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NIOSH Exposure Assessment of Cellulose Insulation Applicators

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PREFACE

The Hazard Evaluations and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employer or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to Federal, State, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Robert E. McCleery, MSPH, Ronald M. Hall, MS, and Joel McCullough, MD, of HETAB in the Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS); and Joseph E. Fernback of the Chemical Exposure and Monitoring Branch (CEMB) in the Division of Applied Research and Technology (DART). Field assistance was provided by Bruce Bernard, Leo Blade, Nancy Burton, Krystyn Bussa, Calvin Cook, Joshua Harney, Brad King, Gregory Kinnes, Ali Lopez, Kenneth Martinez, Dino Mattorano, and Kevin Roegner. Analytical support was provided by Mark Millson of DART, and Data Chem Laboratories, Salt Lake City, Utah. Statistical support was provided by Charles A. Mueller of DSHEFS. Desktop publishing was performed by Robin Smith and Pat Lovell. Review and preparation for printing were performed by Penny Arthur.

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For the purpose of informing affected employees, copies of this report shall be posted by the employer in a prominent place accessible to the employees for a period of 30 calendar days.

Highlights of the NIOSH Health Hazard Evaluations

NIOSH Exposure Assessment of Cellulose Insulation Applicators

Cellulose insulation (CI) was nominated to the National Toxicology Program (NTP) for a comprehensive toxicological evaluation. The NIOSH was presented with an opportunity to assist in the evaluation of CI by conducting the exposure assessment through an interagency agreement with the National Institute of Environmental Health Sciences/NTP.

What NIOSH Did

We took air samples for total dust and respirable dust, and characterized any fibers in the dust.

The fibers in the dust were examined to determine the type of fiber and its length. We also measured the concentration of fibers on the sample filter.

We handed out a medical history questionnaire to employees. In addition, we recorded any short–term health symptoms and conducted an employee breathing test to measure the amount of air exhaled in one second by blowing into a tube during pre–shift, mid–day, and post–shift.

We talked to employees about their jobs, the CI application process, and their concerns with this process.

What NIOSH Found

There is potential for exposures to total dust greater than the OSHA limit during all CI application operations.

Respirable dust levels were typically low during all CI operations.

The CI dust contains mostly particles, not fibers. Most of the fibers in the dust are large and cannot travel into the lower areas of the lung.

Applying moistened CI into attics reduces the amount of CI dust in the air.

What Managers Can Do

Require (at a minimum) NIOSH approved, N95 particulate filtering respirators be worn during CI activities.

Create a respiratory protection program based on OSHA Respiratory Protection Standard, 29, Code of Federal Regulations 1910.134.

If possible, use a moistening system for attic CI application to reduce CI dust.

Use engineering controls (examples are given in the report) in the hopper area to reduce exposures to hopper operators.

Make sure areas of CI use are cleaned on a regular basis to reduce unnecessary dust exposure.

What the Employees Can Do

Wear, at a minimum, a NIOSH approved, N95 particulate filtering respirator during all CI related operations.

Replace these respirators when dirty or damaged.

In attics, apply CI away from body and if possible, reduce amount of time in corners.

Wash your hands, if possible, before eating or drinking.

Clean–up hopper area after your shift is completed to minimize unnecessary generation of CI dust.

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National Institute for Occupational Safety and Health
NIOSH

Health Hazard Evaluation Report 2000–0322–2827
NIOSH Exposure Assessment of Cellulose Insulation Applicators

March 2001

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SUMMARY

In July 1994, cellulose insulation (CI) was nominated to the National Toxicology Program (NTP) for a comprehensive toxicological evaluation. The evaluation consisted of two components: (1) a bulk analytical characterization of CI and (2) an exposure assessment of U.S. contractors applying the CI in residential and commercial buildings. The National Institute for Occupational Safety and Health (NIOSH) was presented with an opportunity to assist in the evaluation of CI by conducting the exposure assessment through an interagency agreement with the National Institute of Environmental Health Sciences/NTP.

NIOSH conducted the CI exposure assessment, which included a medical component, with 10 contractors located across the United States. During each contractor site visit, air samples were collected for total dust, respirable dust, and for scanning electron microscopy (SEM) analysis to characterize any fibers in the dust. The CI installer and hopper operator each had two SEM air samples collected for each day of CI activities. Bulk samples of the CI were collected and analyzed for metals, boron, and sulfate content. Real–time and video exposure monitoring were also conducted to further characterize the CI dust and workers' exposures.

For the 10 contractor site visits, 175 personal breathing zone (PBZ) total dust, 106 area total dust, and 90 area respirable dust air samples were collected during CI related activities. There were 26 employees with total dust eight–hour time–weighted averages (8–hour TWAs) exceeding the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) of 15 milligrams per cubic meter (mg/m^3) and 42 exceeding the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) of 10 mg/m^3. Respirable dust air sampling and real–time monitoring with particle size discrimination indicated low levels of respirable dust generation. The SEM analyses revealed that fibers were on average 28 micrometers (µm) in length and ranged from 5 µm to 150 µm. CI installers' PBZ samples and area air samples for total dust were significantly higher for dry attic applications than wet attic applications ($p < 0.01$). Respirable dust air samples collected in the attic area indicated a significantly higher concentration for dry applications than wet applications ($p < 0.01$). The hopper operators' total dust exposures were significantly higher during wet wall/ceiling applications than dry wall/ceiling applications ($p = 0.02$). Analysis of variance (ANOVA) tests evaluating exposure concentrations revealed that total dust air samples collected in the PBZ of workers (CI installer in attics, CI installer in walls, hopper operator during attic applications, and hopper operator during walls/ceiling applications) varied significantly during dry applications ($p < 0.01$). The respirable dust air samples collected in various areas (attic area, hopper area during attic applications, and hopper area during walls/ceiling applications) differed significantly during dry applications ($p = 0.03$).

Twenty–three workers participated in the medical phase of the investigation. The workers completed a medical and work history questionnaire, performed serial peak flow tests, and completed multiple acute symptom surveys. The medical questionnaires indicated respiratory, nasal, and skin symptoms that employees attributed to CI exposure. The most common symptoms reported while working with CI included nasal symptoms (35%), eye symptoms (35%), and morning phlegm production (25%). There was a temporal association between CI exposure and eye symptoms. There is little evidence of lower respiratory system health conditions associated with CI exposure.

Based on the air sample data collected from the 10 contractor site visits, NIOSH investigators conclude that there is potential for overexposure to cellulose insulation (CI). Employees in virtually all CI application activities were exposed to total dust levels which exceeded the OSHA 8–hour TWA of 15 mg/m^3. CI installers' PBZ total dust samples and area air samples for total and respirable dust were significantly higher for dry attic applications than wet attic applications. Eye symptoms were temporally associated with CI exposure. There is little evidence of lower respiratory tract health conditions associated with CI exposure. Suggestions to improve the health and safety of employees in this industry, through the use of engineering controls and personal protective equipment (i.e., respirators), are presented in the Recommendations section of this report.

Keywords: SIC Code 1742 (Plastering, Drywall, Acoustical, and Insulation work [Insulation buildings–contractors]); cellulose insulation, recycled, newspaper, boric acid, fire–proofing, residential, attic, serial peak flow, respiratory, skin, eye.

TABLE OF CONTENTS

INTRODUCTION

Cellulose insulation (CI) was nominated to the National Toxicology Program (NTP) for a comprehensive toxicological evaluation. The evaluation consisted of two components: (1) a bulk analytical characterization of CI and (2) an exposure assessment of U.S. contractors installing CI in residential and commercial buildings. The National Institute for Occupational Safety and Health (NIOSH) was presented with an opportunity to assist in the evaluation of CI by conducting the exposure assessment through an interagency agreement with the National Institute of Environmental Health Sciences/NTP.

NIOSH conducted the CI exposure assessment with 10 contractors located across the United States, after contacting various contractors, discussing NIOSH and the nature of the research project, and receiving support by contractor management. NIOSH investigators conducted an initial environmental protocol development investigation in Colorado in January 1998. Based upon the initial findings, the NIOSH investigators determined the sampling methods needed to characterize CI applicators exposures to generated CI dust. This report summarizes the NIOSH evaluation and provides recommendations for improving occupational health and safety of CI applicators.

BACKGROUND

CI is manufactured primarily from recycled newspapers and other recovered paper fibers. Fire retardants such as boric acid, borax, other similar borates, or ammonium sulfate are added. Some of the cellulose products contain gypsum or starch. "Stabilized Cellulose" is a form of CI that has a small amount of water added and is applied in attics. This type of insulation has an adhesive added, so that with the addition of water, the applied depth of the CI is stabilized. CI wall spray also has a small amount of water added to assist in securing CI between wall studs. ***(CI with water added is listed as "wet" CI in this report. It should be emphasized that only a small amount of water is added and that the CI is only moist to the touch.)*** There are approximately 30–35 companies currently manufacturing CI in 50–60 plants across the U.S.[1]

Any type of CI must comply with certain federal agencies and industrial standards. These include, but are not limited to: the Consumer Products Safety Commission, Interim Safety Standard for Cellulose Insulation[2]; the American Society for Testing and Materials (ASTM) C739–97, Standard Specification for Cellulosic Fiber (Wood–Base) Loose–Fill Thermal Insulation[3]; and ASTM C1149–97, Standard Specification for Self–Supported Spray Applied Cellulosic Thermal Insulation.[4]

On two different occasions NIOSH has evaluated CI exposures of employees weatherizing homes.[5,6] The first evaluation involved a weatherization company that applied CI into an attic and outside walls. The 8–hour time–weighted averages (TWAs) were as follows: 20.6 milligrams per cubic meter (mg/m^3) and 34.5 mg/m^3 for the CI installers in the attic, 5.2 mg/m^3 for the installer of CI in outside walls, and 0.9 mg/m^3 and 4.3 mg/m^3 for the hopper operator. Employees wore NIOSH approved half–mask respirators with cartridges for dusts, fume, and mist while blowing CI into attics and disposable dust masks while loading CI into the hopper. The second evaluation was another weatherization program involved with reducing the energy consumption of low–income housing. Personal breathing zone (PBZ) air samples were collected for total dust during CI application activities and resulted in the following air sample concentrations: 4.6 mg/m^3 for the employee applying CI into walls, 13.8 mg/m^3 for the employee trying to get the hopper running, 2.2 mg/m^3 for the employee also working on the hopper, 4.3 mg/m^3 for the hopper operator, and $\geq$40.8 mg/m^3 for the CI installer in the attic. All the employees wore half–face respirators with high efficiency particulate air (HEPA)/ organic vapor cartridges.

PROCESS DESCRIPTION

Attic Cellulose Insulation Application

CI application in attics begins with attic preparation (See Appendix F – Picture 1). Attic preparation may be performed by a separate crew or by the same crew that conducts the CI application. Fiberglass batting is laid over the top of pipes and recess lights, barriers are installed in the attic soffit area to prevent CI from passing through the attic to the outside, and other activities are performed depending upon the attic. An application hose is brought up to the attic through an attic access panel. CI is then applied to the specified R–value (resistance to heat flow).[7] CI can be applied dry or wet. When the CI is applied wet, there is a misting device in–line with the application hose close to the hopper area.

Wall Cellulose Insulation Application

Dry Cellulose Insulation

Dry application of CI into existing walls begins with holes being drilled into the inside or outside wall between wall studs. CI is then applied through a smaller diameter hose (1–2 inches ["]) than is used with the other methods of CI application. The CI is applied and the hose is pulled out of the wall as pressure builds (otherwise the wallboard could release from the wall). A plug is then put into the drilled hole to keep the CI in the wall space. The plugs can be many different types of materials.

Wet Cellulose Insulation

For wet CI application into newly constructed walls, a misting device is placed at the end of the application hose. As the CI passes through the hose, the water moistens the CI and the surface of the wall to assist in adherence. The CI is moistened enough to stick into the wall without falling out of the wall space (See Appendix F – Picture 5). Excess material protruding out from between the wall studs is removed with an electric roller. The excess material is then vacuumed directly into the hopper or shoveled into trash bags or cans and put into the hopper for reuse. In some areas of the country, polyethylene sheeting was stapled to the wall studs of exterior walls after the CI application to serve as a vapor barrier and to keep the CI in the wall space. Interior walls with no wallboard backing material, as is found for exterior walls, have a white cloth material (resembling cheese cloth) stapled to the wall studs. CI is then applied to that surface and the process proceeds as previously described. Some contractors will then staple a wire mesh to the walls studs to keep the CI from falling out of the wall space.

Cellulose Insulation Hoppers

Hoppers used for CI applications come in many different shapes and sizes. There were two basic types observed during this project: those with recycling capability built in and those without. The hoppers with their own recycling capability are larger and have more advanced operation controls (setting units in revolutions per minute [rpm] and pounds per square inch [psi]). The smaller hoppers use control plates to set the amount of material being fed through the hopper to the hose and have a dial for the amount of air being sent through the hose. Attic applications typically use no hopper plates and are set for full air. CI application into existing walls will use less air and plates to reduce the amount of material.

CONDUCT OF FIELD STUDIES

Site Selection

Site selection and the number of site visits was based on (1) having at least one contractor from each section of the country (i.e., Northwest, Midwest, Southeast, etc.), (2) the number of consenting contractors, (3) the ability to provide wall and attic CI application sites during survey time period, and (4) appropriate sample size for various statistical comparisons. Before NIOSH personnel arrived for the survey, each contractor was contacted to obtain their consent and a mutually agreeable date for the survey, and to discuss the planned sampling efforts and details of their operation. After each site visit, each contractor received a report which included sections on sampling methods, discussion of job sites sampled, air sample results, conclusions, and recommendations.

Sampling Protocol Development

The first contractor survey was conducted over a three–day period to develop a sampling protocol for the rest of the project. The survey involved PBZ and area air sampling, real–time monitoring using a portable dust monitor (PDM), and video exposure monitoring (VEM) during CI application activities. The survey objective was to observe the CI application process, to work with different parameters of the various sampling methods to determine the most effective set–up, and to facilitate discussion of the process with the employees conducting the application.

Sample Collection

Samples collected at each application site were focused in two areas: around the CI installer and around the employee dumping bags of CI into the hopper. Area and PBZ air samples for total and respirable dust were collected in both areas and subsequently analyzed gravimetrically. Additionally, each sample was analyzed for boron and sulfate content. Two PBZ, scanning electron microscopy (SEM) samples were collected in each of the two areas. The sampling time for each sample depended upon the extent of material loading on the filters. Real–time monitoring of total and respirable dust was conducted during CI applications when the opportunity presented itself.

Employee duties throughout the day were highly variable and no specific task lasted eight hours. Therefore, the air sampling protocol was designed to collect task–based (i.e., short–term) samples for each worker involved with specific CI activities for the duration of each specific work task. Analytical results were used to calculate both total and respirable dust concentrations for each task–based sample and 8–hour TWA exposures for each worker. The 8–hour TWAs included all task–based samples for the entire work–shift by each specific worker. Area 8–hour TWA results are based on the compiled exposure results in that specific area for the entire task period. Calculated area 8–hour TWA concentrations are intended to be representations of potential exposure. In calculating the 8–hour TWAs, time periods of non–involvement with CI–related activities were not sampled and considered to be a zero exposure.

In–depth Surveys

Four in–depth surveys (including VEM or return visit for further evaluation) were conducted. Two of these involved the use of VEM along with air sampling, PDM measurements, and the medical evaluation. VEM was conducted inside the attic with the CI installer and inside the truck with the hopper operator during those CI applications. The other two surveys involved return visits to further evaluate the CI application process due to application system change. One contractor changed from a dry to a moistened CI application system. The second contractor used their original moistening application system not used during the initial survey. In this case, the return survey was to evaluate the contractor's usual CI application operations.

Methods

Industrial Hygiene Sampling

Total and Respirable Dust Sampling

Area and PBZ air samples for total dust were collected on tared 37–millimeter (mm) diameter, 5–micrometer (µm) pore size polyvinyl chloride (PVC) filters, at a calibrated flow rate of 1.0 liter per minute (lpm). The filters were gravimetrically analyzed (filter weight) according to NIOSH Method 0500.[8] Area air samples for respirable dust were collected with tared 37–mm diameter, 5–µm PVC filters in line with a 10–mm cyclone at a calibrated flow rate of 1.7 lpm. The filters were gravimetrically analyzed according to NIOSH Method 0600.[8] The analytical limit of detection (LOD) for the total and respirable dust filters were 0.08 milligrams (mg) and 0.02 mg, respectively, which is equivalent to a minimum detectable concentration (MDC) of 0.8 mg/m^3 and 0.2 mg/m^3, respectively, assuming a sample volume of 100 liters.

Scanning Electron Microscopy (SEM) Sampling

PBZ air samples of the CI dust were collected using a modified version of NIOSH Method 7402.[8] Samples were collected using a 25–mm diameter cassette with an electrically conductive extension cowl, 0.8 µm pore size polycarbonate filters, at a calibrated flow rate of 1.0 lpm. The filter was analyzed by SEM for fiber count, fiber size, and fiber characteristics (cellulose, fiberglass, others). Analyses were conducted in a NIOSH laboratory, using the SEM in the Division of Applied Research and Technology (DART). The final analytical protocol used was as follows:

1. The samples were first given a conductive carbon coat to minimize fiber charging. This also improved the secondary electron images.

2. The prepared sample was placed in the instrument sample holder.

3. The samples were analyzed using a secondary electron detector, which was adjusted to a magnification of 1,200X, and the center of the filter was found using the X–Y manipulators. Fields were examined at regular intervals along a traverse in one direction. Fibers were counted in each field using the "A" rules. Based upon morphology, cellulose and other fiber types were distinguished and the relative proportion of fibrous to non–fibrous material in the field was recorded.

4. A minimum of 40 fields were counted. If the edge of the filters was encountered before 40 fields were analyzed, a new traverse in another direction was begun from the center of the filter.

5. The actual analysis was conducted on the image analyzer which had greater image resolution than the SEM screen. At least two fields were captured and saved on disk for archival and presentation purposes.

6. The fibers were sized by comparison to a calibrated, overlain micron bar.

Bulk Material Sampling

Bulk samples of CI were collected from each contractor and analyzed by two methods. The first method was a water extraction for boron and sulfate content. The second method was NIOSH Method 7300,[8] analyzing for boron, sulfate, and other elemental constituents. These methods analyzed for the following metals: aluminum (Al), arsenic (As), barium (Ba), beryllium (Be), calcium (Ca), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), iron (Fe), lithium (Li), magnesium (Mg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), phosphorus (P), platinum (Pt), selenium (Se), silver (Ag), sodium (Na), tellurium (Te), thallium (Tl), titanium (Ti), vanadium (V), yttrium (Y), zinc (Zn), and zirconium (Zr). Samples were analyzed for both methods using an inductively coupled plasma emission spectrometer.

Particle Count and Sizing

Real–time sampling was conducted to monitor the particulates generated by distinct events during CI application activities in the attics and around hoppers. The Grimm Model 1.105 Dust Monitor (Labortechnik GmbH & CoKG, Ainring, Germany) was used to collect the real–time data.[9] This PDM is a light scattering aerosol spectrometer designed for real–time particulate measurement with particle size discrimination. Eight channels collect count information for particle sizes greater than 0.75, 1, 2, 3.5, 5, 7.5, 10, and 15 µm. For each operation, data were integrated for 1 minute (min) and stored sequentially on the Grimm data card over the entire time period. This particle count and size information was then downloaded to a laptop computer. Start and stop times for distinct events were also recorded.

The mass distribution of particles is reported as a concentration in micrograms of particulate per cubic meter of air (µg/m^3). Particles are sized based upon the amount of light scattered by individual particles. The monitor operates at a flow rate of 1.2 lpm. Estimates were made of the mass median aerodynamic diameter (MMAD) and the associated geometric standard deviation (GSD) based on the integrated particle size discrimination provided by the instrument. *The MMAD is the mid–point of the aerodynamic size distribution where half the particles are larger and half are smaller.* A CI density correction factor for the PDM was applied during data analysis. The density correction factor is the ratio of an integrated total dust sample to the indicated instrument total dust weight of the CI sampled. The conversion factors were used to adjust the instrument concentration values.

Video Exposure Monitoring (VEM)

Real–time particulate sampling, coupled with video recording, was performed during two surveys to evaluate worker exposures. VEM was typically conducted concurrently during both attic CI application and hopper loading operations. The objective of VEM during CI related activities is to observe the work practices of the CI installer and the hopper operator and their associated total dust exposures. The VEM may indicate certain work practices that can increase or reduce the concentration of dust in the air.

During CI application activities, a Hand–held Aerosol Monitor (HAM) (PPM Inc., Knoxville, Tennessee) was used to measure PBZ relative air contaminant concentrations. The HAM operates by continuously drawing aerosols through an illuminated sensing volume and detecting the amount of light scattered by all the particles in that volume.[10] The analog output of the HAM is recorded by a data logger. The information collected on the data logger is downloaded to a computer and converted into a spreadsheet for analysis. The HAM was operated on the

0–200 volt scale during monitored activities in the attic and in the truck with the hopper.

VEM can be used to identify sources of worker exposure to air contaminants and to address questions such as: How does exposure vary among the components of a job, What are the shortcomings of a control, and How quickly does the air contamination decay once an operation has stopped?[11,12] While air concentrations are being measured with the HAM, workplace activities are recorded on videotape. The analog output from direct reading instruments can be overlaid on a video recording as a moving bar that has a height proportional to the air contaminant concentration (See Appendix F – Picture 6 for example of finished product). This technique shows how worker exposures are related to work activities, and it permits control recommendations that are focused upon actual exposure sources.

Medical Monitoring

Health Assessment of Symptoms and Lung Function

NIOSH investigators recruited available workers performing CI application at each work site. The workers were asked to complete a self–administered questionnaire, perform serial peak flow tests, and complete repeated acute symptoms survey.

Questionnaires:

A modified version of the American Thoracic Society (ATS) standardized questionnaire (Appendix G) was administered to all participants to obtain the prevalence of chronic respiratory, eye, nose, throat, and skin symptoms. Also, information concerning smoking history and work history was solicited. This questionnaire took approximately 10–15 minutes to complete. In addition, a short acute symptom survey (Appendix H) was periodically administered by NIOSH investigators to study participants before and after each work shift, 2 times during the work shift, and at bedtime (self–administered) for a total of 5 data collection periods per day. Peak expiratory flow rate (see below) was measured at the same times the acute symptoms surveys were completed.

Peak flow measurement:

NIOSH investigators obtained serial determinations of the peak expiratory flow rate (PEFR) using Wright portable flow meters. Peak flow refers to the amount of air in liters per minute that can be blown through the flow meter in one sharp breath. PEFR was measured concomitantly with the acute symptom surveys (5 times per day from 1 to 4 days). PEFR was measured pre–shift, 3 times during the shift, and at bedtime. The participants were instructed in the proper use of the portable meters. Three exhalations were to be recorded each session, and the maximum of the three was accepted as the PEFR determination. A participant was considered to have significant bronchial lability if the *amplitude percent mean* ([maximum – minimum]/ mean) PEFR was greater than 20%.[13]

Statistical Strategy

Individual air sample concentrations for total and respirable dust were compiled into a statistical analysis system (SAS) database. The data were arranged and grouped according to the type of sample, PBZ or area, and type of CI application. Concentration data were analyzed to compare CI dust concentrations during wet and dry CI applications. T–tests were used to accept or reject a null hypothesis of no significant difference in wet and dry concentrations. Statistical significance was set at a level of 0.05. Additionally, all employee tasks and their respective air sample concentrations during either wet or dry CI applications were grouped separately and analyzed to compare exposure potential. An analysis of variance (ANOVA) was used to accept or reject a null hypothesis of no significant difference in employees exposures. Statistical significance was set at a level of 0.05.

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 increases 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),[14] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[15] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs).[16] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 95–596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short–term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

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

Cellulose Insulation

There is a limited amount of published CI exposure or toxicological data. Available information is largely based on the hazards associated with wood and its organic constituents in the paper production industry, and generated wood dust in occupations such as carpentry.

Environmental

CI is considered a "nuisance" dust and is classified by ACGIH as particulate not otherwise classified (PNOC) or by OSHA as particulate not otherwise regulated (PNOR). Nuisance dusts have been referred to as dusts that have little adverse effect on the lungs and, when maintained under reasonable control, do not result in significant organic disease or toxic effect. However, in sufficient quantities any dust will elicit some cellular response in the lung. The lung–tissue reaction caused by the inhalation of PNOCs has the following characteristics: (1) the architecture of the air spaces remains intact; (2) collagen ("scar tissue") is not synthesized to a significant extent; and (3) the tissue reaction is potentially reversible.[17]

PNOCs in extreme concentrations in the workplace air may cause the following: a serious reduction in visibility; unpleasant deposits in the eyes, ears, and nasal passages; or contribute to injury of the skin or mucous membranes by chemical or mechanical action per se, or by rigorous skin cleansing procedures necessary for their removal.[17]

The OSHA PEL for PNORs is 15 mg/m^3 for total dust and 5 mg/m^3 for respirable dust. Although a NIOSH REL for particulates has not been established, after reviewing available published literature, NIOSH provided comments to OSHA on August 1, 1988, regarding the "Proposed Rule on Air Contaminants" (29 CFR 1910, Docket No. H–020). In these comments, NIOSH questioned whether the proposed OSHA PEL (as an 8–hour TWA) of 10 mg/m^3 for PNORs (defined as total dust in this report) was adequate to protect workers from recognized health hazards.[14]

ACGIH recommends a total dust, 8–hour TLV–TWA of 10 mg/m^3 for inhalable PNOCs containing no asbestos and <1% crystalline silica; and 3 mg/m^3 for respirable dust.[15] For substances, such as PNOC, without a STEL (a 15 minute TWA, which *can not* be exceeded at any time during the workday), ACGIH recommends a concept called an excursion limit.[15] which is defined by the following:

1. Excursions in worker exposure levels may exceed 3 times the TLV–TWA for no more than a total of 30 minutes during a workday.

2. Under no circumstances should excursions in worker exposure levels exceed 5 times the TLV–TWA, provided that the TLV–TWA is not exceeded.

Medical

Human Studies

No epidemiologic studies investigating the association of exposure to CI and respiratory disease in humans were identified in the published medical literature. One case report postulates that inhalation of CI may result in pulmonary alveolar proteinosis. McDonald report the development of this disorder after exposure to household dust from a ventilation system. The dust contained cellulose fire–resistant fibrous insulation material. The affected individual showed symptomatic improvement once exposure to the insulation material ceased.[18]

Although direct effects of CI on human health have not been studied, cellulose particles from other sources have been associated with the formation of foreign body granulomas in humans. Zeltner reported a fatal case of pulmonary granulomatosis in a male drug abuser from illicit intravenous injections of microscopic cellulose, a binding agent in pentazocine tablets.[19] Brittan described a case of cellulose granulomatous peritonitis in a woman which they ascribed to cellulose contamination during a previous surgery. Within the giant cells and necrotic debris, there were numerous hollow fibers of varying length with the characteristic morphological features of vegetable cellulose fibers.[20]

Although there are no occupational health studies of CI workers, a Swedish team reported adverse health outcomes in a soft paper mill. The odds ratios for mortality from chronic obstructive pulmonary disease and from asthma among exposed workers were significantly elevated.[21] A morbidity study found dose–related irritation of the upper respiratory tract. A decrease in vital capacity of the lung was associated with long term exposure to dust.[22] Heederik found evidence lower FEV_1 in workers exposed to paper mill dust compared to unexposed workers.[23]

Animal Studies

In an evaluation of the potential effects of CI inhalation, SPF Wistar rats were exposed to CI dusts. The pulmonary pathology showed evidence of dose–related changes in pulmonary response, characterized by diffuse macrophage infiltration, microgranuloma formation, alveolitis, and epithelial hyperplasia.[24] When Sprague–Dawley rats were exposed to plant dusts, cellulose–induced morphologic changes in the lung were produced that were identical to granulomatous inflammation and fibrosis, whereas fiber–free extract of wood dust did not cause pathological changes in the lung.[25]

Milton instilled respirable cotton dust particles intratracheally in hamsters and produced both granulomata and mild centrilobular emphysema. Cellulose–exposed animals had decreased lung distensibility, noncaseating granulomata, and increased volume density of parenchymal tissue elements. These changes were cited as hallmarks of the histologically apparent lung fibrosis. The fibrotic response to cellulose occurred at a high lung burden (total dose was approximately 3 milligrams per gram [mg/g] lung tissue). The authors noted that toxicity may have been due to overload of the lung's capacity to remove insoluble foreign material as well as any intrinsic toxicity of cellulose.[26] However, cotton dust may provoke different pulmonary effects than cellulose encountered in paper dust.

Boric Acid

Boric acid, BH_3O_3, is also known as boracic acid, orthoboric acid, or borofax. It is colorless, odorless, and takes the form of transparent crystals, white granules, or powder. Boric acid has a number of uses that include, "weatherproofing wood and fireproofing fabrics; as a preservative; manufacture of cements, crockery, porcelain, enamels, glass, borates, leather, carpets, hats, soaps, artificial gems, in nickeling baths; cosmetics; printing and dyeing; painting; photography; for impregnating wicks; electric condensers; and hardening steel. It is also used as an insecticide for cockroaches and black carpet beetles."[27]

Boric acid is a poison when ingested and is moderately toxic by skin contact and subcutaneous routes. Ingestion may cause diarrhea, abdominal cramps, erythematous lesions on skin and mucous membranes, circulatory collapse, tachycardia, cyanosis, delirium, convulsions, and coma. Ingestion of <5 grams has caused death in infants, and 5–20 grams, in adults. Chronic exposure may result in borism (dry skin, eruptions, and gastrointestinal disturbances).[28] Workers exposed to boric acid dust at concentrations of >10 mg/m^3 experienced eye and upper respiratory tract irritation.[29] Heavily impregnated respirable cellulose dust may liberate the readily soluble boric acid in significant amounts in lung tissue.

At this time, there are no relevant evaluation criteria for boric acid.

Borax

Borax, $B_4O_7Na_2 \cdot 10H_2O$, is also referred to as sodium borate decahydrate, disodium tetraborate decahydrate, sodium tetraborate decahydrate, or sodium pyroborate decahydrate. This compound is a white, odorless, crystalline solid. Sodium tetraborates (includes anhydrous, pentahydrate, and decahydrate) are used in the manufacture of glazes and enamels, are found in cleaning compounds and fertilizers, and are used in the artificial aging of wood.[30]

Exposure to borates can result in the irritation of the eyes, nose, and throat. High concentrations can lead to gastrointestinal irritation, kidney injury and death.[31] An investigation was conducted into the relationship of estimated borax dust exposures to respiratory symptoms, pulmonary function, and chest radiograph abnormalities in actively employed borax workers.[32] Acute respiratory irritation symptoms (i.e., dryness of the mouth, nose, and throat; dry cough; nose bleeds; sore throat; productive cough; shortness of breath; and chest tightness) were related to exposures of 4 mg/m^3 or more. The study indicated that radiographic abnormalities were uncommon and unrelated to dust exposure, and that borax dust acted as a simple respiratory irritant. NIOSH conducted a health hazard evaluation (HHE) where borax dust samples were collected.[33] Eight–hour TWA concentrations ranged from 2.9 mg/m^3 to 29.9 mg/m^3. Employees in the borax area reported symptoms of mucous membrane, eye, nose, and throat irritation; some bleeding after nose–blowing; and dry and chapped hands. Workers industrially exposed to borax often suffer from chronic eczema; long–term exposure to borax dust may lead to inflammation of the mucous membranes of the upper airways and to conjunctivitis.[34]

The NIOSH REL and the ACGIH TLV for borax is 5 mg/m^3. OSHA does not have a PEL for borax. However, OSHA concluded that an 8–hour TWA of 10 mg/m^3 (under the vacated 1989 PELs) was appropriate for the tetraborates and that this limit would substantially reduce the risks of eye, skin, and respiratory irritation caused by all forms of sodium tetraborate.[35]

RESULTS

Comprehensive Project Results

Personal Protective Equipment (PPE)

Most of the evaluated contractors provided disposable, particulate respirators to their employees. Some of these respirators included North® full–face w/ HEPA filters, 3M® particulate facepieces, and Gerson® particulate facepieces. Approximately half of the contractors were familiar with the new OSHA Respiratory Protection Standard,[36] the NIOSH respirator certification system,[37] and had implemented these into their company's day–to–day operations. Few contractors had a written respiratory protection program established in their workplace. One contractor's employees wore Tyvek™ suits during attic preparation and CI application.

Cellulose Insulation Statistical Analyses

The airborne CI concentration data were log–transformed to perform statistical analyses on normally distributed data. Table 1 displays the t–tests comparing wet and dry concentrations of CI. The table also presents the geometric means, standard deviation, maximum and minimum concentrations, and p–values. CI installers' exposures to total dust are significantly higher during dry attic applications compared to wet attic applications ($p < 0.01$). Area air samples for total and respirable dust also revealed a significantly higher CI concentration during dry attic applications than wet attic applications ($p < 0.01$). The hopper operators' exposure to total dust was significantly higher during wet wall/ceiling applications than dry wall/ceiling applications ($p = 0.02$).

Table 2 displays the ANOVA analyses comparing employees' or area exposure concentrations using wet or dry CI, including the geometric means, standard deviation, maximum and minimum concentrations, and p–values. PBZ air samples for total dust varied significantly during dry applications ($p < 0.01$). The area air samples for respirable dust indicated a significant difference in concentration during dry applications ($p = 0.03$).

Medical Evaluation

Twenty–three workers participated in the medical phase of the investigation. All workers who were present at the site visits and who were involved in CI application agreed to participate. Medical evaluations took place at 7 sites. The average age at the time of the investigations was 36 years (range: 21–62). Their average time that these workers were employed in the CI industry was 4 years. Almost all installed CI full–time and year round.

Medical History Questionnaire

On the questionnaire, workers reported several symptoms while working with CI. Six workers (26%) reported that they experienced some respiratory symptoms since they began working with CI. The only chronic respiratory symptom reported on the questionnaire was the production of phlegm in the morning; one worker reported having it always, 2 often, 2 sometimes, and 1 rarely. Of the workers who reported morning phlegm, four were current smokers, one was an ex–smoker, and one was a never–smoker. The smokers were more likely to report phlegm production than nonsmokers, but the difference was not statistically significant.

Eight (35%) workers reported nasal symptoms. These included stuffy nose or drainage. However, none of these workers reported a temporal relationship between their nasal symptoms and working. Eight (35%) workers also reported eye symptoms on the questionnaire, including red, itchy, or watery eyes more than twice in the previous 12 months. Four (50%) of these workers reported a temporal association between their eye symptoms and working. Three (13%) workers reported skin symptoms, which included skin rash, dermatitis, hives, or eczema. Two of the three workers reported a workplace association with their skin symptoms.

Acute Symptoms Survey

Ten (43%) of the 23 workers reported at least one symptom during the survey. The most common symptom reported on the symptom survey was coughing with, 5 of 23 workers reporting being bothered by coughing at least on one occasion. Two workers reported wheezing. One of these workers reported wheezing on 25% of the symptoms survey responses; however, this worker noted that he had a respiratory tract infection at the time of the survey. The next most common symptoms were nose symptoms and throat symptoms, with four workers reporting at least one nose symptom and four reporting at least one throat symptom. Only two workers reported eye symptoms and each reported it only once during the site visit. Seven workers reported job–related ache or pain within the 12 months prior to completing the questionnaire. The most common complaint was lower back pain (five workers), followed by shoulder pain (two workers).

Peak Flow Monitoring

PEFR was measured on 22 workers five times per day. The median number of days that the workers were monitored was 3 (range: 1–4). All monitoring was at work except the bedtime reading. No monitoring occurred on days while the workers were away from work. The percent amplitude mean was less than 20% for all workers. The median percent amplitude mean was 7.8%. The highest was 16.9%. None of these three workers with percent amplitude means greater than 15% reported acute respiratory symptoms on the symptom survey.

Individual Contractor Results

The following provides a background of each sampling site and summary results for air sampling, PDM, and VEM conducted during each contractor site visit. Appendices A–E present the individual contractor data (in tabular form) for the PBZ and area air samples, the SEM air samples, the bulk sample analyses, PDM, and VEM results, respectively. For the SEM analyses, the fiber lengths and averages are estimates and are probably understated due to the difficulty in accurately measuring the fibers. Each contractor received an individual report of their evaluation after the site visit was completed.

Contractor 1

Background

During January 13 and 14, 1998, NIOSH evaluated three CI application projects in Colorado. The first site was an existing attic CI application. The attic was approximately 450 square feet (ft^2), had a roof approximately 4–5 feet (ft) high, and was not equipped with an outside attic ventilation damper (located in attic wall). The application consumed 27 bags (installed dry) to an approximate depth of 8–10". The hopper control was set at full air (10 on a 1–10 scale) with no control plates in place. The second site was an existing residential wall CI application. Interior walls were injected with CI until full through holes made between wall studs at the top and bottom. The hopper control was set at 8; a control plate was in place. The third site was an existing residential attic CI application. The attic was approximately 800 ft^2, had a 5–6 ft high roof, and was equipped with an outside ventilation damper. Forty bags of CI were applied dry to a depth of approximately 6–10". The hopper control was set at full air; no control plates were in place.

Sampling

Total and Respirable Dust Air Sampling

Over the January 13 and 14, 1998, sampling period, the area and PBZ, total dust concentrations ranged from 0.73 mg/m^3 to 109.3 mg/m^3, while the area respirable dust concentrations ranged from 0.57 mg/m^3 to 2.65 mg/m^3. The highest total and respirable dust concentrations were found while applying CI into the attic area on January 13. All PBZ and area, total and respirable dust, 8–hour TWA results were below the OSHA PELs.

There were excursions in worker exposure levels that exceeded 5 times the TLV–TWA during the January 13 and 14, 1998, sampling period. The PBZ total dust concentrations were approximately 100 mg/m^3 for the attic and hopper workers on January 13 and were approximately 70 mg/m^3 for the attic CI installer on January 14.

Scanning Electron Microscopy Air Samples

Samples collected for SEM analysis were used for experimental purposes to help define significant parameters to guide future sampling efforts. These factors included: collection time and pump volume for optimal filter loading, configuration of SEM instrument parameters for best observation of material collected, initial observation of material leading to specific characterization procedures, and the general practice of analyzing the samples. Most of the samples taken were overloaded with material.

Portable Dust Monitor Measurements

PDM measurements were collected during CI–related activities in an existing residential attic on January 13. Measurements were collected in the attic during preparation activities before the CI application began. The MMAD was estimated at 7.9 µm with a GSD of 1.9. The respirable mass fraction of the sample mass was approximately 20%. During the CI application in the attic, the MMAD was estimated at 15 µm with a GSD of 2.5 during the CI application in the attic. The respirable mass fraction of the sample mass was approximately 10%. The PDM inside the truck indicated an estimated MMAD of 18 µm and a GSD of 2.2. The respirable mass fraction of the sample mass was approximately 5%. PDM measurements were collected during an existing residential attic CI application on January 14. During the CI application in the attic, the MMAD was estimated at 28 µm with a GSD of 2.4. The respirable mass fraction of the sample mass was approximately 2%. Inside the truck during the CI application in the attic, the MMAD was estimated at 58 µm with a GSD of 2.8. The respirable mass fraction of the sample mass was approximately 1%.

Video Exposure Monitoring

VEM was performed on CI activities during an existing residential attic CI application. VEM was conducted inside the attic and truck to measure relative air contaminant concentrations and improve our understanding of how the worker's individual tasks affect personal exposure to air contaminants.[38] Samples for total particulate were collected at the exit of the HAM probe (near the worker's breathing zone) during cellulose operations for calibration purposes. The samples were used to convert HAM output (volts) to concentration of total dust. In doing the conversion, one assumes that the aerosol content is constant. During the following discussion of results, the HAM output will be given in terms of "estimated particulate exposure."

The air sample collected at the exhaust of the HAM sampling probe, during VEM activities in the attic, indicated a total dust concentration of 28.5 mg/m^3. The peak estimated particulate exposure measured with the HAM during attic CI activities was approximately 128 mg/m^3. Appendix E – Figure 1 presents the HAM concentration responses during CI activities in the attic.

VEM was also performed in the truck while the worker dumped bags of CI into the hopper. The air sample collected at the exhaust of the HAM sampling probe, during VEM activities in the truck, indicated a total dust concentration of 7.1 mg/m^3. The peak estimated particulate exposure measured with the HAM during CI activities in the truck was approximately 55 mg/m^3. Appendix E – Figure 2 presents the HAM concentration responses during CI activities in the truck.

Contractor 2

Background

During April 27–30, 1998, NIOSH investigators (including two industrial hygienists and one medical officer) evaluated four CI application projects in Missouri. The first site involved a new residential home attic CI application. The attic roof was approximately 5 ft high and was not equipped with an outside ventilation damper. This application consumed 58 bags (installed dry) to an approximate depth of 10". The hopper control was set at full air; no control plate was in place. The second site involved an existing residential garage ceiling CI application. Ceiling sections were injected with CI until full through holes made in various ceiling locations. The hopper control was set at 3½. The third site involved an existing residential attic CI application. This was a partial attic/wall application project in the attic above the garage. The attic roof was approximately 7–8 ft high and was not equipped with an outside ventilation damper. The fourth site involved a continuation of the project started on April 29. However, application of CI occurred in the main house attic. The attic was approximately 936 ft^2, with a 6–7 ft high roof, and was not equipped with an outside ventilation damper. Fifty–three bags of dry CI were applied to an approximate depth of 8–10". The hopper control was set at full air; no control plate was in place.

Sampling

Total and Respirable Dust Air Sampling

Over the April 27–30, 1998, sampling period, the area and PBZ total dust concentrations ranged from non–detectable to 431 mg/m^3, while the area respirable dust air sample concentrations ranged from non–detectable to 3.52 mg/m^3. The highest PBZ total dust concentration (431 mg/m^3) was collected on the CI installer during the attic application on April 27. The highest respirable dust concentration (3.52 mg/m^3) was collected in the attic area during the CI application on April 30.

During the four days of sampling, three total dust, PBZ, 8–hour TWAs exceeded the OSHA PEL and five total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV. The CI installer on April 27 exceeded the OSHA PEL. The application occurred in a new residential attic, which was relatively compact, and the CI was applied dry. The CI installer on April 29 also exceeded the OSHA PEL during an attic CI application located above the garage with a wall application around a bedroom closet from the second floor. The attic was spacious except in the corner areas enclosed by the bedroom wall, closet wall, and the roof. The CI installer on April 30 exceeded the OSHA PEL. The two PBZ, 8–hour TWAs over the ACGIH TLV, but not the OSHA PEL, were from the CI installer of the garage ceiling on April 28 and the hopper operator on April 29. The CI installer, PBZ, 8–hour TWA included air samples collected during the ceiling preparation (hole drilling in drywall) and the CI application in the garage ceiling.

The sampling on April 30 indicated an excursion in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The PBZ, total dust concentration for the hopper operator was approximately 33 mg/m^3.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 36%. The CI fibers ranged from 5 µm to greater than 150 µm in length. The average CI fiber length was 36 µm.

Portable Dust Monitor Measurements

Near the hopper on April 28, the MMAD was estimated at 11 µm with a GSD of 1.9. The respirable mass fraction of the sample mass was approximately 11%. Near the hopper on April 29, the MMAD was estimated at 13 µm with a GSD of 2.1. The respirable mass fraction of the sample mass was approximately 9%. During the CI application in the attic on April 30, the MMAD was estimated at 20 µm with a GSD of 2.5. The respirable mass fraction of the sample mass was approximately 7%.

Contractor 3

Background

During July 7–10, 1998, NIOSH investigators (including two industrial hygienists and one medical officer) evaluated four CI application sites in Ohio. The first site involved a multi–residential home wall CI application. The house was three stories high and was inhabited by different families. The application was the last in a series of applications for this particular house. Bedroom and living room interior walls of the second floor were applied with CI. This site consumed 10 bags of dry CI. The second site involved a new residential application. Dry CI was applied to first and second floor attics. The approximate total surface area of the two attics was 570 ft^2, with the second floor attic being slightly larger than the first. Each attic was roughly 6 ft high. This site consumed 22 bags of CI for the second floor attic and 19 bags for the first floor attic at an approximate depth of 6–10". The third site involved an existing residential attic application in a six–unit housing complex. The housing complex was sectioned into an attic above four housing units and an attic above two. Both attic sections were approximately 7 ft high and were equipped with outside ventilation dampers. These dampers were used to gain entrance into the attics. The job consumed 51 bags of dry CI with the four–unit housing side using 28 bags at a depth of approximately 8–10". The fourth site involved another six–unit housing attic. This attic was not separated into two distinct sections. The attic was approximately 7 ft high, and was equipped with an outside ventilation damper. Fifty–five bags of CI were applied dry at a depth of approximately 8–10".

Sampling

Total and Respirable Dust Air Sampling

Over the July 7–10, 1998, sampling period, the area and PBZ, task specific, total dust air sample concentrations ranged from 0.53 mg/m^3 to

141 mg/m³, while the area respirable dust air sample concentrations ranged from non–detectable to 2.59 mg/m³. The highest PBZ, total dust air sample (141 mg/m³) was collected on the CI installer during the attic application on July 8. The highest respirable dust air sample (2.59 mg/m³) was collected in the attic area during the CI application on July 8.

During the four days of sampling, three total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV, but not the OSHA PEL. The CI installer in the attic on July 7 exceeded the ACGIH TLV. This was an existing residential wall application. Polyethylene sheeting was used to confine generated CI dust to a small area of the room. The CI installer on July 8 exceeded the ACGIH TLV. Two new residential attics were applied with CI, both of which were relatively small. The CI installer in the attic on July 9 exceeded the ACGIH TLV. This application consisted of attic preparation and applying CI.

Sampling conducted on July 9 and 10 indicated excursions in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The total dust concentrations for the hopper operator were approximately 35 mg/m³ and 47 mg/m³ on July 9 and 10, respectively.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 36%. The observed CI fibers ranged from 5 µm to 90 µm in length. The average CI fiber length was 33 µm.

Contractor 4

Background

During August 10–13, 1998, NIOSH investigators (including three industrial hygienists) evaluated five CI application projects in Wisconsin. The first day involved a new commercial building wall CI application. The application of CI at this site took two days to complete. Exterior and some interior walls were applied with CI. The first day's application consumed 70 bags of CI. The hopper ran at approximately 1700 rpm with an air volume pressure of 9–10 psi. Seventeen bags of CI were consumed to complete this job during the second day. The hopper ran at approximately 2000 rpm and 3 psi. The third day's applications involved two new residential attics. The first residential attic was approximately **b** cathedral style that required crawling between ceiling joists, and **a** consisted of a 4–5 ft high roof. The attic was not equipped with an outside ventilation damper. Fifty bags of moistened CI were applied to an approximate depth of 11½" with an R value of 44. The CI was moistened by a misting device in–line with the CI application hose. The second residential attic was applied with 85 bags to an approximate depth of 13" with an R factor of 50. This attic was not equipped with an outside ventilation damper. The fourth day involved a new residential attic application. The attic consisted of a 6–7 ft high roof and was not equipped with an outside ventilation damper. One hundred twenty–six bags of moistened CI were applied to an approximate depth of 11½" with an R value of 44. CI was applied over the garage portion of the attic at an approximate depth of 5".

Sampling

Total and Respirable Dust Air Sampling

Over the August 10–13, 1998 sampling period, the area and PBZ, total dust air sample concentrations ranged from 0.31 mg/m³ to 33.3 mg/m³, while the area respirable dust air sample concentrations ranged from non–detectable to 1.18 mg/m³. The highest PBZ air sample for total dust (33.3 mg/m³) was collected on the hopper/roller operator during the wall CI application on August 10. The highest respirable dust air sample (1.18 mg/m^3) was collected in the attic area during the CI application on August 12.

During the four days of sampling, three total dust, PBZ, 8–hour TWAs exceeded the OSHA PEL. All three 8–hour TWAs exceeding the OSHA PEL occurred during the commercial wall CI application on August 10. The CI installer, hopper/roller, and the worker with miscellaneous jobs were overexposed.

Sampling conducted on August 13 indicated excursions in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The PBZ, total dust concentration for the hopper loader was at approximately 33 mg/m^3.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 38%. The observed CI fibers ranged from 5 µm to 90 µm in length. The average CI fiber length was 22 µm.

Portable Dust Monitor Measurements

Near the hopper on August 11, the MMAD was estimated at 16 µm with a GSD of 2.9. The respirable mass fraction of the sample mass was approximately 11%. During the CI application in the attic on August 12, the MMAD was estimated at 8.2 µm with a GSD of 3.2. The respirable mass fraction of the sample mass was approximately 28%. During the CI application in the attic on August 13, the MMAD was estimated at 8.5 µm with a GSD of 4.2. The respirable mass fraction of the sample mass was approximately 32%.

Contractor 5

Background

During September 29 – October 2, 1998, NIOSH investigators (including two industrial hygienists and one medical officer) evaluated seven CI application projects in Michigan. The first day involved two new residential home attic and two condominium attic CI applications. The first attic application consumed 70 bags of moistened CI to an approximate depth of 5" resulting in a R–value of 19. The attic was not equipped with an outside ventilation damper. The second day involved a condominium attic and a new residential attic application. The condominium attic application consumed 91 bags of moistened CI. The new residential attic application applied CI to an approximate depth of 10" resulting in a R–value of 38. The third day involved one existing residential attic application. The attic roof was approximately 3–4 ft high and was not equipped with an outside ventilation damper. The application applied CI to an approximate depth of 7½" resulting in a R–value of 21. The fourth day involved a new residential wall application. The residence was two stories with a basement. The application included exterior and interior walls.

Sampling

Total and Respirable Dust Air Sampling

Over the September 29–October 2, 1998, sampling period, the area and PBZ, total dust air sample concentrations ranged from 2.08 mg/m^3 to 60.9 mg/m^3, while the area respirable dust air sample concentrations ranged from non–detectable to 0.99 mg/m^3. The highest PBZ air sample for total dust (47.4 mg/m^3) was collected on the CI installer during the attic application on October 1. The highest respirable dust air sample (0.99 mg/m^3) was collected in the hopper area during the CI application on October 1.

During the four days of sampling, one total dust, PBZ, 8–hour TWA exceeded the OSHA PEL, and two total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV. The CI installer on October 2 exceeded the OSHA PEL. The overexposure occurred during a new residential wall application. The PBZ, 8–hour TWA exceeding the ACGIH TLV, but not the OSHA PEL was the CI installer of the new residential attics on September 29.

Sampling conducted on September 30 indicated two excursions in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The PBZ, total dust concentration for the CI installer and hopper operator were approximately 34 and 35 mg/m^3, respectively.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 38%. The observed CI fibers ranged from 5 µm to >90 µm in length. The average CI fiber length was 34 µm.

Portable Dust Monitor Measurements

During an attic application on September 29, the MMAD was estimated at 15 µm with a GSD of 2.4. The respirable mass fraction of the sample mass was approximately 8%.

Contractor 6

Background

During December 15–18, 1998, NIOSH investigators (including three industrial hygienists) evaluated thirteen CI application projects in North Carolina. The first day involved applying CI in a space above a residential garage and six residential attics. The initial site was an application of the space between the first floor and the ceiling of the garage. Each attic was roughly 1000–1500 ft^2 and was applied with roughly 8–10" of moistened CI. The six attics were equipped with two outside ventilation dampers. The second day involved a new residential wall application. The residence was two stories with CI application in exterior and interior walls. The third day's applications involved three new and one existing residential attic application. The third attic applied with CI was equipped with two outside ventilation dampers. The fourth day involved a new residential attic CI application. The residence was two stories with CI application in exterior and interior walls. During the application the hopper was set with the following parameters: 2000 rpm, air pressure at 4.0–4.5 psi, and the water pressure at 200 psi.

Sampling

Total and Respirable Dust Air Sampling

Over the December 15–18, 1998, sampling period, the area and PBZ, total dust air sample concentrations ranged from 0.72 mg/m^3 to 61.3 mg/m^3. The area respirable dust air sample concentrations ranged from non–detectable to 2.43 mg/m^3. The highest PBZ air sample for total dust (41.7 mg/m^3) was collected on the hopper operator during the attic application on December 15. The highest respirable dust air sample (2.43 mg/m^3) was collected in the hopper area during the CI application on December 18.

During the four days of sampling, no total dust, PBZ, 8–hour TWAs exceeded the OSHA PEL. There were three total dust, PBZ sample results that exceeded the ACGIH TLV. The CI installer's 8–hour TWA exceeded the ACGIH TLV on December 16 and 18, and the hopper operator's 8–hour TWA exceeded the ACGIH TLV on December 18.

Sampling conducted on December 15 and 17 indicated excursions in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The PBZ, total dust concentration for the hopper operators were 41.7 and 37.0 mg/m^3, respectively.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 37%. The observed CI fibers ranged from 5 µm to 85 µm in length. The average CI fiber length was 24 µm.

Contractor 7

Background

During February 23–26, 1999, NIOSH investigators (including three industrial hygienists) evaluated three CI application projects in Colorado. The first day of the evaluation did not result in any residences or buildings appropriate for air sampling. The second day involved an existing residential attic and a wall CI application at the same residence. The attic application consumed 44 bags of moistened CI to an approximate depth of 5" resulting in an R–value of 19. The attic roof was approximately 4 ft high. There was existing fiberglass insulation in the attic. The combination of fiberglass and cellulose insulation resulted in an R–value of 30. The misting device orifice was changed midway through the attic application. The original orifice was changed to decrease the amount of water supplied into the system due to CI clogging the application hose. The wall CI application was performed on the same house and was conducted by two separate CI application crews each with their own hopper. The third day of the evaluation did not result in any residences or buildings appropriate for air sampling. The fourth day involved an existing residential attic CI application. The attic was roughly 900 ft^2. The application applied an R–19 of CI to an existing layer of insulation for an overall R–value of 30. The attic roof was approximately 7 ft high.

Sampling

Total and Respirable Dust Air Sampling

Over the February 23–26, 1999, sampling period, the area and PBZ, total dust air sample concentrations ranged from 3.82 to 202 mg/m^3. The area respirable dust air sample concentrations ranged from 1.71 mg/m^3 to 12.9 mg/m^3. The highest PBZ air sample for total dust (171 mg/m^3) was collected on the CI installer during the attic application on February 26. The highest respirable dust air sample (12.9 mg/m^3) was collected in the hopper area during the CI application on February 26.

During the four days of sampling, one total dust, PBZ, 8–hour TWA exceeded the OSHA PEL and three total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV. The hopper operator on February 24 exceeded the OSHA PEL. The hopper operator was involved with both applications on February 24. The PBZ, 8–hour TWAs over the ACGIH TLV, but not the OSHA PEL were the CI installer of the new residential attic on February 26 and the hopper operator on February 26.

Sampling conducted on February 24 indicated excursions in worker exposure levels that exceeded 3 times the TLV–TWA for a total of 30 minutes or more, while the 8–hour TWA was below the TLV–TWA. The PBZ, total dust concentration for the two samples on the CI installer were approximately 40 mg/m^3 and 53 mg/m^3. Hopper operator #2 had a PBZ, total dust concentration of approximately 45 mg/m^3.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 34%. The observed CI fibers ranged from 5 µm to >85 µm in length. The average CI fiber length was 19 µm.

Portable Dust Monitor Measurements

During an attic application on February 24, the MMAD was estimated at 29.0 µm with a GSD of 2.5. The respirable mass fraction of the sample mass was approximately 2.5%. During a wall application on February 24, the MMAD was estimated at 20 µm with a GSD of 2.3. The respirable mass fraction of the sample mass was approximately 2.5%. During an attic application on February 26, a NIOSH investigator carried the PDM while following the CI installer around the attic for the first half of the CI application. The MMAD was estimated at 64 µm with a GSD of 2.5. The respirable mass fraction of the sample mass was approximately 0%. During the second half of the attic application on February 26, the PDM was located in the general hopper area. The MMAD was estimated at 55 µm with a GSD of 2.8. The respirable mass fraction of the sample mass was approximately 1%.

Video Exposure Monitoring

VEM was performed in the attic during CI activities. The air sample collected at the exhaust of the HAM sampling probe indicated a total dust concentration of 34.6 mg/m^3. The peak estimated particulate exposure measured with the HAM during attic CI activities was approximately 178 mg/m^3. Appendix E – Figure 3 presents the HAM concentration responses during CI activities in the attic.

VEM was also performed in the truck while the worker dumped bags of CI into a hopper during the attic application. The air sample collected at the exhaust of the HAM sampling probe indicated a total dust concentration of 140 mg/m^3. The peak estimated particulate exposure measured with the HAM during CI activities in the truck was over 200 mg/m^3. The HAM was at or above the maximum of 200 mg/m^3 from 14:47:55 to 14:47:58. Appendix E – Figure 4 presents the HAM concentration responses during CI activities in the hopper area.

Contractor 8

Background

During March 23–26, 1999, NIOSH investigators (including three industrial hygienists) evaluated six CI application projects in Arizona. The first day's project was a conclusion of the previous day's new residential wall CI application. The application included interior and exterior walls. The second day involved a new residential interior/exterior wall CI application. The third day consisted of a new residential attic and wall CI application. The residential attic CI application applied 8" (R–30) in the garage and 10" (R–38) in the house. The application used 177 bags of CI.

The residential wall CI application was located in the new additions to the existing house, and involved exterior walls in a portion of the first and second floors of the residence and the ceiling of the second floor. The fourth day involved two new residential houses, one with an attic CI application and one with a wall CI application. The application in the attic applied an insulation R–value of 38. The second residence involved a wall CI application of interior and exterior walls.

Sampling

Total and Respirable Dust Air Sampling

Over the March 23–26, 1999, sampling period, the area and PBZ, total dust air sample concentrations ranged from 1.26 mg/m^3 to 97.3 mg/m^3. The area respirable dust air sample concentrations ranged from non–detectable to 4.51 mg/m^3. The highest PBZ air sample for total dust (97.3 mg/m^3) was collected on the CI installer during the attic application on March 26. The highest respirable dust air sample (4.51 mg/m^3) was collected in the attic area during the CI application on March 26.

During the four days of sampling, nine total dust, PBZ, 8–hour TWAs exceeded the OSHA PEL and eleven total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV. The 8–hour TWA of worker #2 and #3 exceeded the OSHA PEL for total dust on March 23. Both workers were involved with operating the hopper and rolling/recycling the excess CI from the wall application. Worker #2's 8–hour TWA exceeded the OSHA PEL for total dust on March 24. The worker was involved with operating the hopper and rolling/recycling the excess CI from the wall application. All three workers' 8–hour TWAs exceeded the OSHA PEL for total dust on March 25 and 26. The 8–hour TWAs of worker # 1 and #3 exceeded the ACGIH TLV, but not the OSHA PEL on March 24. Worker #1 was the wall CI installer. Worker #3 was involved with operating the hopper and rolling/recycling the excess CI from the wall application.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 36%. The observed CI fibers ranged from 5 µm to greater than 100 µm in length. The average CI fiber length was 29 µm.

Portable Dust Monitor Sampling

During a new residential attic CI application on March 25, the PDM was located in the attic area. The MMAD was estimated at 115 µm with a GSD of 3.4. The respirable mass fraction of the sample mass was approximately 0%. During a new residential attic CI application on March 26, the PDM was located in the general hopper area. The MMAD was estimated at 13 µm with a GSD of 2.4. The respirable mass fraction of the sample mass was approximately 11%.

Contractor 9

Background

During September 27–30, 1999, NIOSH investigators (including three industrial hygienists) evaluated two CI application projects in Missouri. The first three days were at a new residence. The first day's project was an exterior wall CI application in the basement of the house. Thirty–four bags of CI were used. The second day involved CI applications in two of the three attics in the house. The attic CI application applied 147 bags of CI at a depth of 11½" (R–40). The third day involved the last of the three new residential attics. The attic had CI applied to a depth of 11½". This attic application used 83 bags of CI. The fourth day involved an existing wall CI application. The CI was inserted into the walls from the exterior of the house. Twenty–two bags of CI were used.

Sampling

Total and Respirable Dust Air Sampling

Over the September 27–30, 1999, sampling period, the area and PBZ, total dust air sample concentrations ranged from 1.3 mg/m^3 to 58.9 mg/m^3. The area respirable dust air sample concentrations ranged from non–detectable to 0.29 mg/m^3. The highest total dust air sample (58.9 mg/m^3) was collected in the breathing zone of the CI installer during the attic application on September 27. The highest respirable dust air sample (0.29 mg/m^3) was collected in the attic area during the CI application on September 29.

During the four days of sampling, two total dust, PBZ, 8–hour TWAs exceeded the OSHA PEL and two total dust, PBZ, 8–hour TWAs exceeded the ACGIH TLV. The CI installer's 8–hour TWA exceeded the OSHA PEL on September 27, 1999. The hopper operator's 8–hour TWA exceeded the OSHA PEL on September 28. The CI installer's 8–hour TWA exceeded the ACGIH TLV, but not the OSHA PEL on September 28. The hopper operator's 8–hour TWA exceeded the ACGIH TLV, but not the OSHA PEL on September 29.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 38%. The observed CI fibers ranged from 5 µm to >100 µm in length. The average CI fiber length was 30 µm.

Contractor 10

Background

During April 5–7, 2000, NIOSH investigators (including three industrial hygienists) evaluated 15 CI application projects in Colorado. The first day's project involved ten new residential attic CI applications. All houses received 9" of CI in the attic, which is an R value of 34. There was a total of 271 bags of CI used for the ten houses. The second day involved three new residential wall CI applications. The applications used 122 bags of CI. The third day consisted of two new residential wall CI applications.

Sampling

Total and Respirable Dust Air Sampling

Over the April 5–7, 2000, sampling period, the area and PBZ, total dust air sample concentrations ranged from 1.33 mg/m^3 to 68.7 mg/m^3. The area respirable dust air sample concentrations ranged from a non–detectable to 0.94 mg/m^3. The highest PBZ air sample for total dust (68.7 mg/m^3) was collected on the CI installer during the wall applications on April 6. The highest respirable dust air sample (0.94 mg/m^3) was collected in the hopper area during the CI application on April 6.

During the three days of sampling, four total dust, PBZ sample results exceeded the OSHA PEL, and six total dust, PBZ sample results exceeded the ACGIH TLV. The 8–hour TWA of workers #1 , #2, and #3 exceeded the OSHA PEL for total dust on April 6. Worker #2's 8–hour TWA exceeded the OSHA PEL for total dust on April 7. The worker was involved with operating the hopper and rolling/recycling the excess CI from the wall application. The CI installer's (Worker #1) 8–hour TWA exceeded the ACGIH TLV, but not the OSHA PEL on April 5. The CI installer's 8–hour TWA exceeded the ACGIH TLV, but not the OSHA PEL on April 7.

Scanning Electron Microscopy Air Sampling

The samples collected for SEM analysis indicated that a majority of the material observed was CI particles. The percentage of fibrous material was approximately 37%. The observed CI fibers ranged from 5 µm to >90 µm in length. The average CI fiber length was 24.6 µm.

Portable Dust Monitor Measurements

During attic CI applications on April 5, the PDM was located in the general hopper area. The MMAD was estimated at 16.7 µm with a GSD of 2.31. The respirable mass fraction of the sample mass was approximately 7%. During wall CI applications on April 6, the PDM was located in the general hopper area. The MMAD was estimated at 13.1 µm with a GSD of 2.39. The respirable mass fraction of the sample mass was approximately 11%. During wall CI applications on April 7, the PDM was located in the general hopper area. The MMAD was estimated at 17.7 µm with a GSD of 2.46. The respirable mass fraction of the sample mass was approximately 7%.

DISCUSSION

Application of Dry Cellulose Insulation

The application of dry CI into attic areas resulted in the generation of PBZ, total dust air sample concentrations significantly higher than wet CI attic applications ($p < 0.01$). The CI installer in the attic environment has considerable potential for an 8–hour TWA exceeding the OSHA PEL for total dust. This is especially true when the actual CI application time (per job and/or the day) increases, the attic area is small, and when the attic requires the installer to crawl into and apply CI in enclosed areas such as cathedral ceilings. The settling of CI dust is relatively slow. Therefore, as application time increases, the cloud of CI dust becomes more dense, increasing the potential for higher exposure.

CI installers have the potential for 8–hour TWAs exceeding the OSHA PEL for total dust during wall CI applications. When applying CI into existing walls, pressure is generated in the wall. When the application nozzle is taken out of the wall, the pressure inside the wall forces CI out of the wall hole which creates a considerable cloud of dust. The dust is typically released into the breathing zone of the installer. Some contractors, when involved with this type of application hang polyethylene sheeting to reduce the amount of CI dust settling on interior furniture, pictures, etc. This creates an enclosed area where the generated dust can become more dense and increase the exposure potential.

The ANOVA analysis indicated that the area respirable dust concentrations varied significantly by work area during dry CI applications ($p = 0.03$). Higher respirable concentrations were found during the application of CI in attic spaces than in other areas for two possible reasons. First the enclosed nature of attic spaces creates an environment with minimal air movement.

Additionally, the lack of air exchange with the outdoors limits dilution of CI dust in the attic space. Limited air movement will bias airborne concentrations to the respirable range as larger particulates settle out. Therefore, the attic space should see a gradual increase in airborne respirable CI over time. Second the extensive amount of CI dust generated will naturally contain a larger amount of respirable material.

Application of Wet Cellulose Insulation

A moistening system, which is operating correctly, has the potential to reduce the concentration of CI dust during attic CI applications. This results in less potential for CI installers to exceed the OSHA PEL for total dust (example, Contractor 4). The proper operation of the system depends upon the correct amount of water being added (according to the manufacturers specifications) and sufficient hopper strength to force moistened CI from the truck into the attic. When there are problems with this system, the exposure potential increases (example, Contractor 7). Higher concentrations were found during this wet attic application (and one sample with Contractor 8) which were not found during all other site visits with contractors having misting systems.

CI installers, hopper operators, and CI recyclers all have the potential for 8–hour TWAs exceeding the OSHA PEL for total dust during wet wall CI applications. When applying CI between wall studs, the force of the CI being released from the application hose and hitting the wall generates a cloud of CI dust. The nature of this type of application requires that all three employees be in close proximity to the wall and therefore the generated dust. After the CI fills the space between wall studs, a roller is used to roll off the excess CI, to provide a consistent depth. To roll off the material between 8–10 ft in height, the roller operator has to stretch his/her arms to reach the top of the wall. This results in excess CI falling onto that employee and into his/her breathing zone. This excess material is then recycled by a vacuum connected to the hopper or it can be collected by shovel and deposited back into the hopper by bags, cans, etc. The closeness of the recycling operation to the CI application can lead to high airborne concentrations. The hopper operator had total dust exposures significantly higher during wet wall/ceiling applications than dry ($p = 0.02$). The hopper operator during wet wall/ceiling applications typically works with the hopper, the roller, and sometimes the recycling portion of the process. This exposes the worker to greater exposure potential as was described above.

Fiber Characterization of Cellulose Insulation

Cellulose fibers were observed and characterized by SEM analysis, which indicated that fibers were on average 28 µm in length and ranged from 5 µm to 150 µm. The fibers come in various shapes and sizes, are rarely linear, can be found attached to cellulose particles, and do not typically have a uniform diameter. The variable fiber diameter could not easily be measured. The fibers tend to curve and twist, especially the longer fibers, into convoluted shapes that were difficult to characterize (see Appendix F – Pictures 7 and 8). This also caused many of the fibers to not lay flat on the filter. This resulted in differential charging of the fibers, making them less stable. This reduction in stability primarily affected the image quality.

The various shapes, sizes, diameters, and non–linearity of CI fibers, complicates the issue of fiber respirability. Classifying whether a fiber is respirable or not depends heavily on the diameter of the fiber. The inability to measure the diameter of CI fibers makes it difficult to conclude whether they are respirable or not. Further research into CI fiber characteristics is warranted before a respirability conclusion is made.

Bulk Samples of CI

The CI bulk samples were analyzed by a water extraction and a strong acid extraction. The water extraction indicated a boron and sulfate range of 4700–25000 µg/g of material and 25000–97000 µg/g of material, respectively. The strong acid extraction indicated a boron and sulfate range of 5900–26000 µg/g of material and 29577–94000 µg/g of material, respectively. Assuming that all boron and sulfate detected originates from the fire–retarding materials added, the amount is approximately 0.5–2.5% and 2.5–10% by weight of CI material, respectively. The boron levels are low in the bulk samples. The potential for exposures to high concentrations of boron in individual air samples is extremely unlikely. Sulfate levels are higher than boron levels in the bulk samples. However, sulfates occur naturally in wood products and probably add to the overall amount detected. Both extraction methods found a number of other metals in both analyses. The metals consistently detected included: aluminum, calcium, copper, iron, lithium, magnesium, manganese, sodium, titanium, and zinc.

Real–time Monitoring

The real–time monitoring with the PDM assisted in characterizing the particulate size of the generated CI dust. The real–time monitoring during the various CI related activities resulted in MMADs typically greater than 10 µm with GSDs between 2.0 and 3.0 (See Appendix D). This indicates that the particle size distribution is biased towards particle sizes out of the respirable range of 10 µm and smaller. The percent respirable material was typically lower than 11%. The amount of respirable material calculated from the PDM data agrees with the respirable dust air sampling results. A large amount of respirable material is not generated during CI applications. However, both the PDM and the respirable dust samples were area and not PBZ samples. A higher concentration of dust, as seen in attics during dry application, may result in a larger amount of respirable material and an increased exposure potential to employees not indicated by area sampling.

Contractors 7 and 8 had real–time monitoring events where the calculated respirable mass fraction was at or slightly above 0%. The PDM has a maximum concentration that it can measure. At or above this maximum concentration, the instrument is unable to classify the particles into the eight size ranges. The instrument indicates that each size range has the same amount of mass. Therefore, when the respirable mass fraction is calculated from the data provided by the instrument and that data has concentration readings above the maximum, the percentage is lower.

Video Exposure Monitoring

The VEM assisted in our understanding of the relationship between employee CI related activities and total dust concentrations (See Appendix E – Figures 1–4). A qualitative assessment of the concentrations measured with the HAM during VEM indicate that the CI installer is exposed to the highest particulate concentrations when working in "tight areas" such as in the edges of the attic or applying the insulation near the body. The hopper operator is exposed to the highest particulate concentrations when dumping the bags of CI into the hopper. The initial positioning of the CI block into the hopper creates a large cloud of dust, thus creating a higher concentration.

Engineering Controls, Administrative Controls, and Personal Protective Equipment

Engineering controls in the hopper area can assist in the control of CI dust (Figures 1 and 2). The figures show baffles around the sides of the hopper and an exhaust fan. The baffles will assist in keeping the CI dust in a controlled area, which the fan will exhaust to the outside of the truck. (Note: Figure 1 – high winds could decrease the effectiveness of the exhaust fan.) Engineering controls for other CI applications are not a practical solution to controlling dust concentrations. The VEM during attic applications indicated that employees had greater potential for exposure to CI dust when applying CI in corners and close to the body. Minimizing these practices when possible will reduce the potential exposure. This may be accomplished by utilizing a light weight (i.e., light weight metal) extension that would extend approximately 4 ft from the end of the application hose. This extension could have handles so the worker can manipulate the hose and extension to point into the tight areas; therefore, reducing the possibility of the worker having to physically enter the enclosed area.

The wide range of dust concentrations measured during CI applications complicates the respirator selection process for the CI industry. The exposure data in this report indicate that workers were exposed to CI total dust concentrations above the OSHA PEL. Therefore, until engineering controls and work practices are developed that will reduce exposures to safe levels, the OSHA Respiratory Protection Standard, 29, Code of Federal Regulations 1910.134[39] requires that CI employers must provide respirators to their employees and establish and maintain a respiratory protection program in accordance with the standard's requirements.

Respirators typically have an assigned protection factor (APF) which describes the level of respiratory protection in the workplace that should be expected by a certain respirator under conditions where an employee has been fit tested and has had appropriate training. Based on the variation in CI total dust concentrations, the overexposures to the OSHA PEL for total dust, and the APF of each respirator, employees in all areas of CI related activities (CI installer, hopper operator, and CI recycler) should wear at a minimum, a disposable, half–mask, particulate filtering respirator. Respirators used should be NIOSH–approved with an N95 designation (as defined by the current NIOSH certification procedures 42 CFR 84 effective July 10, 1998).[40] The N95 designation indicates that the filter material has been shown to remove 95% of particles greater than or equal to 0.3 µm. (The "N" stands for, Not resistant to oil). Unfortunately, there is no APF for disposable respirators. A NIOSH document on Histoplasmosis[41] suggests an APF of 5–10 for disposable respirators. NIOSH is currently studying these types of respirators to assign a permanent APF. If these respirators are being used, the employees should be quantitatively fit–tested to ensure an acceptable fit.

The exposure data indicates that there are instances, such as applying dry CI into attics, where the use of a more protective respirator would be recommended. Elastomeric, half–face, air–purifying respirators with N95 filters are assigned an APF of 10 and are acceptable for dust concentrations of 10 times the OSHA PEL (150 mg/m^3). Elastomeric, full–face, air–purifying respirators have an APF of 50 times the PEL (750 mg/m^3) and also have the benefit of eye protection. Employers will have to review the exposure data and decide what is the most appropriate respiratory protection for their workers.

Medical

Twenty–three CI workers were studied for possible health effects associated with CI exposure. These workers reported a variety of symptoms which may or may not be associated with their workplace exposure to CI. The most common chronic respiratory symptom reported was morning phlegm production. However, most of those who reported that symptom were current smokers, which could explain their symptoms. Smokers were more likely to report phlegm production.

The most common symptom, reported on the questionnaire, to be temporally related to CI exposure was that of eye irritation (cough and nasal symptoms were reported relatively frequently, but they were not temporally related to exposure to CI). Thirty–five percent of the workers reported that they had eye symptoms that were worse during exposure to CI. These symptoms may be due to additives in CI, such as boric acid, or to dust. Most workers did not wear eye protection. Most workers reported that their eye symptoms improved once exposure ended.

None of the workers had evidence of bronchial hyper–reactivity (percent amplitude means of greater than 20%), an indication of occupational asthma. However, the small number of workers studied decreased the likelihood of finding bronchial hyper–reactivity because the prevalence of occupational asthma is relatively low for most allergens.[42] Also, PEFR was measured mostly at work which limits the ability to detect the maximum change in PEFR that may have occurred. Measuring PEFR only on workdays and not the weekend (or extended time away from work) reduces the likelihood of seeing a work–related pattern and delayed effects. However, there are several limitations to our ability to assess bronchial hyper–reactivity, which may indicate asthma. A few workers reported lower respiratory tract symptoms, but these symptoms were classified as mild and infrequent and did not worsen with continued exposure.

CONCLUSIONS

Based on the air sample data collected from the ten contractor site visits, NIOSH investigators conclude that there is a potential for overexposure to CI. Employees in virtually all CI application activities had the potential to be exposed to CI

total dust levels which would exceed the OSHA 8–hour TWA. There is also a possibility for exceeding ACGIH excursion limits even if the 8–hour TWA limits themselves are not exceeded. Area respirable dust concentrations were typically low. However, there is increased potential for 8–hour TWAs exceeding the OSHA PEL for total and respirable dust when employees are involved in CI application activities for longer periods of time during the day.

Applying wet CI into attics significantly reduces the amount of generated dust.

Applying CI in close proximity to attic walls or corners and in tightly enclosed areas can result in exposure to elevated concentrations of CI dust.

The hopper operator can be exposed to high concentrations of CI dust, especially during attic applications, when putting bags of CI into the hopper.

There is evidence of work–related eye and mucous membrane irritation among some workers. This may be due to the additives present in CI, such as boric acid. From this investigation there is little evidence of lower respiratory system health conditions associated with CI exposure. However, this investigation has several limitations in addressing this issue.

RECOMMENDATIONS

The following recommendations are based on the findings of this investigation and offered to improve the safety and health of employees working with the CI operations discussed in this report.

1. Continue the use of personal protective equipment, specifically respirators. Engineering controls are the preferred method of control, however, until effective engineering controls can be implemented, respirators are an effective interim measure.

! A written respiratory protection program should be developed. This program should include the following components: selection of respirators; medical evaluation; fit testing; use of respirators; maintenance and care of respirators; identification of filters; training and information; program evaluation; and recordkeeping.

! Employees should be provided at least disposable, half–mask, particulate filtering respirators. Respirators used should be NIOSH–approved with an N95 designation.

! In enclosed attic spaces (i.e., cathedral ceilings) the CI concentrations may be high; therefore, a respirator with a higher APF (i.e., N95 elastomeric half–face or full–face respirator) should be used.

! Publications developed by NIOSH can be referenced when developing an effective respiratory program; these include the NIOSH Respirator Decision Logic[43] and the NIOSH Guide to Industrial Respiratory Protection.[44]

2. Use a moistening device when applying CI into attic spaces.

3. Refer to Figures 1 and 2 for suggested engineering controls for the hopper area. Employers should contact a qualified engineering firm to assist in developing effective engineering control measures.

4. Appropriate housekeeping and hygiene should be standard practice with CI companies. A regular cleaning schedule for trucks and company facilities will help keep CI dust to a minimum. Good hygiene practices may reduce the possibility of exposures by routes other than inhalation, such as ingestion by hand–to–mouth contact.

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