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Aubrey K. Miller, M.D.
Eric J. Esswein, M.S.P.H., C.I.H.
James Allen, M.D.

PREFACE

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ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Aubrey K. Miller, M.D., Eric J. Esswein, M.S.P.H., C.I.H., of the Hazard Evaluations and Technical Assistance Branch, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), and James Allen, M.D., a visiting scientist from the U.S. Navy. Field assistance was provided by Evan Davies, M.D., a visiting scientist from the University of Cincinnati. Desktop publishing by Patricia C. McGraw.

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Aubrey K. Miller, M.D.
Eric J. Esswein, M.S.P.H., C.I.H.
James Allen, M.D.

SUMMARY

In December 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Center to Protect Workers' Rights in Washington, D.C., to evaluate construction worker exposures and potential health effects associated with dusts generated by drywall finishing during renovation activities. In response to this request, personal breathing zone (PBZ) samples were collected on two workers as they performed drywall sanding at an office building (Machinists Union Building) in Washington, D.C., and eight workers as they performed drywall sanding at a low-income public housing apartment complex (Ellicott Towers) in Buffalo, New York. A medical evaluation assessing workers' health symptoms was also performed in conjunction with the exposure evaluation of the eight workers at the Buffalo, New York, site. Furthermore, NIOSH researchers performed a laboratory evaluation of six different off-the-shelf dry wall joint compounds, purchased at retail construction supply stores in the Cincinnati, Ohio, area, to determine the qualitative mineral composition of each compound.

Results of full-shift PBZ monitoring for the two locations revealed that concentrations of total and respirable dust exceeded the Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs) of 15 milligrams per cubic meter of air (mg/m^3) total dust and 5 mg/m^3 respirable dust during the time periods sampled. Exposures exceeding the criteria for total dust were more common than exposures exceeding the criteria for respirable dusts. Results of PBZ samples for respirable silica indicate that while silica was present, it was at "trace" concentrations, defined as measurements between the analytical limit of detection (LOD) and the limit of quantitation (LOQ), for all except two samples. The two PBZ samples collected for respirable silica at the Washington, D.C., location contained 0.04 and 0.08 mg/m^3 of respirable silica as quartz. One sample exceeded the NIOSH recommended exposure limit (REL) of 0.05 mg/m^3 as respirable quartz but did not exceed the OSHA calculated PEL for silica exposure. Cristobalite was not detected (ND) in any air samples.

Analysis of the mineral phase of the six bulk samples of joint compound purchased from retail stores revealed that the products were very similar to each other, with the primary constituent being calcite. None of the samples contained asbestos, three contained minor quantities of silica and perlite, two contained minor quantities of gypsum and talc, and one contained a minor quantity of clay.

Among the eight dry wall finishers surveyed at the Buffalo, New York, site, the most frequently reported non-musculoskeletal symptoms during the 12 months prior to the survey were phlegm production, cough, shortness of breath, and eye irritation. All workers reporting phlegm production or cough were either current or former smokers. Three of these workers reported these symptoms as being chronic (i.e., occurs on most days for as much

as three months during the year). During the survey, the symptoms most frequently identified by workers as work-related were eye irritation and nasal congestion.

The most frequently reported musculoskeletal symptoms during the 12 months prior to the survey were pain, stiffness, or numbness in the elbows/forearms, back, and hands/wrists. Workers reported a considerable amount of chronic (occurrence of a particular symptom at least once a week) musculoskeletal symptoms over the prior year, with the highest frequency of symptoms occurring in the back (75%), elbows/forearms (63%), and hands/wrists (50%). Most musculoskeletal symptoms were reported to be of “moderate” intensity, with the greatest severity reported for the back and shoulder. While workers reported frequent, and at times severe, musculoskeletal symptoms, only two workers had their conditions (shoulder and back) evaluated by a health care provider. None of the workers reported missing work, being assigned to a different job, or being placed on work restriction because of their musculoskeletal conditions.

An occupational health hazard was determined to exist from exposure to particulates created during drywall finishing operations. During drywall finishing activities, total dust, and in some cases, respirable dust, exposures exceeded the OSHA PELs of 15 mg/m^3 for total dusts and 5 mg/m^3 for respirable dust. Two personal air samples from one location had quantifiable concentrations of respirable crystalline silica, one of which exceeded the NIOSH REL. Otherwise, sampling for respirable silica indicated that while silica (as quartz) was found to be present in air samples collected during work operations, the values for quartz were found to be between the LOD and the LOQ. Cristobalite was not detected. Surveyed workers at one site reported work-related eye irritation, nasal congestion, and shortness of breath. Based on the findings of this investigation, the use of engineering controls, wet finishing techniques, and personal protective equipment are recommended as methods to limit exposures to dusts created during dry wall finishing operations.

KEYWORDS: SIC 1742 (special trade contractors: plastering, drywall, and insulation), dry wall, sanding, gypsum, joint compound, calcite, calcium carbonate, silica, talc, kaolin, perlite, respirable dust, total dust, silica, respirable crystalline silica, particulates, particulate exposures.

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INTRODUCTION

In December 1993, the National Institute for Occupational Safety and Health (NIOSH) received a request from the Center to Protect Workers' Rights in Washington, D.C., to evaluate construction worker exposures to total and respirable particulates, possibly containing silica, generated from drywall finishing during building renovation. In response to this request, NIOSH investigators performed a health hazard evaluation (HHE) for the Center to Protect Workers' Rights (a research arm of the Building and Construction Trades Department of the AFL-CIO) and the International Brotherhood of Painters and Allied Trades to evaluate worker exposures and any health symptoms associated with drywall finishing work.

On December 16, 1993, personal breathing zone (PBZ) samples were collected on two drywall finishers as they performed drywall sanding during renovation of an office building in Washington, D.C. On August 11-12, 1994, PBZ monitoring was performed on eight drywall finishers as they sanded drywall installed during renovation of a low-income public housing apartment complex (Ellcott Towers) in Buffalo, New York. A medical evaluation assessing workers' health symptoms was performed in conjunction with the exposure evaluation at the Buffalo, New York, site. NIOSH researchers also performed a laboratory evaluation of six different off-the-shelf dry wall joint compounds, purchased at retail construction supply stores in the Cincinnati, Ohio, area, to qualitatively determine the mineral composition of each compound, including specific testing for silica and asbestos.

BACKGROUND

Construction or renovation of building interiors often involves installation of drywall, plasterboard, or "sheetrock," as it is commonly referred to in the trades.[1] The drywall consists of a non-combustible core, primarily gypsum, with paper or vinyl coverings on the sides and the long edges.[1] Drywall "installers" fit these boards to wall studs or ceiling joists and secure them with screws. After installation, drywall "finishers" (DWFs) prepare the surfaces for painting. The joints between the drywall sheets are taped and then pasted over with joint compound, commonly called mud, to fill the joints and any defects in the drywall board.[2] Drywall joint compound is applied as a wet paste, which is troweled into the drywall joints. Once the drywall compound has dried it is quite firm and has the consistency and texture of chalk. The joint compound is then sanded or finished to create a smooth uniform surface. DWFs typically use dry sanding techniques to create the desired surface. Dry sanding involves rubbing a coarse sand paper over the dried joint compound. Depending on the location of the work, the DWFs may use pole-mounted, swivel-head pad sanders and occasionally they hand sand surfaces using a sanding block. These work activities can generate a tremendous amount of fine dust. Overhead sanding, and sanding in tight confines such as closets, appears to cause the greatest amount of dust to fall in the worker's breathing zone. The alternative, wet sanding, requires an extra step of wetting the dried joint compound prior to sanding. Wet sanding techniques greatly reduce the airborne dust levels but also delays subsequent work, such as painting, until the wall is completely dry.[2]

METHODS

Industrial Hygiene

Personal Breathing Zone Samples

To characterize exposures to total and respirable particulates, ten employees (two in Washington, D.C., and eight in Buffalo, New York) were asked to wear two personal sampling trains; one sampling train was configured to sample for respirable particulate, another was configured to sample for total particulate. Respirable particulates were collected using tared 37 millimeter (mm), 5-µm PVC membrane filter closed-face cassettes mounted in 10 mm nylon Dorr-Oliver cyclones and attached to Gilian® personal sampling pumps. Total particulates were collected using tared 37 (mm), 5-µm PVC filters mounted in closed-face cassettes. The sampling trains were calibrated to a flow rate of either 1.7 (respirable) or 2 liters (total) per minute (Lpm). Cassettes were positioned in the worker's breathing zone. Pre-and post-sampling calibration (including flow checks during the day) were performed using a calibrated hand-held rotameter.

Samples were analyzed gravimetrically for total weight according to NIOSH Method 0600[3] with two standard laboratory modifications: 1) filters were stored in an environmentally controlled room to reduce the stabilization time between tare weighings to 5-10 minutes and; 2) the filters and backup pads were not vacuum desiccated. The instrumental precision of the weighings (using an electrobalance) was reported at 0.02 milligrams (mg). All samples were analyzed for total weight. Respirable dust samples were also analyzed for the presence of crystalline silica (as quartz and cristobalite) using x-ray diffraction (XRD) for analysis. NIOSH Method 7500[4] was used for silica analysis with the following laboratory modifications: 1) filters were dissolved in tetrahydrofuran rather than ashed in a furnace; and 2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.

Joint Compound Bulk Sample Analysis

To determine the accuracy of drywall joint compound product labeling and to further evaluate the potential for silica and asbestos exposure, six different containers of drywall joint compounds, of varying sizes, were purchased (off the shelf) from retail construction supply stores in the Cincinnati, Ohio, area. These samples were analyzed by XRD and polarized light microscopy. The former permits quantitative analysis of silica while the later permits a semi-quantitative analysis of silicates based on their microscopic appearance.

Medical (Buffalo, New York)

All eight drywall finishers at the Buffalo, New York, site were recruited to participate in a health assessment. During a rest break, workers were given a health questionnaire which collected information concerning pertinent past medical and work histories, recent health symptoms (emphasis on eye, nose, throat, and respiratory systems), and tobacco use. Additionally, information concerning musculoskeletal symptoms was collected because of observations, by NIOSH investigators, of DWF work practices involving risks for musculoskeletal injury (i.e., awkward postures, repetitive forceful motion, and overhead work) at the Washington, D.C., site. Information concerning the frequency, severity, and work-relatedness of symptoms was solicited.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs)[5], (2) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs™)[6], and (3) the U.S. Department of Labor, OSHA permissible exposure limits (PELs)[7]. In July 1992, the 11th Circuit Court of Appeals vacated the 1989 OSHA PEL Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report reflect the 1971 values.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Drywall or Joint Compound

Many different formulations are marketed under the generic terms wallboard compound or joint compound. The specific formulation of joint compounds vary. Joint compound is typically composed of a "mineral phase," which provides the bulk of the material, and an "organic phase" which is the adhesive binder. Calcite (calcium carbonate) is commonly used in the mineral phase, and starch is a commonly used in the organic phase of joint compounds. Premixed joint compounds are typically 60% mineral phase, 40% water, and less than 1% organic phase (wet weight).

A material safety data sheet (MSDS) for the ready-mix joint compound used at the Buffalo, New York, site listed water, calcite (calcium carbonate), mica (aluminum silicate), and quartz (crystalline silica) as the predominant mineral phase constituents. The MSDS also indicated that talc (magnesium silicate), gypsum (calcium sulfate), perlite (a noncrystalline silicate), and clays (which include attapulgite and kaolinite) may be present in the compound.

Particulates, Not Otherwise Classified

The health effects associated with long-term chronic airborne exposure to the dust or particulates generated during drywall sanding are not known. When the individual components of an airborne particulate do not have established occupational health criterion, it has been standard convention to apply a generic exposure criterion to the dust. Formerly referred to as "nuisance dust," a preferred terminology for these dusts is "particulates not otherwise classified"[6] (p.n.o.c) or "not otherwise regulated" (n.o.r.).[7]

The ACGIH recommended TLV for exposure to p.n.o.c. is 10 mg/m^3 for total dust and 3 mg/m^3 for respirable particulate, both as 8-hour time-weighted averages (TWAs).[6] The OSHA PEL for an 8-hour TWA p.n.o.r. is 15 mg/m^3, and 5 mg/m^3 for the respirable fraction.[7] These generic criteria for airborne dusts are based on the premise that the substances comprising the dust do not produce significant organic disease when exposures are kept under reasonable control.[6] These criteria may be legally applicable, but are not necessarily toxicologically appropriate for dusts containing substances (e.g., silica) that have a demonstrable biologic effect.

Criteria for Specific Constituents Potentially Found in Joint Compound

The respiratory effects associated with airborne exposure to the joint compound constituents identified during this evaluation have been previously studied in workers under different working conditions. The known respiratory effects and evaluation criteria for these joint compound constituents are presented below (Table 1).

Table 1
Toxicity and Exposure Criteria Information
Center to Protect Workers' Rights (HETA 94-0078)

Compound	Toxicity Review	Exposure Criteria
Calcite (calcium carbonate)	Calcite is the chief constituent of limestone and typically is the primary constituent of joint compounds. Inhalation of calcite dust in humans has not been associated with adverse lung effects.[8]	The NIOSH REL is 10 mg/m^3 total dust and 5 mg/m^3 respirable dust, 10-hour TWA. The OSHA PEL is 15 mg/m^3 total dust and 5 mg/m^3 respirable dust, 8-hour TWA. The ACGIH TLV® is 10 mg/m^3 inhalable dust; 8-hour TWA (<1% crystalline silica, no asbestos).
Gypsum (calcium sulfate)	In humans, radiographic changes consistent with pneumoconiosis have been observed in a few groups of gypsum miners, however, it is generally felt that these findings were related to the presence of quartz (silica) in the dust.[9] Despite the radiographic changes seen in some gypsum miners, rates of respiratory symptoms and lung function abnormalities were not increased.[8] In animals, prolonged inhalation of gypsum has not been shown to cause pulmonary fibrosis.[9]	The NIOSH REL is 10 mg/m^3 total dust and 5 mg/m^3 respirable dust, 10-hour TWA. The OSHA PEL is 15 mg/m^3 total dust and 5 mg/m^3 respirable dust, 8-hour TWA. The ACGIH TLV® is 10 mg/m^3; 8-hour TWA (<1% crystalline silica, no asbestos).
Mica (aluminum silicate)	Pneumoconiosis has rarely been associated with uncontaminated exposure to the mica group of minerals (Muscovite, phlogopite, vermiculite). In the few workers with radiographic changes consistent with pneumoconiosis, the abnormalities are usually mild. In animals, prolonged inhalation of mica has not been shown to cause pulmonary fibrosis.[10]	The NIOSH REL is 3 mg/m^3 respirable, 10-hour TWA (<1% crystalline silica). The OSHA PEL is 20 mppcf, 8-hour TWA (<1% quartz). The ACGIH TLV® is 3 mg/m^3; 8-hour TWA.
Kaolin (hydrated, aluminum silicate)	Workers exposed to kaolin (china clay) have been found to have varying degrees of pneumoconiosis, with the prevalence of abnormal radiographic findings corresponding to the length of exposure.[8,10] Additionally, pulmonary function impairment has been associated with kaolin exposure and correlates with findings of worsening pneumoconiosis.[8,10]	The NIOSH REL is 10 mg/m^3 total dust and 5 mg/m^3 respirable dust, 10-hour TWA. The OSHA PEL is 15 mg/m^3 total dust and 5 mg/m^3 respirable dust, 8-hour TWA. The ACGIH TLV® is 2 mg/m^3 respirable dust; 8-hour TWA.
Perlite (noncrystalline silicate)	Perlite has not been associated with adverse lung effects in humans or animals.[8,11]	The NIOSH REL is 10 mg/m^3 total dust and 5 mg/m^3 respirable dust, 10-hour TWA. The OSHA PEL is 15 mg/m^3 total dust and 5 mg/m^3 respirable dust, 8-hour TWA. The ACGIH TLV® is 10 mg/m^3 inhalable dust; 8-hour TWA (<1% silica, no asbestos).

Talc (magnesium silicate)	Workers exposed to talc have been found to have varying types of pulmonary abnormalities (nodular lesions, interstitial fibrosis, foreign body granulomas) and severity of pneumoconiosis. However, the majority of talc workers have also be exposed to other fibrogenic dusts (silica, tremolite, mica); thus, it is not clear if exposure to pure talc really causes pulmonary fibrosis. Progressive symptoms of chest tightness and cough tend to develop after 15 years of exposure to industrial grade (≥50% impurities) talc. Pulmonary function impairment has been associated with talc exposure, and generally the degree of impairment corresponds with radiographic findings of worsening pneumoconiosis.[10]	The NIOSH REL is 2 mg/m^3, 10-hour TWA (no asbestos). The OSHA PEL is 2 mg/m^3, 8-hour TWA (no asbestos). The ACGIH TLV® is 2 mg/m^3 respirable dust; 8-hour TWA (no asbestos).

Respirable Silica and Cristobalite

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs. Symptoms including cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses usually develop insidiously. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high.[12] The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 50 µg/m^3(or, 0.05 mg/m^3), as TWAs, for up to 10 hours per day during a 40-hour work week.[8,13] These RELs are intended to prevent silicosis. However, more recent evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.[14,15] The OSHA PEL for respirable silica is dependent upon the percent silica in the sample, the respirable dust exposure for an 8-hour TWA must not exceed the value obtained from the formula:

$$\frac{10 mg/m^3}{\%SiO_2 + 2}$$

The ACGIH TLVs for respirable quartz and cristobalite are 100 and 50 µg/m^3, respectively, as 8-hour TWAs.[6]

RESULTS

Industrial Hygiene

Particulates n.o.c.

On December 16, 1993, two workers were monitored at a construction site in Washington, D.C., and on August 11-12, 1994, eight workers were evaluated at a site in Buffalo, New York. Work practices in both locations involved the use of a pad-mounted pole sander with occasional hand sanding as needed.

Personal breathing zone sampling results for two workers on December 16, 1993, are listed in Table 2. One sample exceeded the 15 mg/m^3 OSHA PEL for total dust (this sample contained 17.9 mg/m^3 of total particulate). On August 11-12, 1994, 23 sample sets (total, respirable, and respirable quartz) were collected on eight workers performing renovations at a public housing complex (Table 3). Overall, concentrations of total dust were found to be much higher than concentrations of respirable dusts. Total dust measurements ranged from less than the OSHA PEL to more than 10 times the OSHA PEL. Eight of 9 samples (89%) collected for total dust exceeded the OSHA criterion of 15 mg/m^3, but only 2 of 13 (15%) of the respirable dust samples were greater than the OSHA criterion of 5 mg/m^3.

Respirable Silica

The minimum detectable concentration (MDC) for silica in these samples was calculated to be 0.01 mg/m^3 based on average sample volumes of 747 liters (L). The analytical limit of detection (LOD) for the sample set was reported as 0.01 mg/sample. Respirable silica (as quartz) was reported above the limit of detection on both of the samples from the Washington, D.C., investigation (Table 2) and in trace quantities on 15 of 22 (68%) of the samples from the Buffalo, New York, investigation (Table 4). When the presence of silica was reported by the laboratory, it was found to be quartz. Cristobalite was not reported on any samples. Table 4 describes the results of the PBZ samples collected for total dust, respirable dust, and respirable quartz at the Buffalo, New York, investigation. The quartz concentrations were determined to be either not detected (ND) or at trace concentrations which are between the analytical limit of detection (LOD) and the limit of quantitation (LOQ) for the method. Samples which were determined to contain quartz greater than the LOD were the two PBZ samples from the Washington, D.C., investigation. These samples were found to contain 0.04 mg/m^3 and 0.08 mg/m^3 as quartz, respectively. One PBZ sample (0.08 mg/m^3) exceeded the NIOSH REL of 0.05 mg/m^3 crystalline silica. The calculated OSHA PEL for this sample (based on the presence of 0.41% crystalline silica) is 4.10 mg/m^3. Thus, while the measured concentration is in excess of the NIOSH criteria, the calculated results are below the OSHA PEL.

Results of Drywall Compound Labeling and Bulk Sample Analysis

Analysis of six bulk samples of joint compound was performed to determine the composition of the pre-mixed compound prior to application and sanding. The bulk samples evaluated varied from a half pint container, typically used for home repairs, to a 62-pound pail, commonly used by commercial contractors. Two of the containers had printed labels providing warnings of potential silica exposure during usage. Three of the containers had labeling which recommended the use of a respirator during sanding and four recommended wet sanding techniques to reduce exposures.

Compositional analysis of the mineral phase of the six bulk samples revealed that the products were very similar to each other, with the primary constituent being calcite. None of the samples contained asbestos. Three of the samples contained minor quantities of silica and perlite, two contained minor quantities of gypsum and talc, and one contained a minor quantity of clay (Table 5). For the most part, the results of each sample analysis agreed with the composition stated in the manufacturers' material safety data sheets (MSDS's) accompanying each product.

Medical

All eight of the workers at the Buffalo, New York, site completed the health questionnaires. All workers were male, with an average age of 33 years (range 25-42 years). The average duration of employment as a DWF was 12 years (range 4 months - 25 years). Six of the workers had worked as DWFs for more than ten years, one worker was an apprentice and had been working for only four months, and one worker did not answer the question.

Table 6 shows the prevalence of non-musculoskeletal symptoms. The first column of Table 6 shows the percentage of workers who reported the occurrence of a particular symptom at any time during the preceding 12 months prior to the survey. The most frequently reported symptoms were phlegm production (63%), cough (50%), shortness of breath (50%), and eye irritation (38%). All workers reporting phlegm production or cough were either current or former smokers. Three of these workers reported that their symptoms were chronic (i.e., occurs on most days for as much as three months during the year). The second column of Table 6 shows the percentage of all eight workers who specifically reported a symptom to be temporally associated with their drywall finishing work activities or reported that the symptom improved when they were away from work. With the exception of eye irritation and nasal congestion, a lower percentage of symptoms were identified as having an apparent work-related pattern. The symptoms that were most frequently identified as

work-related were eye irritation, nasal congestion, and shortness of breath.
None of the workers reported a past history of emphysema, tuberculosis, bronchitis, pneumonia, or asthma. Two workers reported a history of hay fever or seasonal allergies. Three workers currently smoked cigarettes, four were former smokers, and one did not provide a smoking history.

Table 7 shows the prevalence of work-related musculoskeletal symptoms (i.e., symptom frequency and severity was reported to be temporally associated with drywall finishing work activities). The first column shows the percentage of workers who reported the occurrence of a particular symptom during the preceding 12 months prior to the survey. The most frequently reported symptoms were pain, stiffness, or numbness in the elbows/forearms (88%), back (75%), and hands/wrists (63%). The second column of Table 7 shows the percentage of workers who experienced a particular symptom at least once a week for the 12 months preceding the survey. Workers reported a considerable prevalence of chronic musculoskeletal symptoms over the prior year, with the most commonly affected areas being the back (75%), elbows/forearms (63%), and hands/wrists (50%). The third column shows the percentage of reported symptoms classified by the intensity of the condition. Symptom intensity was classified as "no pain," "mild," "moderate," "severe," and the "worst pain ever in life." Most musculoskeletal symptoms were reported to be of "moderate" intensity, with the greatest severity of symptoms reported for the back and shoulder.

All workers were right-handed and tended to report a higher frequency and intensity of musculoskeletal symptoms in their right extremities. While workers reported frequent and, in many cases, severe musculoskeletal symptoms, only two workers had their conditions (shoulder and back) evaluated by a health care provider. None of the workers reported missing work, being assigned to a different job, or being placed on work restriction because of their musculoskeletal conditions.

DISCUSSION AND CONCLUSIONS

Industrial Hygiene

The purpose of the industrial hygiene component of this HHE was to evaluate the dusty conditions encountered during drywall sanding and finishing and determine if employee exposures to total and respirable dusts, and respirable silica, represented a potential health hazard to employees. Based on observations of work practices and sampling results, considerable variability in PBZ exposures was present during the work activities. For example, when workers were sanding ceilings, or in tight confines such as closets or in corners, more dust appeared to be present in the workers' breathing zones than when they were sanding flat surfaces below eye-level, such as horizontal sections of wallboard joints. The sampling results reflect these observations; the two highest concentrations of total dust measured occurred during ceiling sanding. Also, when several finishers were working together in the same room, there was increased generation of particulates and worker dust exposures. While most of the dust did not appear to be respirable, workers were exposed to varying levels of respirable dust (two samples exceeded the OSHA PEL for respirable dust), depending on workplace conditions. Exposures in excess of the OSHA PEL for total dust were more frequent than exposures exceeding the standard for respirable particulate (15 mg/m^3 vs. 5 mg/m^3, respectively).

The MSDSs which were obtained from the manufacturers of the joint compounds used at the job sites indicated that quartz was present, but no concentration percentages were shown on the MSDS. This finding is consistent with a review of MSDS's taken from six different off-the-shelf joint compounds purchased in the Cincinnati, Ohio, area.

It is possible, and indeed likely, that minor product variations are attributable to variation in the natural mineral content from which the constituents are obtained, and also from product manufacturing variations.

Bulk sample analysis of the six different off-the-shelf joint compounds revealed the presence of small amounts of silica in three of the six samples tested. This finding in conjuction with personal sampling conducted during this survey indicates that: 1) silica is present in joint compounds and, 2) the sanding of silica-containing joint compounds during drywall finishing may result in silica exposures which exceed applicable exposure criteria under certain conditions (i.e., one PBZ sample was above the NIOSH REL for silica exposure). Given the low percentage of silica found in the PBZ and bulk samples, silica exposures during drywall sanding are typically expected to be below the OSHA PEL. None of the bulk samples of joint compound contained asbestos, suggesting that asbestos, which had previously been used in joint compounds, is no longer a constituent of these products.

The results of total dust exposure measurements made during this survey suggest that methods to control worker exposures, such as wet sanding, engineering controls, and personal protective equipment, should be used during drywall finishing. The OSHA PEL for otherwise unregulated particulates is based on the premise that the dust is not toxic. This criterion may not be appropriate to drywall sanding dust given the presence of various constituents (i.e., silica, kaolin, talc) which can potentially affect the lungs. The long term health consequences from exposure to dust generated from the joint compounds currently in use is unknown.

Medical

A number of constituents present in joint compounds (i.e., talc, calcite, mica, gypsum), and presumably in the dust, have been associated with varying degrees of mucosal and respiratory tract irritation.[5] Over time, these exposures may result in chronic throat and airway irritation and can lead to symptoms of cough, phlegm production, and possibly bronchoreactivity. The findings of this evaluation are consistant with these effects, although the small numbers of workers evaluated, and the fact that most of the workers were current or former smokers, preclude us from drawing conclusions about the relationship between workers' symptoms and their drywall dust exposures. Additionally, exposed workers with ongoing respiratory problems, such as asthma and bronchitis, may experience periodic exacerbations or a worsening of their condition. Furthermore, cigarette smoking in conjunction with continual high dust exposures may result in increased risk and severity of both cigarette and-dust-related pulmonary health problems.

Over 50% of the workers reported experiencing work-related musculoskeletal symptoms of the back and upper extremities (excluding the shoulder). For many of the workers, these symptoms were chronic (experienced on a weekly basis), though they typically were not incapacitating and did not necessitate treatment by a health professional. Observation of work practices revealed that workers had to perform constant repetitive sanding motions with either a pole sander or hand sanding block. Worker postures during sanding varied in height (i.e., kneeling, overhead work) and awkwardness, depending on the area being finished. Based on these findings, it is likely that ongoing back and upper extremity musculoskeletal symptoms are either caused or aggravated by the physical demands (i.e., forceful and repetitive motions, awkward postures) of drywall finishing. Current epidemiologic evidence implicates risk factors such as force, posture, and repetition in the development of work-related musculoskeletal disorders of the neck, shoulder, hands and wrists, and back.[16] Ergonomics programs which will appropriately modify tools, materials, and work practices need to be developed to prevent and reduce work-related musculoskeletal disorders associated with this trade.

RECOMMENDATIONS

The following recommendations are offered in the interests of creating healthy and safe conditions for workers performing drywall finishing operations.

1. Engineering controls and respiratory protection are needed to reduce occupational exposures to drywall dust. Engineering controls, however, should be considered the primary means of control.

a. When respirators are used, employees should use NIOSH approved respirators with a minimum assigned protection factor (APF) of 10. Variations in exposures can be significant and the data obtained in this study indicate that a few TWA total dust exposures during finishing operations exceeded the maximum use criteria for traditional half-mask air purifying respirators having an APF of 10. Considering this fact, the use of engineering controls to limit dust generation is particularly important, and should be used as a primary means of controlling exposures. When respirators are used a complete employee respiratory protection program should be developed. The minimum standards for such a program are described in the Occupational Safety and Health Administration (OSHA) General Industry Standards, 29 CFR 1910.134.

b. Some drywall compounds (and the resultant dust) may contain crystalline silica and other potentially toxic components. Limiting the potential for exposures to respirable crystalline silica or other toxic compounds involves controlling total and respirable dust exposures. Currently a wide variety of respirators are commercially available including the traditional reusable half-masks, disposable half masks, and resposable masks (reusable for several times, then disposable). While a half-mask respirator with an elastomeric face piece will provide the best protection, other suitable masks offering high efficiency protection without the weight and bulk of an elastomeric face piece may be a more reasonable choice of respirator and may be more acceptable for workers performing this type of work. NIOSH approved respirators with a minimum protection factor of N95 (95% efficient against non-oil based aerosols) should be used. Since manufacturers of respirators design the shape of each face piece to be slightly different, employees should have the option to choose from a selection of several masks in order to find a face piece that allows adequate comfort and fit.

c. While the majority of joint compounds analyzed had very low amounts of quartz (less than 0.5%), some quartz is present. Wet sanding techniques should therefore be used whenever possible. In situations where wet sanding is not possible, engineering control modifications for swivel head pole sanders to achieve local exhaust ventilation on the sander itself, are currently available, and should be made. A NIOSH engineering control technology report detailing some of these commercially available engineering controls is currently available.[17]

2. Appropriate medical surveillance for drywall finishers should be tailored to evaluate each worker's potential for past exposure to asbestos-containing joint compounds, and ongoing medical conditions or symptoms a worker may be experiencing. Drywall finishers only exposed to joint compounds, used in recent years, may not be at greater risk for pneumoconiosis. However, they may still be at risk for other pulmonary problems, such as bronchitis. Drywall finishers working in the industry before the mid 1980's were most likely exposed to joint compound formulations containing asbestos[18,19] and higher concentrations of silica.[19] These workers are at increased risk for health problems associated with these substances and should discuss this issue with their physicians or occupational health professionals. Those workers who may have had prior exposure to asbestos-containing joint compounds should have an appropriate medical evaluation and ongoing medical surveillance in accordance with OSHA guidelines.[20]

3. Cigarette smoking in conjunction with continual high dust exposures may result in increased risk and severity of both cigarette and-dust-related pulmonary health problems. Efforts such as enhanced employee education, improved smoking policies, and increased

availability of smoking cessation programs should be undertaken to encourage and help workers to quit smoking.

4. Work-related musculoskeletal disorders have been associated with factors such as forceful and repetitive motions, awkward postures, and overhead work. Wherever possible, ergonomic modifications should be implemented to reduce those risk factors associated with work practices and tool design. For example, adjustable sanding poles may reduce overhead sanding and awkward postures in confined areas. A NIOSH publication "Elements of Ergonomics Programs" is currently available to help guide in the development of appropriate ergonomic programs to prevent and reduce work-related musculoskeletal disorders.[21]

5. Any workers experiencing chronic or worsening symptoms of mucosal irritation, cough, phlegm production, or shortness of breath should discuss their condition and work exposures with their physician or other knowledgeable occupational health professionals.

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Table 2
Office Building Renovation
December 16, 1993
Center to Protect Workers' Rights
HETA 94-0078
(Washington, D.C., Site)

2 Employees work observed *PPE used	**Sample #**	**Sample Type** (i.e., total, respirable, quartz)	**Time** (min)	**Volume** (liters)	**Filter weight** (µg)	**Concentration**** (TWA mg/m^3) for period sampled
Finisher A sanding ceilings & walls, dust mask	4996	respirable	443	753	1220	1.62
	4992-96	total	443	886	9860	11.0
	4996	respirable quartz	443	753	30 (0.41% quartz)	0.04
Finisher B sanding ceilings & walls, dust mask	4988	respirable	435	740	2700	3.64
	4987-88	total	281	534	9560	**17.9**
	4988	respirable quartz	435	740	60 (0.45% quartz)	0.08

* PPE= personal protective equipment
** Bolded concentrations exceeded relevant OSHA criteria

Table 3
Apartment Building Renovation
August 11-12, 1994
Center to Protect Workers' Rights
HETA 94-0078
(Buffalo, New York, Site)

8 Employees work observed *PPE used	**Sample #**	**Sample Type** (i.e., total or respirable)	**Time** (min)	**Volume** (Liters)	**Filter Wt.** (µg)	**Concentration**** (TWA mg/m^3) for period sampled
August 11						
Finisher C	2600	respirable	382	649	4550	**7.0**
sanding ceilings, dust mask	2613, 2598	total				**173**
Finisher D	2594	respirable	244	415	2420	3.9
sanding all areas, dust mask	2588, 2590	total				**80**
Finisher E	2605	respirable	373	634	3080	4.8
sanding ceilings, closets, no dust mask	2604, 2585	total	359	718	81620	**114**
Finisher F	2577	respirable	251	427	1070	2.5
sanding walls, no dust mask	2603, 2586	total	261	505	29940	**59**
Finisher G	2595	respirable	263	447	630	1.4
sanding all areas, dust mask	2581, 2599	total	263	523	20420	**39**
Finisher H	2609	respirable	185	315	530	1.7
sanding all areas, dust mask	2584, 2587	total	184	365	9230	**25**
Finisher I	2592	respirable	82	139	120	0.86
sanding all areas, dust mask	2597, 2579	total	171	339	9480	**28**
Finisher J	2596	respirable	165	281	1620	**5.8**
sanding all areas, dust mask	no sample	total	-	-	-	n/a
August 12						
Finisher C sanding all areas, no dust mask	2591	respirable (no total dust sample)	552	938	740	0.78
Finisher D sanding all areas, no dust mask	2580	respirable (no total dust sample)	734	1248	470	0.37
Finisher E	2593	respirable	413	702	2610	3.7
sanding all areas, dust mask	2579, 2606	total	413	826	4901	5.9
Finisher H sanding all areas, no dust mask	2582	respirable (no total dust sample)	361	614	2610	4.3
Finisher I	2583	respirable	412	700	2030	2.9
sanding all areas, dust mask	2589	total	412	824	50530	**61**

*PPE= personal protective equipment; ** Bolded concentrations exceeded relevant OSHA criteria

Table 4
Apartment Building Renovation
Evaluation for Respirable Crystalline Silica (as quartz)
August 11-12, 1994
Center to Protect Workers' Rights
HETA 94-0078
(Buffalo, New York, Site)

8 Employees	**Sample #**	**Sample type** total, respirable	**Time** (min)	**Volume** (L)	**Filter weight** (mg.)	**Quartz** (% by weight)	Quartz (mg/m^3)
	August 11						
Finisher C	2600	respirable	383	649	4.55	ND	ND
	2598	total	383	779	135	1.2	Tr
Finisher D	2594	respirable	365	621	2.42	0.8	Tr
	2588	total	364	728	58.42	0.53	Tr
Finisher E	2605	respirable	373	634	3.08	ND	Tr
	2585	total	359	718	81.62	0.97	Tr
Finisher F	2577	respirable	251	427	1.07	ND	Tr
	2586	total	261	505	29.94	0.72	Tr
Finisher G	2595	respirable	263	447	0.63	ND	Tr
	2581	total	263	523	20.42	0.90	Tr
Finisher H	2609	respirable	185	315	0.53	ND	ND
	2587	total	184	365	9.23	ND	Tr
Finisher I	2592	respirable	82	139	0.12	ND	ND
	2579	total	171	339	9.48	1.10	Tr
Finisher J	2596	respirable no total dust sample	165	281	1.62	ND	ND
August 12							
Finisher C	2591	respirable no total sample	552	939	0.74	ND	ND
Finisher D	2580	respirable no total sample	734	1248	0.47	ND	ND
Finisher E	2593	respirable	413	702	2.61	ND	Tr
	2579	total	413	826	4.90	0.80	Tr
Finisher H	2582	respirable no total sample	361	614	0.73	ND	ND
Finisher I	2583	respirable	412	700	2.03	ND	Tr
	2589	total	412	824	50.53	0.73	Tr

Tr = trace quantity, between LOD and LOQ; ND = not detected to LOD for method

Table 5
Analysis of Joint Compound Bulk Samples
Center to Protect Workers' Rights
HETA 94-0078

Sample #	1	2	3	4	5	6
Product size	½ pint	62 lb	50 lb	4.5 gal	8 lb	12 lb
Chrysotile* (asbestos)						
Quartz (crystalline silica)		+		+	+	
Talc				+		+
Mica		+	+	+	+	+
Calcite**	++	++	++	++	++	++
Gypsum	+					+
Clays***						+
Perlite				+	+	+

\+ secondary, minor, or trace constituent
++ primary constituent

* includes all species of asbestos
** includes calcium carbonate, dolomite, and limestone
*** includes attapulgite and kaolinite

Table 6
Non-musculoskeletal Symptoms Experienced by Eight Workers Over the Past 12 Months
Center to Protect Workers' Rights
HETA 94-0078
(Buffalo, New York, Site)

Symptoms	Symptoms experienced during the past 12 months	Symptoms associated with work or improve when away from work
phlegm production >3 days/week	63% (5/8)	13% (1/8)
Morning or day cough >3 days/week	50% (4/8)	13% (1/8)
Shortness of breath or chest tightness	50% (4/8)	25% (2/8)
Red, itching, or irritated eyes	38% (3/8)	38% (3/8)
Stuffy nose, sinus congestion or drainage	25% (2/8)	25% (2/8)
Skin rash, dermatitis, hives, or eczema	25% (2/8)	13% (1/8)
Wheezing or whistling noises in the chest	25% (2/8)	none

Table 7
Work-related Musculoskeletal Symptoms in Eight Workers
Center to Protect Workers' Rights
HETA 94-0078
(Buffalo, New York, Site)

Symptoms	Symptoms experienced during the past 12 months	Symptoms experienced at least once/ week over past 12 months	Intensity of symptoms experienced over the past 12 months	
Elbows / forearms pain, stiffness, or numbness	88% (7/8)	63% (5/8)	mild moderate severe	14% (1/7) 57% (4/7) 29% (2/7)
Back pain, stiffness, or numbness	75% (6/8)	75% (6/8)	moderate severe	17% (1/6) 83% (5/6)
Hands / wrist pain, stiffness, or numbness	63% (5/8)	50% (4/8)	mild moderate severe	20% (1/5) 60% (3/5) 20% (1/5)
Neck pain or stiffness	38% (3/8)	25% (2/8)	moderate	100% (3/3)
Shoulder pain, stiffness, or numbness	38% (3/8)	25% (2/8)	moderate severe	33% (1/3) 67% (2/3)