175–1000 rpm) with a soft stripping pad to agitate the mastic remover over the floor. Peat moss, sawdust, or other absorbent is then applied to the surface, mixed together to form a semi-solid, and manually scooped into disposal bags. The floor is then wet-mopped and allowed to air dry.

### 4.2. Alternative B: the wet grinding methodology

The wet grinding methodology shares similar preparatory phases with the chemical stripping method. Both methods require the erection of a work area separated by plastic barriers to exclude the work area from the rest of the facility. The exception is that walls are covered from floor to ceiling to inhibit fibers from plating-out onto vertical surfaces. The mode of floor tile removal is similar as well. The difference resides in the removal of the floor tile mastic.

At the start of the floor tile mastic removal activity, the floor is liberally covered with water and a small amount of fine sand. A low rpm floor tile buffer is then fitted with a hard steel mesh disc and applied to the sand and water mixture. Some technique is required to adequately clean near edges and oftentimes, doors must be removed to sufficiently clean the jamb area. Those areas not reachable by the buffer such as corners, must be hand scraped using a wire brush or scratch pad. This process also generates a sludge, which is a mixture of the water, sand, and the mastic compound. The sludge is then collected and containerized similar to the chemical stripping methodology. The floor is then wet-mopped twice to remove the sand and grindings and allowed to air dry. The perception is that implementing this methodology costs more, emits more fibers, takes more time, and is generally more difficult.

## 5. The study design

The work sites for this study were two medical centers both located in Northeast Ohio. The specific work areas were similar in size and included exam rooms, offices, and hallways. The work was performed by a licensed asbestos abatement contractor with over 22 years of asbestos abatement experience. The project consultant and air-monitoring professional had over 18 years of asbestos experience. The study included a detailed assessment of costs, airborne fiber emissions, perception of stakeholders, and efficacy of each removal procedure.

The chemical stripping and wet grinding methods for asbestos abatement of floor tile and mastic were evaluated in this study. Several variables were held constant during this study so as not to influence the results. First, the same contractor using the same work crews conducted both projects to account for variation in workflow and project requirements. Second, the job sites were similar in size and usage. Third, the same individual was responsible for the purchasing of raw materials, implementation decisions, and attainment of the project's outcomes. Fourth, the containment barriers were constructed and air filtration devices installed such that a negative pressure differential within the enclosure measured −0.02″ of mercury on the water column. These variables were held constant to dissipate any influence these variables might have had on the implementation, outcome, and evaluation of the work.

### 5.1. The emissions sampling strategy

Samples were taken inside the work areas before asbestos abatement to determine the baseline airborne fiber concentration resident under normal operating considerations. Five baseline samples were collected in each work area at both facilities. Ten "area" samples inside the work zone were collected per day to judge the emission of fibers during the removal operations. Individual "personal" samples were taken on the abatement workers conducting the removal activity. Two field blanks were collected per day in each work area as a control for filter contamination. All samples were collected using 25-millimeter (mm) sampling cassettes with a 0.8-micron (μm) filter pore size. The cassette filters were composed of a mixed cellulose ester (MCE). These sampling cassettes were of a three-piece construction design and had a diffusing filter, cellulose support pad, and a 50-mm conductive extension cowl.

#### 5.1.1. Sample methods

During removal of the floor tile and mastic, five area samples were collected per 4-h time interval, which equaled ten per shift. These samples were collected inside the work area during all aspects of the asbestos abatement operations. All activities were observed, recorded, and emissions generated were captured by the sampling. The sample cassette was connected to a high volume, electric (110 VAC) 1/6-horse power, air sampling pump operating at a flow rate of 10 L of air/min. Samples were positioned

approximately 4 feet off the floor where the open face of the cassette was at a 45° angle toward the floor.

In addition, five personal samples were collected from the workers during each day of the abatement activity. Samples were collected on the individual operating the equipment and those individuals inside the work area in the immediate vicinity of the abatement activity. Personal samples were collected using a battery powered portable air pump in the breathing zone of the worker being tested. The sample flow rate was 2 L/min acquiring air over a 1–4 h work period for each individual sampled. These are considered task length averages (TLA) because of the variability in sample time. All area and personal samples were analyzed using Phase Contrast Microscopy (PCM).

#### 5.1.2. Analytical methods

The MCE filters were prepared and analyzed in accordance with the National Institute for Occupational Safety and Health (NIOSH) Method 7400 (Revision 3, June 5, 1989). The analytical sensitivity (i.e.: Detection Limit) was 0.002 f/cc of air sample. The sensitivity is provided by the laboratory and is consistent with other similar studies (Lorber et al., 2007). All fibers were counted per 100 microscopic fields. This includes any fiber that measured greater than 5 μm in length and had a length-to-width aspect ratio of 3:1.

#### 5.1.3. Statistical methods

Airborne asbestos fiber concentrations are reported as both arithmetic mean and geometric mean. This is because airborne asbestos concentrations, when not log-normally distributed should be reported as a geometric mean yet the arithmetic mean may best represent an average dose and might more appropriately indicate health risks (Lange et al., 1996; Paik et al., 1983). A *z*-test was conducted and correlation performed using logarithmic values for sample data comparison. Common logarithm transformation was used for an assessment of the non-normally distributed data. Air sample data was converted to a base-10 log form to determine the correlation coefficients per Niven et al. (1992). The corresponding standard deviation was determined.

Confidence intervals (CI) were calculated for the sample data using a technique for non-normal populations. A mathematical determination of distribution for the asbestos fiber data was performed using a Shapiro–Wilk test. Airborne asbestos fiber data was tested for normality and non-normality. Paik et al. (1983) suggest that airborne asbestos fiber concentrations are non-normally distributed at one standard deviation. This is consistent with this study where, at one standard deviation, the data is non-normally distributed, but at two and three standard deviations, a more normalized distribution occurs.

Fiber emission concentrations in this study are comparable for similar floor tile and mastic removal studies reported in the peer-reviewed literature (Lange and Thomulka, 2000; Lange, 2001). The arithmetic mean and the geometric mean for the area airborne concentrations for both the floor tile removal operations are below the current OSHA PEL of 0.1 f/cc. Likewise, the arithmetic mean and the geometric mean for the personal airborne concentrations during both the floor tile removal operations are below the current OSHA Excursion Limit of 1.0 f/cc.

#### 5.1.4. Quality assurance

All air samples were marked with a discrete sample number, the date, time, locale, sampler information, and other information deemed pertinent to the identity of the sample. Chain-of-custody procedures were an integral part of documenting the sample control from the point of collection until delivery to the laboratory. The laboratory's internal recordkeeping procedures then documented the custody through to the delivery of results. Specific quality control and quality assurance procedures were followed to ensure precision of the analysis including spike samples, trip blanks, field blanks, lot blanks, and duplicate sample analysis.

### 5.2. The evaluation of abatement costs

Subsequent to the completion of the two asbestos abatement operations, the asbestos contractor voluntarily allowed a records review of abatement cost data. Individual data sources included manifest records, vendor invoices for raw materials and supplies, and wage information to calculate and present the costs for each project. In addition, field observations and measurements of the individual project sites aided in the extrapolation of the meaning of this data relative to the entirety of the project.

### 5.3. The qualitative data evaluation

The qualitative portion of the study included interviews to obtain intricate details about the experience that are difficult to extract using solely numeric measures. This includes a determination of the perspective of the stakeholders about the two different abatement techniques. The data management strategy involved a series of cooperative one-on-one interviews using a set of questions designed to elicit information from the participant. This is essential because interviews capture a multitude of views about an experience in a manifold social perspective (Kvale, 1996).

The purpose of the interview portion of this study is to understand the experience from the participant's perspective to gain a more holistic measure of the event. The participants were the employees, the owner, the new flooring contractor, and a regulatory official involved in or affected by the renovation. A sample size of 15–20 is appropriate for this study given the stakeholder population. The exact number is less crucial to qualitative assessments because sample size is not as ratio-dependent as in quantitative assessments (Creswell, 2007). All participants were encouraged to freely respond to questions about the work and the outcomes in an unencumbered manner. This information was voluntary, the participant was anonymous, and confidentiality was assured.

The approach of this data management strategy was three-phased. First, the interview data was transcribed into written format. The raw interview data was coded using NVivo™ software. This computer software assisted with the sorting, separating, and presenting of the data. Second, the data was deconstructed to judge similarities, differences, recognize trends, and to synthesize meaning. The Riemen (1986) model was used to further examine this raw data by relating experiences across participants, developing significant themes, and understanding textural and structural descriptions. These yield composite descriptions of the experience. Finally, a strategy table assisted in formulating an understanding of the conclusions drawn and was used in a format similar to Miles and Huberman's (1994) model. Validity was a primary consideration and was accomplished by considering the aspects of credibility, dependability, and generalizability as detailed by Trochim (2001).

## 6. Data presentation and discussion

### 6.1. Researcher observation of the methodologies

The two methodologies present different benefits. The chemical stripping methodology has enjoyed a long history and has been the preferred method for most asbestos abatement contractors. This method is also faster than the wet grinding method because of the efficiency of the mastic removal compound. Further, cleaning

corners, edges, and door jambs is easier on the worker and the mastic is removed in a noticeably cleaner manner.

The wet grinding methodology also has advantages. Most important is the lack of odor emission during removal. This is especially important to operating facilities and certainly in healthcare facilities. Further, since the process does not employ chemicals, the management of this regulated material is not present, moving drums of chemicals is unnecessary, and the cost to the abatement contractor is less. This is especially relevant since an increase in raw material costs (i.e.: chemicals, absorbent, disposal bags, etc.) ultimately adds to the disposal costs.

There are disadvantages to the two methodologies. The chemical stripping methodology requires the purchase, acquisition, loading, transportation, and usage of a regulated material, which is the mastic remover. These chemicals are costly and have a noticeable and definitive aroma. Even using the so-called "no-odor" mastic remover, an unpleasant residual odor is noticed for days after the removal operation. Moreover, these fumes are effusive, pervasive, and persistent causing irritation to the respiratory tract, general unease and discomfort, and various physiological symptoms owing to the petroleum distillates (Aliphatic Naphtha Solvents), ethers (2 Diethylene Glycol N-Butyl Ether or Monobutyl Ether), Dodecene, or Nonylphenol Polyethoxylate resident in these compounds. Other materials are also consumed thus increasing the cost of the removal operation including protective gloves and goggles not necessarily worn during the wet grinding method.

The disadvantages of the wet grinding methodology are inherent in the process. A significant concern is present in the regulatory acceptance of a methodology that renders a heretofore non-friable material friable. The process is also slowed because no aggressive chemical reaction hastens the mastic removal. Further, unevenness in the flooring substrate inhibits complete removal resulting in "black spots" anywhere flooring surface variations exist. The fine cleaning process is more time consuming because of the need to hand scrape corners, edges, and under doors. Finally, additional preparation is necessary to erect a full containment versus a typical floor tile containment.

### 6.2. Presentation of the abatement costs

The costs of implementing both methods were discretely studied. The data confirms the increased cost and time demands of using the wet grinding methodology. Fig. 1 displays the costs of each method to the asbestos abatement contractor.

The price differential between the two methodologies suggests that wet grinding costs, in this case, are 4.2% more than chemical stripping. Much of this differential is related to the increased time demand of personnel. This increase in labor dollars is only somewhat dispelled by the savings in disposal and raw materials cost.

Professional fees associated with the project such as project design preparation, air monitoring, and project oversight are not included in the above because they were not a cost of the abatement contractor. In addition, laboratory fees were held constant, were not included in the above, and were the expense of the owner not the asbestos abatement contractor.

### 6.3. Air emissions data

The relative change in airborne fiber concentration was assessed by comparing the ratio of the overall average (arithmetic mean) concentrations per half shift during the removal operations to the overall average (arithmetic mean) concentration in the background samples. The Shapiro–Wilk test using logarithmic values was used to test the null hypothesis and indicates the sample population has a standard normal distribution at 95% confidence. Ratios were compared by converting the natural logarithm value (transformed) and comparing the average by using a standard analysis of variance (ANOVA) technique. Fig. 2 presents the descriptive data for the sample set.

| | Chemical Stripping | | Wet Grinding | |
|---|---|---|---|---|
| **Item/Material** | **Units** | **Cost** | **Units** | **Cost** |
| Mastic Remover | 55 gallons | $825.00 | 0 gallons | $0.00 |
| Labor: Supervisor | 32 hours | $704.00 | 44 hours | $968.00 |
| Labor: Workers | 160 hours | $2,560.00 | 208 hours | $3,328.00 |
| Administrative Time | 1 @ 5 hours | $450.00 | 1 @ 10 hours | $900.00 |
| Absorbent: Peat Moss | 4 bags | $40.00 | 3 bags | $30.00 |
| Plastic Sheeting | 4 rolls | $60.00 | 6 rolls | $90.00 |
| Scrubber Pads | 3 boxes | $135.00 | 0 boxes | $0.00 |
| Doodlebug Pads | 1 box | $41.00 | 0 boxes | $0.00 |
| Tyvek™ Suits | 2 boxes | $160.00 | 3 boxes | $240.00 |
| Zip Walls | 3 | $30.00 | 3 | $30.00 |
| Transportation & Disposal | 242 bags | $1694.00 | 228 bags | $1596.00 |
| Rinsing Agent | 1 case | $75.00 | Water only | $0.00 |
| Disposal Bags | 92 bags | $276.00 | 70 bags | $210.00 |
| Floor Buffer Pads: Soft | 5 pads | $30.00 | 0 pads | $0.00 |
| Floor Grinding Pads: Hard | 0 pads | $0.00 | 15 pads | $255.00 |
| Razor Scrappers/Wire Brushes | 15 | $25 | 30 | $50.00 |
| Duct Tape | 1 case | $51.00 | 2 cases | $102.00 |
| Pop-Up Air Locks/Showers | 2 stage | $50.00 | 3 stage | $80.00 |
| Misc. Safety Supplies/PPE | -- | $250.00 | -- | $200.00 |
| AFD Filters: Pre-Filters | 10 | $20.00 | 10 | $20.00 |
| AFD Filters: HEPA-Filters | 10 | $600.00 | 10 | $600.00 |
| Total Per Method | | $8,076.00 | | $8,699.00 |
| Square Footage Abated | | 4,890 | | 5,060 |
| Avg. Cost Per Square Foot | | $1.65 | | $1.72 |

**Fig. 1.** Cost of each type of asbestos abatement.

Fig. 3 displays the overall average (arithmetic mean) concentrations of fibers released per half shift measured before and during the chemical stripping and the wet grinding asbestos abatement processes. All averages are expressed in fibers per cubic centimeter of air (f/cc). None of the individual samples exceeded OSHA's Permissible Exposure Limit (PEL) of 0.1 f/cc.

The average number of area airborne fiber emissions measured during the chemical stripping operation was approximately four times greater than the average background concentration. The 95% confidence interval for this proportion (0.0032, 0.0041) indicates this elevated fiber emission during the chemical stripping operation. The lower 95% confidence interval is greater than 1, which indicates there is a statistically significant increase ($p = 0.0029$) over the background concentrations. The average area airborne fiber concentration measured during the wet grinding operation was approximately seven times greater than the average background concentration. The 95% confidence interval for this proportion (0.0049, 0.0058) indicates this increase over the background concentration. The lower 95% confidence interval is also greater than 1, which indicates there is a statistically significant increase ($p = 0.0037$) over the background concentration.

Although the mean relative volume of airborne emissions during the wet grinding method was greater than that of the chemical stripping method, the difference between the two methodologies was not statistically significant ($p = 0.1226$). Total maximum emissions over the duration of each project were 0.006 f/cc for chemical stripping and 0.009 f/cc for wet grinding.

| Type of Abatement | Sample Type | *N* | Mean | GM | Range | Sample Distribution |
|---|---|---|---|---|---|---|
| **Chemical Stripping** | Area | 80 | .0037 | .0031 | .002-.006 | 1SD-91%<br>2SD-95%<br>3SD-98% |
| **Wet Grinding** | Area | 110 | .0052 | .0046 | .002-.009 | 1SD-86%<br>2SD-95%<br>3SD-97% |
| **Chemical Stripping** | Personal | 20 | .0087 | .0072 | .004-.015 | 1SD-89%<br>2SD-96%<br>3SD-100% |
| **Wet Grinding** | Personal | 28 | .0124 | .0099 | .007-.024 | 1SD-86%<br>2SD-95%<br>3SD-98% |

**Fig. 2.** Descriptive data results of fiber counts by abatement activity.

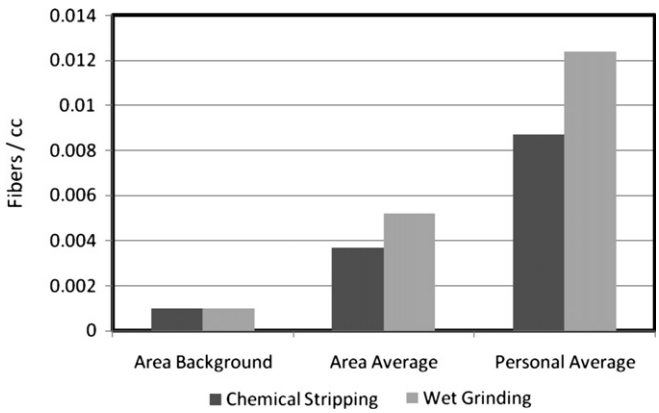


**Fig. 3.** Fiber emissions by task.

However, in all cases, the maximum measurement did not exceed the OSHA PEL of 0.1 f/cc. This shows the acceptability of both methods in achieving environmental and safety compliance such that both techniques offer an acceptable alternative.

### 6.4. Retrospective qualitative data presentation

Interviews were conducted to assess the perceptions of the various stakeholders about the asbestos abatement work. In the first facility, chemical stripping was used. At this facility, 60 employees work on a daily basis and twenty-five percent were interviewed ($n = 15$). In the second facility, 300 employees work on a daily basis and approximately seven percent were interviewed ($n = 20$). Wet grinding was used at this facility. Employees were asked to discuss their opinions as to the presence of odors, general comfort, and symptoms (either real or perceived) during both abatement procedures. The acceptability of the procedures to the owner and regulatory officials was likewise documented. In this assessment, the employee group varied between the two facilities. The owner, their representatives, the new flooring contractor, and the regulatory officials remained constant between the two facilities. The data suggests three general themes were resident in this study.

The first theme is; *Odors provide a constant reminder that an asbestos abatement activity was in progress*. One participant's statement summarized most of the other comments at the facility where chemical stripping was used. She stated, "The odor was always present; you know, it did not smell clean, like a hospital." The employees suggested the residual mastic remover odor was indicative of an adverse air quality situation. Further, most participants admitted to being afraid of, "an unseen hazard." This was stated by many as instilling "an ongoing fear" which, they disclosed, resulted in lost productivity and propagated rumors. According to the owner, "The work resulted in undesirable and counterproductive distractions." In the facility where wet grinding was used, one participant commented, "I kind of forgot what they were doing over there. It did not really disturb me that much." This is indicative of the remainder of the comments from other participants at the second facility.

The second theme is; *The stakeholder's believe their health was personally affected by the abatement activity*. In the facility where chemical stripping was used, stakeholder dissatisfaction ran high. One employee would not work in the facility because of the symptoms, either real or perceived, due to the "vapor emissions." According to the personnel manager, "five employees exercised their right to use between one and three sick days each and fifteen others voiced concerns over symptoms including desiccated nasal passages, irritation to the respiratory system, dry and itching eyes, migraine headaches, and other symptoms." According to the facility administrator, "eight patients voluntarily rescheduled appointments to other neighboring medical centers and three physicians rescheduled patient exams and procedures due to the odors." At the facility where wet grinding was used, employee complaints were minimal. Most of these complaints dealt with issues unrelated to the asbestos abatement such as the requisite re-routing of walkways and increased contractor traffic. "The physicians and patients lodged no complaints," as stated by the administrator at the second facility.

The third theme is; *The work outcomes were not equivalent*. The acceptability of the work outcome was the subject of some debate. In the first facility, where chemical stripping was used, the owner had no concerns over the efficacy of the work outcome. The flooring contractor had concerns over the usage of the mastic remover relative to the adhesion of the new floor to this surface however; he later stated that he, "did not think this would be a problem." The regulatory officials, as well, had no concerns over the condition of the floor after the abatement activity was complete. In the second facility where wet grinding was used, the owner voiced concern over the "black spots" remaining on the cement floor after the wet grinding and hand scraping operations. They understood that this was unavoidable and stated, "if it is acceptable to the new flooring contractor and the regulatory officials, it is acceptable to us." The flooring contractor preferred this method and believed it was more amenable to the manufacturer's warranty. The regulatory officials, once they felt the remaining black spots to understand the thoroughness of the hand scraping and wet grinding, considering the non-friability of the remaining mastic, and the subsequent encasement using a floor sealer, were satisfied that there were no relevant regulatory concerns.

The qualitative themes summarize the perceptions of the various stakeholders of this activity. Qualitative data, in a mixed methods study, fortifies the statistical data by providing insight into the human experience of the event (Miles and Huberman, 1994). Eisner (1991) suggests it is the merging of the evidence between the data given by the participant and the objective evaluation of other data that creates a "compelling whole." The attainment of this holistic perspective provides additional pragmatism to the outcome of this study.

## 7. Addressing the disadvantages

Not much can be said for the current state of the art with regard to the odors associated with mastic removers. The industry has come a long way since the development and usage of concentrated citric acid compounds, inauspiciously known as "agent orange." However, some individuals find the residual smell of the "no-odor" mastic removal chemical offensive. This is due to the petroleum distillates, ethers, and other chemicals resident in these types of compounds. These compounds irritate nasal and respiratory passages, aggravate the eyes, incite nausea, and induce headaches. Resultantly, these chemicals are not generally perceived as being conducive to the healthcare environment.

For the wet grinding method, a significant impediment continues to be the regulatory palatability of the process. The argument by regulatory officials is that the process allows a non-friable material to become friable because of the grinding of the mastic. This requires the erection of more elaborate containment systems thus increasing the project's costs, irrespective of the airborne asbestos emissions data. Air tests from both operations, holding other variables constant, yield results that are statistically similar and below the OSHA PEL of 0.1 f/cc of air.

Some of the other disadvantages of the wet grinding method cannot be assuaged. Unevenness in substrate surfaces will continue

to impede the usefulness of the process. While the chemical method allows ready cleaning of corners, edges, and jambs, the limitations of the equipment used in wet grinding, will continue to hamper its effectiveness. Finally the need to "fully contain" the work environment for wet grinding of floor tile mastic seems unnecessary given the data at hand.

## 8. Conclusions

The acceptance of any floor tile and mastic abatement process hinges on removing the asbestos-containing materials such that an acceptable work environment with minimal asbestos fibers is present subsequent to the abatement activity. The data suggests a statistical difference in fiber emissions concentration relative to background concentrations during the removal process. However, this difference was not considered to be biologically (health) significant. Both methodologies maintained an average concentration below the OSHA PEL of 0.1 f/cc, inside the work area. Comparatively, there is not a statistically significant difference between the two methodologies even though the wet grinding method does generate higher fiber emissions.

The cost of each method is also an important factor in determining its practical implementation. The wet grinding method is more expensive for the asbestos abatement contractor and this certainly translates into higher prices for the owner. Yet, the differences are not excessive. Most of the differential is related to the cost of labor (i.e.: supervisory, administrative, and worker) but is somewhat mitigated by the savings in disposal and raw materials cost. It is apparent that, even though additional site preparation is necessary, wet grinding is an effective economic alternative to chemical stripping in certain situations.

The interview data generated in this study suggests a stakeholder preference for the wet grinding methodology over the chemical stripping methodology. The owner, employees, physicians, and patients had less aversion to the wet grinding method than the chemical stripping method. This is mainly due to the minimal perception of odors associated with the removal action. Further, employee satisfaction with the abatement activity was overwhelmingly negative for the chemical stripping methodology.

Regulatory acceptance of both methodologies appears to be similar even though skepticism is present for the wet grinding methodology. Most of the regulatory acceptance is framed by the achievement of a safe work environment after the abatement is complete. This was achieved using either asbestos abatement technique.

It is clear that the flooring contractor perceived the wet grinding methodology as superior. This was based on the absence of chemical residue believed to remain on the substrate. Further, the flooring contractor believed the wet grinding method was more consistent with the manufacturer's warranty provisions and the belief that a more suitable adhesion to the substrate was attainable.

Based on the above, the wet grinding technique presents a viable alternative to the chemical stripping method. It is especially advantageous in situations where odor emissions might be perceived as problematic, such as in the case of the healthcare setting. Moreover, considering the variables of stakeholder satisfaction, wet grinding presents unique benefits to owners and operators of healthcare facilities undergoing renovation.

## 9. Recommendations for future study

Additional study will certainly benefit the asbestos abatement industry. Research into truly "no-odor" mastic removers should be continued. Because of its time savings, chemical stripping provides a faster means of abating asbestos-containing floor tile mastic. However, researchers and manufacturers in this discipline should remain cognizant of the minimal price elasticity between the two methodologies so that the cost of any truly no-odor removal chemical does not leverage the equation in favor of wet grinding. Further, if the so-called "no-odor" mastic removal compounds are actually made to be no odor, any problems caused by their use will be assuaged.

Continued attention of the regulating agencies should be paid to alternative methodologies where limitations to the existing methodologies are present. Additional efforts in framing the classification of floor tile and floor tile mastic removal operations as non-regulated activities should be considered based on the most recent research relative to fiber type, fiber size, and exposure. More research is necessary in this area so that both OSHA and EPA consider the existing body of research in this regard. Further, the rote classification of asbestos-containing floor tile and mastic removal operations that incorporate abrasive techniques should be reconsidered especially where water or other dust suppressants minimize fiber emission to below the PEL, such as in the case of the wet grinding methodology.

## References


Bernstein, D.M., Hoskins, J.A., 2006. The health effects of chrysotile: current perspective based upon recent data. Regulatory Toxicology and Pharmacology 45 (3), 252–264.

Berry, G., 1999. Models for mesothelioma incidence following exposure to fibers in terms of timing and duration of exposure and the biopersistence of the fibers. Inhalation Toxicology 11, 101–120.

Bohling, H., Hain, E., 1973. Cancer in relation to environmental exposure, type of fiber, dose, occupation and duration of exposure. In: Bogovski, P., Gilson, J.C., Timbrell, V., Wagner, J.C. (Eds.), Proceedings of the Conference on Biological Effects of Asbestos, Lyon, France, p. 217.

Berman, D.W., Crump, K., 2004. Technical Support Document for a Protocol to Assess Asbestos-related Risk. Technical Support Document Prepared for the US Department of Transportation and US Environmental Protection Agency, Washington, DC.

Camplin, J.C., 2003. Asbestos. Professional Safety 48 (8), 32–39. Retrieved July 20, 2009, from: ABI/INFORM Global (Document ID: 386383121).

Creswell, J.W., 2007. Qualitative Inquiry and Research Design. Sage Publications, Thousand Oaks, CA.

Davis, J.M.G., June 26, 1986. OSHA hearings included in 51 Federal Register. Institute of Occupational Medicine, Edinburgh, Scotland.

Eisner, E.W., 1991. The Enlightened Eye: Qualitative Inquiry and the Enhancement of Educational Practice. Macmillan Publishing, New York, NY.

Elmes, P.C., Simpson, M.J.C., 1971. Insulation workers in Belfast. British Journal of Industrial Medicine 28, 226.

EPA, 1973. Clean Air Act: 40 CFR 61 Section 112 Subpart M. The National Emissions Standards for Hazardous Air Pollutants. Retrieved on June 26, 2009 from: http://www.epa.gov/region4/air/asbestos/asbmatl.htm.

Ferris, K.D., n.d. The Risks and Regulation of Vinyl Asbestos Floor Tile: A Case Study of Over Regulation. Retrieved on June 26, 2009 from: http://www.rcsiweb.org/bulletins/Asbestos.doc. SUNY, Genesco, NY.

Hodgson, J.T., Darnton, A., 2000. The quantitative risks of mesothelioma and lung cancer in relation to asbestos exposure. Annals of Occupational Hygiene 11 (8), 565–601.

Kominsky, J.R., Freyberg, R.W., Boiano, J.M., 1995. Airborne asbestos concentrations during buffing, burnishing, and stripping of resilient floor tile. United States EPA – National Risk Management Research Laboratory Project Summary, Cincinnati, OH, pp. 1–7.

Kvale, S., 1996. Interviews: An Introduction to Qualitative Research Interviewing. Sage Publications, Thousand Oaks, CA.

Lange, J.H., Lange, P.R., Reinhard, T.K., Thomulka, K.W., 1996. A study of personal and area airborne asbestos concentrations during asbestos abatement: a statistical evaluation of fibre concentration data. Annals of Occupational Hygiene 40 (4), 449–466.

Lange, J.H., Thomulka, K.W., 2000. An evaluation of personal airborne asbestos exposure measurements during abatement of drywall and floor tile/mastic. International Journal of Environmental Health Research 10 (1), 5–19.

Lange, J.H., 2001. Airborne asbestos concentrations during abatement of floor tile and mastic: evaluation of two different containment systems and discussion of regulatory issues. Indoor and Built Environment 10, 193–199.

Levin, S.M., Kann, P.E., Lax, M.B., 2000. Medical examination for asbestos-related disease. American Journal of Industrial Medicine 37, 6–22.

Lorber, M., Gibb, H., Grant, L., Pinto, J., Pleil, J., Cleverly, D., 2007. Assessment of inhalation exposures and potential health risks to the general population that resulted from the collapse of the World Trade Centers. Risk Analysis 27 (5), 1203–1221.

Meldrum, M., 1996. Review of Fibre Toxicology. HSE Books, Sudbury, UK.
Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis: An Expanded Sourcebook, second ed. Sage Publications, Thousand Oaks, CA.
Murphy, R.L.H., Ferris, G.C., Burgess, W.A., Worchester, J., Gaensler, E.A., Dec. 1976. Revised Recommended Asbestos Standard. NIOSH Publication No. 77-169. US Department of HEW – National Institute for Occupational Safety and Health, Government Printing Office, Washington, DC. Retrieved on June 26, 2009 from: http://www.cdc.gov/niosh/docs/77-169/pdfs/77-169b.pdf.
Newhouse, M.L., Berry, G., Wagner, J.C., Turok, M.E., 1972. A study of the mortality of female asbestos workers. British Journal of Industrial Medicine 29, 143.
Niven, R.M., Fishwick, D., Pickering, C., Fletcher, A.M., Warburton, C.J., Crank, P., 1992. A study of performance and comparability of the sampling response to cotton duct of work area and personal sampling techniques. Annals of Occupational Hygiene 36, 349–362.
OSHA, 1986a. Revised recommended asbestos standard. Federal Register 51, 22644.
OSHA, 1986b. Revised recommended asbestos standard. Federal Register 51, 22632.
OSHA, 1994. Occupational exposure to asbestos – final rule. Federal Register 59, 40966.
Paik, N.W., Walcott, R.J., Brogan, P.A., 1983. Worker exposure to asbestos during removal of sprayed materials and renovating activity in buildings containing sprayed material. The American Industrial Hygiene Journal 44, 428–432.
Riemen, D.J., 1986. The Essential Structure of a Caring Interaction: Doing Phenomenology. Nursing Research: A Qualitative Perspective. Appleton-Century-Crofts Publications, Norwalk, CT.
Rubion, G.F., Scansetti, G., Conna, A., Palestro, G., 1972. Epidemiology of pleural mesothelioma in North-Western Italy (Piedmont). British Journal of Industrial Medicine 29, 436.
Selikoff, L.J., 1976. Asbestos disease in the United States (1918–1975). In: Paper Presented at the Conference on Asbestos Disease, Rouen, France, October 27, 1975.
Sichletidis, L., Chloros, D., Spyratos, D., Haidich, A.-B., Fourkiotou, I., Kakoura, M., Patakas, D., 2009. Mortality from occupational exposure to relatively pure chrysotile: a 39-year study. Respiration 78 (1), 63–68. doi:10.1159/000163443.
Stumphius, J., 1971. Epidemiology of mesothelioma on Walcheren Island. British Journal of Industrial Medicine 28, 59.
Trochim, W.M.K., 2001. Research Methods Knowledge Base, second ed. Atomic Dog Publishing, Cincinnati, OH.