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BOISE CASCADE PLYWOOD
KETTLE FALLS, WASHINGTON**

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I. SUMMARY

A confidential request for a health hazard evaluation (HHE) was sent to the National Institute for Occupational Safety and Health (NIOSH) from employees at the Boise Cascade Timber and Wood Products Division in Kettle Falls, Washington. The request described possible exposures to manganese-containing fly ash around fluidized bed combustors and wood veneer dryers. An employee at the facility reported a medical diagnosis of manganese (Mn) poisoning which the employee's personal physician imputed to be related to occupational exposure. Following an opening conference on October 2, 1992, medical interviews were conducted and a medical records review was performed by a NIOSH medical investigator.

A walkthrough industrial hygiene survey was also conducted in the plywood mill and in an adjacent area of the facility where two fluidized bed combustors were located. The combustors incinerate "hogging fuel" (a mixture of bark, wood chips, sawdust, and wood scrap) and produce heat necessary to remove moisture from freshly peeled wood veneer used in the manufacture of plywood.

Bulk samples of residue collected on the inside and outside surfaces of veneer dryers indicated Mn to be present in concentrations ranging from 1,900 micrograms per gram ($\mu\text{g/g}$) to 6,600 $\mu\text{g/g}$. Fly ash collected near the fluidized bed combustors ranged in Mn concentration from 3,300 $\mu\text{g/g}$ to 5,200 $\mu\text{g/g}$. One sample of a kaolin clay-based refractory sand (IONE Grain 422) used in a fluidized bed combustor was found to contain 30,000 $\mu\text{g/g}$ (3%) Mn.

A follow-up visit was made over the weekend of July 4th, 1993, to collect personal breathing zone (PBZ) and area air samples for Mn-containing dust, respirable dust, and respirable silica during a scheduled bi-annual clean-out operation of the fluidized bed combustors. Eleven PBZ concentrations for Mn (as a total dust) ranged from not detected to 0.41 milligrams per cubic meter (mg/m^3). Eleven area samples for Mn collected inside and around the fluidized bed combustor, and in the veneer plant, ranged from not detected to 0.53 mg/m^3 . The Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) and the American Conference of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) for Mn is currently 5 mg/m^3 for an 8-hour Time Weighted Average (TWA). The NIOSH TWA-Recommended Exposure Limit (REL) is 1 mg/m^3 . ACGIH published a notice of intended change in 1992 to lower the adopted TLV-TWA of 5 mg/m^3 to 0.2 mg/m^3 to reduce the potential for preclinical adverse pulmonary effects, central nervous system effects, and adverse effects on male fertility.

Twelve PBZ exposures to respirable dust ranged from 0.09 mg/m^3 to 6.7 mg/m^3 . An area sample taken inside one of the combustors as clean-out operations were being performed measured 15 mg/m^3 during the period sampled. Full-shift PBZ respirable dust exposures to employees in the veneer plant ranged from 0.15 mg/m^3 to 0.41 mg/m^3 . None of the sample results were in excess of calculated OSHA PELs for respirable quartz. Two of twelve personal samples, and one of eight area samples for respirable silica (quartz), exceeded the NIOSH REL of 0.05 mg/m^3 for the time period sampled. Cristobalite was not detected in any samples.

The source of the Mn was determined to be from Mn-containing wood ash generated by the combustion of hogging fuel. An essential trace element in trees, Mn is known to range in concentrations from the tens of parts per million (ppm) in heartwood (inner wood of the tree), to upwards of several hundred ppm in bark. Bulk samples of sawdust

and hogging fuel ranged from 46 ppm for sawdust from peeled timber to 310 ppm for a predominantly bark sample.

A potential occupational health hazard was determined to exist at the Boise Cascade Kettle Falls plywood mill for employees exposed to Mn-containing dusts and respirable silica during fluidized bed combustor maintenance operations. Results of the NIOSH HHE indicate that Mn and respirable crystalline silica (quartz) were present in fly ash and dusts generated from combustion of hogging fuel. Personal and area air monitoring for concentrations of Mn did not exceed the OSHA PEL or ACGIH TLV of 5 mg/m³, or the NIOSH REL of 1 mg/m³. However, these criteria may not be the most protective. In 1992, ACGIH proposed a revised TLV-TWA for Mn of 0.2 mg/m³. During combustor clean-out, Mn concentrations for two personal, and one area sample exceeded 0.2 mg/m³ during the period sampled. Respirable silica concentrations also exceeded the NIOSH REL during the period sampled. This investigation reports and describes a possibly unsuspected health hazard—exposure to Mn from wood ash—a Mn exposure in a work environment not commonly associated with exposures to this metal. The source of the Mn was determined to be from the wood burned in the combustors. Silica exposures were determined to be related to the presence of silica in the refractory sand. The report offers recommendations for respiratory and dermal protection and suggests possible modifications to the veneer dryers to improve working conditions and health and safety practices for employees at the Boise Cascade Kettle Falls plywood plant. Recommendations to develop comprehensive respiratory protection and confined space entry programs are also included in the report.

Keywords: SIC 2436 (Softwood Veneer and Plywood), Manganese, Mn, wood ash, fluidized bed combustion, plywood operations, respirable crystalline silica, respirable dust.

II. BACKGROUND AND PROCESS

The Boise Cascade (BC) Timber and Wood Products Division plywood mill is located along the banks of the Columbia River, a few miles west of the town of Kettle Falls, in rural north-central Washington State. The plant began production at its present location in 1967 and has operated continuously since that date. The facility employs approximately 155 workers in the production of plywood, and 27 individuals in management and support positions. The Kettle Falls plant manufactures 19/32" (CDX grade) plywood. Felled timber is trucked to the mill from the cutting site and stored on-site in the log yard. According to BC management, the timber consists primarily of Douglas fir (90%) and Western larch (10%). The logs are first debarked, cut to eight foot lengths, and placed under high pressure steam which heats the core of the log to 105°F. Steaming forces moisture into the wood, making the log easier to peel. The logs are peeled mechanically on a rapidly-rotating lathe, a device which shaves the logs into long, thin sheets of veneer. The veneer sheets are cut into four-foot sections then travel on a belt conveyer for inspection, sorting, and stacking. The stacks of green veneer are stored until being manually or mechanically fed into a veneer dryer—essentially a series of slow moving rollers in an oven operating at temperatures of 350°F - 400°F—which removes moisture from the veneer as it passes through the hot, dry air. Two dryers, a Coe (with an upper and a lower deck known as Dryers #1 and #2) and a Prentice (Dryer #3), were initially used in the plant. In June 1993, another Coe dryer (a smaller, single deck version of Dryer #1) was installed and is known as dryer #4.

The sheets of veneer leave the dryers, and are graded, stacked, and then moved to a lay-up line for assembly into plywood. Lay-up consists of assembling the veneer along a series of moving belts and glue application stations. Glue, containing water, flour, dried animal blood, and a phenol-formaldehyde resin is applied to each layer of veneer. Any knots in the wood are patched with small pieces of veneer. The rough plywood is then aligned and moved to the "pre-rack" or accumulator where pressure and heat (400°F and 325 pounds per square inch) bond the layers of veneer into a single sheet of plywood. The plywood leaves the heat press, and goes through a final sawline for trimming. It is inspected, graded, stenciled with a BC logo, and loaded onto rail cars for transport.

The HHE request described possible employee exposure to fly ash and smoke emissions from veneer dryers in the plant, and around two fluidized bed (or fluid bed) combustors which are adjacently located to the plant. The combustors generate heat for the veneer dryers used at the mill. Fluidized bed combustion is a biomass-to-energy transfer system widely used in the wood products industry. Mill wastes, or "hogging fuel" such as bark chips, sawdust, wood shavings, and wood scraps have an inherent heat value which can be used to heat veneer dryers or produce energy while at the same time, avoiding the costs of solid waste disposal. Hot air, produced from combustion of the hogging fuel directly supplies heat to the three dryers in the plant. A heat exchanger between the combustors and the dryers is not used.

A fluidized bed combustor consists of a cylindrical vessel, into which combustion air is provided with a forced-draft fan. Nozzles on a series of supply manifolds distribute air through a 2 to 5 foot deep bed of a refractory material which can be sand, limestone, or calcined clay. The interior of the vessel is lined with a refractory material designed to resist thermal and physical degradation. Combustion air moves up through the heated bed and burns the fuel used in the system. To initially bring the system on-line, natural

gas and preheated air are used as fuel until the combustor reaches an appropriate ignition temperature for the fuel of choice. Generally, this is a temperature range of 800°F-1000°F.

As temperatures stabilize, more air and fuel are added to increase the thermal output, the natural gas supply is slowly eliminated, and the system can be operated at 1500°F to 1800°F. With combustion stabilized, a bed of extremely hot particles become fluidized by the air passing up through the bed material. The upward velocity of the air, combined with tremendous heat, creates a buoyant effect on the upper layer of sand which appears to have the physical qualities of a fluid; that is, the bed looks like a boiling pot of liquid. Fly ash is captured using a wet scrubber and a multiclone (a number of small cyclones arranged in parallel rows). Multiclones can have capture efficiencies for particulates down to 2 microns (μm) in diameter.

Bi-annual cleanout and maintenance for the two fluidized bed combustors occurs during Christmas and 4th of July holidays. This is necessary to exchange the refractory sand, repair any damage to the refractory liner, and replace any air nozzles which may have broken from the manifold. IONE Grain 422, a high-fired kaolin-based grain, is the refractory sand in the BC fluidized beds. According to a material safety data sheet provided from the supplier, IONE Grain 422 is composed of silica (53%-54%) and aluminum (43%-44%). Trace amounts of iron oxide (0.4%-0.7%), titanium (1.8%-2.4%), and magnesium (0.0%-0.2%) are also present.

Fluidized bed clean-out and maintenance was performed by a Dryer Tender and an employee with a Clean-Up/Utility job classification. The Clean-Up worker essentially acted as a Laborer. The NIOSH investigator observed that significant amounts of fine particulate (fly ash) are generated during clean-out operations. This may occur outside of the combustor as the sand is removed, or inside the combustor as the walls and nozzles and manifold are cleaned using compressed air, or at the tramping screen where rocks, wire and other "tramp" materials (which have entered the fuel source) are removed from the bottom of the combustor. During the first NIOSH site visit in October 1992, obvious accumulation of fly ash was evident on horizontal sections of the angle iron structural supports for the two combustors and throughout the multiclone room. Accumulations of fly ash on these same surfaces were not as evident during the second site visit in July, 1993. Based on the observation of the NIOSH investigator, combustor cleanout appeared to be the dustiest operation, secondarily would be work on the multiclone, and then maintenance activities inside the veneer dryers (inside the plant). Observations made in the plant suggested that employees working around the veneer dryers (Dryer Feeders, Veneer Graders, and Dryer Tenders) may be exposed to smoke and particulates from the veneer dryers although to a considerably lesser degree than activities involving work inside the combustors, dryers or in the multiclone room. A blue haze, which appears to be smoke coming from the dryers, was noticeable in the plant during both site visits. The dryers appear to be slightly positively pressurized. This was apparent at several of the dryer doors where a noticeable brown-grey accumulation of residue was found on the outside of dryer doors. This material appears to be deposited by blow-by of material between the door and the door frame. Engineering controls in the plant consist of several roof-mounted, axial exhaust fans and a metal roll-curtain vestibule suspended from the roof surrounding the area above the dryers. Dryer Feeders interviewed by the NIOSH investigator said that installation of the vestibule reduced smoke and haze in the plant but did not eliminate the problem

completely. Smoke and haze on the operators platform on the upper Coe dryer was reported to be worse than for Dryer Feeders working at the floor level.

III. METHODS AND MATERIALS

Medical Evaluation

The medical evaluation consisted of employee interviews, review of the Occupational Safety and Health Administration (OSHA) 200 Logs, and informal discussions with management. The purposes of the interviews were to identify any adverse health effects of primary concern to the labor force and to obtain information on past and current chemical and physical agents believed to present exposure hazards in the work environment.

Ten first and second shift-employees who worked in the veneer dryer area, or who routinely assisted with cleaning and maintenance of the dryers, and who were present during the NIOSH visit, were interviewed. Employees were questioned as to their contact with hazardous substances and the type of protective equipment that they routinely used, their current health status, whether they were under the care of a physician in the past year for a health concern, and whether they had submitted blood or urine samples to their private physicians to be evaluated for manganese.

Environmental Evaluation

The industrial hygiene investigation involved collecting personal breathing zone (PBZ) samples and area samples to determine exposures to Mn, respirable dust, and respirable silica (quartz and cristobalite). Employees were asked to wear two personal sampling pumps configured to sample respirable dust and silica on one media, and Mn (total dust) on another media. Area samples were also collected in several locations and were analyzed for the identical air contaminants. To evaluate Mn concentrations of the products of combustion, bulk samples were collected of residues from inside and on the outside of the veneer dryers. Samples of fly ash were collected around the fluidized bed combustor area and settled dust was collected from rafters in the glue loft of the plant. Settled dust samples were also collected in the fluidized bed control room. Samples of IONE Grain 422 were collected prior to use in the combustors and after it had been used and removed from a combustor. To evaluate the Mn content of wood, sawdust samples were collected at the debarker, near the "grizzly" (a wood chipper), and of hogging fuel in a storage bin near the combustors. Samples of the combustor liner, A P Green, (the patching cement used to repair the refractory) and of the small white rocks which are found on the tramping screen were collected and analyzed.

PBZ samples for Mn (total dust) consisted of 0.8-micron (μm) mixed cellulose-ester membrane filter cassettes connected to a Gilian® constant-flow personal sampling pump calibrated to either 1 or 2 liters per minute (Lpm). During the first site visit, area and personal samples were collected at 1 Lpm to determine if Mn was present in either personal or area air samples. These samples confirmed the presence of airborne concentrations of Mn. In order to evaluate exposures during combustor cleanout, (anticipated as a worst-case exposure scenario) PBZ and area samples were collected

during the second site visit, at the higher flow rate of 2 Lpm. This was done to obtain an adequate sample volume anticipating that some tasks might not extend to an entire 8-hour shift. Pre-and post-sampling calibration, including flow checks during the day, were made with a calibrated rotameter. The Mn samples were analyzed using a modified NIOSH Method 7300 which was designed to optimize for the presence of Mn.¹ Filters were transferred to a 125 milliliter (mL) Phillips beaker and digested using aqua regia (nitrohydrochloric acid) and perchloric acid. The digestion solution contained 3 mL of concentrated hydrochloric acid, 1 mL of concentrated nitric acid and 1 mL of perchloric acid. A Thermo Jarrell Ash ICAP 61 inductively coupled plasma emission spectrometer controlled by a NEC personal computer-AT was used for all Mn measurements.

Respirable dust and respirable silica (quartz and cristobalite) were collected on tared, 37 mm, 5- μ m polyvinyl chloride (PVC) membrane filter cassettes mounted in 10 mm Dorr-Oliver nylon cyclones. The cyclones were connected to Gilian® constant-flow personal sampling pumps calibrated to a flow rate of 1.7 Lpm. The samples were analyzed gravimetrically for total weight according to NIOSH Method 0600² with the following modifications: (1) filters were stored in an environmentally controlled room ($21 \pm 3^\circ\text{C}$ and $50 \pm 5\%$ RH) for several days to allow for stabilization prior to tare weighing, and (2) filters and backup pads were not vacuum desiccated. According to the laboratory, studies on the physical integrity of various PVC filters have shown that the weight of the filter may vary by 0.02 mg. Accordingly, the limit of detection for respirable dust was reported as 0.02 mg. The instrumental precision of the microbalance was reported as 0.001 mg.

After analysis for total weight, the samples were analyzed for crystalline respirable quartz and cristobalite using x-ray diffraction. NIOSH Method 7500 was used with the following modifications: 1) filters were dissolved in tetrahydrofuran rather than ashed in a furnace; and 2) standards and samples were run concurrently and an external calibration curve was prepared from the integrated intensities rather than using the suggested normalization procedure.³

IV. 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 hazardous chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to ten hours a day, forty hours a week for a working lifetime without experiencing adverse health effects. However, it is important to note that not all workers will be protected from adverse health effects if 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 to the limit set by the evaluation criterion. These combined effects are often not considered by the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increase the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are the following: 1) NIOSH Criteria Documents and Recommended Exposure Limits (RELs), 2) the U.S. Department of Labor, OSHA Permissible Exposure Limits (PELs), and 3) the American Conference of Governmental Industrial Hygienists' (ACGIH) Threshold Limit Values (TLVs).^{4,5,6} In July 1992, the 11th Circuit Court of Appeals vacated the 1989 Air Contaminants Standard. OSHA is currently enforcing the 1971 standards which are listed as transitional values in the current Code of Federal Regulations; however, some states operating their own OSHA approved job safety and health programs will continue to enforce the 1989 limits. NIOSH encourages employers to follow the 1989 OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criterion. The OSHA PELs reflect the feasibility of controlling exposures in various industries where the agents are used, whereas NIOSH RELs are based primarily on concerns relating to the prevention of occupational disease. It should be noted when reviewing this report that employers are legally required to meet those levels specified by an OSHA standard and that the OSHA PELs included in this report are the 1971 values.

Time-weighted average (TWA) concentrations refers to the average airborne concentrations of a substance during a normal 8-to 10-hour workday. Some substances have recommended short-term exposure limits (STELs,) which also may be TWAs, or ceiling values (a value which should never be exceeded) which are intended to supplement the TWA where there are recognized toxic effects from brief, high exposures.

Manganese (Mn)

Manganese (Mn) is a naturally occurring mineral that is widely distributed in the igneous, sedimentary, and metamorphic rocks of the earth's crust. It is an essential trace

element in human physiology and serves as a cofactor for various enzymatic reactions. Manganese is present in all living organisms. It is found in a natural background level in urban air at concentrations of 0.02-0.04 micrograms per cubic meter of air ($\mu\text{g}/\text{m}^3$).⁷ Concentrations in soil range from 20 to 3000 parts per million (ppm), and average approximately 600 ppm.⁸⁻⁹ The principal form of Mn intake in man is from food, where it is present in grains, fruits, nuts, tea, and some spices. The usual daily intake can vary from 2,000 μg to 9,000 μg per day, depending on one's diet.⁸ Industrial uses for Mn include steelmaking (to impart hardness), the production of dry-cell batteries, ceramics, matches, welding rods, fertilizers, and dyes.

Manganese poisoning (manganism) was first reported by Couper in 1837.¹⁰ Industrial exposures generally occur through inhalation to dusts or fumes of manganese dioxide (MnO_2) in mining, steelmaking, and in the production of dry cell batteries. Manganese dioxide is the most stable oxide of Mn. Most occupational exposures to Mn have been documented in workers exposed to dusts and fumes during mining and foundry operations. Manganese may be directly neurotoxic, or it may affect certain neurotransmitters such as dopamine. The development of manganism involves three stages: (1) a subclinical stage involving subtle, non-specific effects, (2) a clinical stage involving psychological and psychomotor effects, and (3) the fully developed disorder of chronic manganese poisoning indistinguishable from Parkinson's disease. Symptoms reported in the clinical stage include an expressionless face, rigidity, resting tremor, stooped posture, and a shortened gait. These symptoms generally are apparent after several years of exposure, some individuals, however, may show signs and symptoms after only 1-3 months of exposure.⁸ Marked differences in individual susceptibility to inhaled Mn exist; these differences may be related to alcohol use (alcoholism), anemia, carbon monoxide exposure, or individuals having pre-existing pulmonary disease. The lowest exposure levels for pre-clinical adverse effects to the central nervous system (CNS) and lungs are unknown.¹¹

Acute inhalation exposures to Mn in mining and manufacturing can result in a debilitating form of lung disease known as manganese pneumonitis.¹² In chronic exposure situations, psychiatric disorders characterized by irritability, difficulty in walking, speech disturbances, and compulsive behavior can result. Episodes of "manganese madness" have been documented which include cases of running, fighting, and singing.¹² The usual form of chronic manganese poisoning primarily involves the CNS. Symptoms include languor, sleepiness, and weakness in the legs. A stolid, mask-like appearance of the face, along with emotional disturbances (such as uncontrollable laughter) and spastic gait with a tendency to fall while walking are findings in the more advanced cases.¹³ Diagnosis of Mn poisoning is based on symptomatology. Measurement of urinary Mn (Mn-U) or serum Mn (Mn-B) using biological monitoring methods is not useful for determining individual health effects or individual exposures.¹¹ On a group basis, however, the biological significance of Mn-U appears to reflect recent Mn exposure as the half-life for Mn-U is less than 30 hours. Mn-B may be an indicator of a person's overall body burden, and this may not necessarily reflect occupational exposure.¹¹

Besides inhalation exposure, another route of entry for Mn is through drinking water. However, only two epidemiological reports are available documenting the adverse effects from drinking water contaminated with Mn. Sixteen cases of manganese poisoning in a small Japanese community have been described. Three of these cases

resulted in fatal poisoning, one death was from suicide. The exposures were apparently caused by approximately 400 dry cell batteries which were buried within 2 meters of a domestic drinking water well. The well served as the community water supply. The Mn content of the water was about 14 milligrams per liter (mg/L). Concentrations of about 8 and 11 mg/L were found in two other wells. The community members exhibited psychological and neurological disorders associated with manganese poisoning. High levels of Mn and zinc were found to be present in the organs of those persons who were autopsied.¹⁴ Another report, from Greece, indicated that increases in Mn concentration in drinking water (in a range of 0.003-2.3 mg/L) were associated with progressively higher prevalences of neurological symptoms of chronic Mn poisoning in older individuals.¹⁵

The NIOSH REL-TWA⁴ for Mn compounds is 1 mg/m³. The OSHA PEL for Mn compounds is 5 mg/m³ as a ceiling limit.⁵ The ACGIH TLV-TWA⁵ is 5 mg/m³. However, in 1992, ACGIH published a notice of intended change to reduce the TLV for Mn as a total dust from 5 mg/m³ to 0.2 mg/m³. The ACGIH proposal considered the epidemiological studies of Roels *et al.* and Lauwerys *et al.* which indicate that TWA exposures to total Mn dust at approximately 1 mg/m³ may lead to preclinical adverse pulmonary effects and effects in male reproductive capacity.^{11,16,17} The notice of intended change recognizes that uncertainty exists regarding thresholds for the lowest levels of Mn exposure and the development of preclinical pulmonary effects and adverse effects on male reproductive health.¹⁸

Respirable Silica (quartz and cristobalite)

Crystalline silica (quartz) and cristobalite have been associated with silicosis, a fibrotic disease of the lung caused by the deposition of fine particles of crystalline silica in the lungs.¹⁹ Symptoms usually develop insidiously, with cough, shortness of breath, chest pain, weakness, wheezing, and non-specific chest illnesses. Silicosis usually occurs after years of exposure, but may appear in a shorter period of time if exposure concentrations are very high.²⁰ The NIOSH RELs for respirable quartz and cristobalite, published in 1974, are 0.05 mg/m³, as TWAs, for up to 10 hours per day during a 40-hour work week.⁴ These RELs are intended to prevent silicosis. However, evidence indicates that crystalline silica is a potential occupational carcinogen and NIOSH is currently reviewing the data on carcinogenicity.²¹⁻²³ OSHA requires that the 1971 PEL for respirable silica be dependent upon the percent silica in the sample, and that the respirable dust exposure for an 8-hour TWA not exceed the value obtained from the formula:

$$\frac{10 \text{ mg} / \text{m}^3}{\% \text{SiO}_2 + 2}$$

The ACGIH TLVs for respirable quartz and cristobalite are 100 and 50 µg/m³, as 8-hour TWAs, respectively.⁶

Nuisance Dusts

Although TLVs and PELs⁵⁻⁶ have been established for nuisance dusts or PNOCs (particulates not otherwise regulated/classified), these criteria may not be protective enough when other toxic substances are present. In this investigation, varying amounts of Mn and respirable silica were found in samples of combustor ash. The OSHA PELs for total and respirable dusts are 15 mg/m³ and 5 mg/m³, respectively.⁵ Currently, NIOSH does not have a REL for PNOCs.

V. RESULTS

Medical

Ten employees, eight male and two female, were interviewed. Their ages ranged from 33 to 62 years old, with an average of 45 years. Duration of employment at the mill ranged from 8.5 to 25.5 years, with an average duration of 17.75 years. Job classifications of those interviewed included Dryer Feeder, Dryer Operator, Dryer Utility, Dryer Tender, Stacker Operator, and Plywood Grader.

Most employees who assisted with the maintenance and cleaning and of the dryers reported wearing heavy rubber or leather gloves while working on the dryers. Workers who repaired or maintained the multiclone and fluid bed combustor reported that they wore full-face air-purifying respirators while performing those jobs but other employees reported that in the past it was common practice to wear only a disposable dust mask. Some workers who reported wearing full-face respirators had beards which would interfere with the sealing surface of those masks.

Employees reported seeing a physician in the previous year for a variety of conditions including wrist/hand discomfort, lower back pain, arthritis, and cardiovascular disease. None of the ten workers reported visiting a physician for symptoms suggestive of Mn toxicity, although three individuals stated that they had submitted blood for Mn testing in 1991, and all three reported being informed that their blood manganese level was within a range which they were told was considered normal. Several employees stated that in previous years they experienced muscle twitching while working around the fluidized bed combustor area. The workers recalled that symptoms of muscle twitching stopped soon after the installation of new equipment in the fluid bed area that reduced the amount of fly ash in the work area.

Manganese

Results of personal air monitoring for all employees revealed that exposures to Mn as total dust were below the OSHA PEL of 5 mg/m³, the NIOSH REL of 1 mg/m³ and the current ACGIH TLV of 5 mg/m³. The highest personal exposures (see Table 1 and Figure 1) were measured on a Clean Up-Utility/Basic, also referred to in this report as a Laborer (0.41 mg/m³), and a Dryer Tender (0.35 mg/m³). The Dryer Tender worked predominantly around the fluidized bed combustor and the tramping screen (and for short times in the plant) as the IONE Grain 422 was being removed from the combustor. The Laborer operated a bucket loader at the area where sand was draining from the

combustor, and also occasionally used a wheel barrow to move quantities of the sand after it had drained from the combustor. Personal protective equipment for the Dryer Tender consisted of coveralls and, at times, a two-piece plastic rain suit, leather gloves, and a full-face air purifying respirator. This employee, however, had facial hair which may have interfered with the fit of the respirator. The Laborer wore coveralls and a disposable dust mask. The NIOSH investigator observed that, at times, the Laborer (working outside near the sand collection bin) appeared to be exposed to as much dust as the Dryer Tender working on the tramping screen beneath the combustor. Exposures to the Dryer Tender and the Laborer exceeded the ACGIH 1992 notice of intended change criteria of 0.2 mg/m^3 for the periods sampled. The sampling times were less than an 8-hour time period (268 and 234 minutes, respectively). Full-shift samples were not obtained because the work was intermittent. Full-shift sampling on Dryer Tenders working mostly in the plant were considerably lower, 0.014 and 0.002 mg/m^3 . Full-shift exposures to Dryer Feeders in the plant were measured at 0.001 mg/m^3 and 0.002 mg/m^3 .

In-plant area samples (located at breathing zone height) at dryers #3 and #4 (on the dry wood side of both dryers) measured 0.001 mg/m^3 . Area measurements taken during initial site visit on October 2, 1992, indicated that Mn was not detected at the Prentice dryer (Dryer #3) wet feed work platform, but was found at a concentration of 0.12 mg/m^3 on the catwalk. This sample was placed close to the dryer in-feed, an area which was notably smoky during both NIOSH investigations. Smoke emitted from the in-feed area appeared to be due to positive pressurization of the dryer.

Bulk Samples

Bulk samples of a variety of materials were found to range widely in their Mn content. Samples of hogging fuel and sawdust ranged from 46 micrograms per gram ($\mu\text{g/g}$) in samples of fine light colored wood dust to $310 \mu\text{g/g}$ for dark brown hogging fuel collected near the screw auger (Table 2). A sample of reddish colored wood/bark collected near the grizzly chipper was found to contain $52 \mu\text{g/g}$. Samples of used and unused IONE Grain 422 ranged from not detected (ND) in new IONE Grain 422 to $30,000 \mu\text{g/g}$ (3% Mn) in one composite sample from a pile of IONE Grain 422 which had been used in the combustor. Samples of fly ash collected around the combustor and in the multiclone room ranged from $840 \mu\text{g/g}$ to $5,200 \mu\text{g/g}$. In the plant, samples of residues collected inside the doors of veneer dryers ranged from $3,900 \mu\text{g/g}$ to $6,600 \mu\text{g/g}$. Samples of residues collected on the outside of the veneer dryer doors (deposited from blowby due to dryer pressurization) ranged from $1,900 \mu\text{g/g}$ to $2,800 \mu\text{g/g}$. Boiler ash ranged from $180 \mu\text{g/g}$ to $2900 \mu\text{g/g}$. Chip samples of the refractory lining from the combustor wall contained $120 \mu\text{g/g}$ Mn. AP Green, the patching cement used to repair the liners, contained $40 \mu\text{g/g}$.

Respirable Dust

Personal exposures to respirable particulates (dusts) ranged from 0.09 mg/m^3 to 6.7 mg/m^3 (Table 3). Area samples ranged from 0.21 mg/m^3 to 15 mg/m^3 . Exposures to Dryer Tenders ranged from 0.09 mg/m^3 to 0.64 mg/m^3 . Veneer Graders' exposures were measured at 0.18 mg/m^3 and 0.26 mg/m^3 . Exposures to Dryer Feeders were measured at 0.15 mg/m^3 to 0.30 mg/m^3 . A Laborer working around the fluidized bed was determined to be exposed to 6.7 mg/m^3 , a concentration which exceeded the OSHA criteria for

respirable dust during the period of sampling. Area samples were less than 5 mg/m³ with the exception of two samples, one (15 mg/m³) was taken inside FB 200 as cleanout operations were occurring. Initially this sample was placed on the Dryer Tender using compressed air to clean the manifold inside the combustor. However, the pump and cassette became unwieldy, so the employee removed the sampling train and hung it on the vessel wall at approximately a breathing zone height. Another sample (6.2 mg/m³) was taken on the catwalk of the in-feed deck of the Prentice Dryer, a location which was notably smoky.

With one exception of a measurement of 6.7 mg/m³, PBZ exposures to respirable dusts were low. The OSHA PEL for respirable dust is not an appropriate comparison criteria, however, as the respirable dusts evaluated in this investigation contain both Mn and respirable silica. The material also appears to be quite alkaline—one sample of dryer residue had a pH of 12.5—and therefore, could be classified as corrosive. Workers exposed to this dust who use inadequate or inappropriate respiratory protection may be at increased risks from inhalation hazards and adverse pulmonary effects of an additive or possibly synergistic nature. Dermal hazards are also considerable; however, from the perspective of pulmonary toxicity, this material poses a unique health hazard and should not be considered or classified as a nuisance dust.

Respirable Crystalline Silica (quartz and cristobalite)

Two personal samples taken on the Dryer Tender and a Laborer (0.08 mg/m³ and 0.07 mg/m³, respectively) exceeded the NIOSH criteria for respirable quartz of 0.05 mg/m³ for the period sampled (Table 4). Cristobalite was reported as not detected on all samples. The limit of detection (LOD) for the samples was reported as 0.01 mg. The minimum detectable concentration (MDC) was 0.02 mg/m³ based on an average sample volume of 407 liters. One area sample collected inside the combustor was reported at 0.06 mg which equates to a TWA of 0.19 mg/m³ for the period sampled. The remainder of the samples were between the LOD and the limit of quantitation (LOQ) and are considered trace quantities which, while detectable, are not quantifiable. The highest measurement was the area sample (0.19 mg/m³) collected inside combustor FB 200 during cleanout, this sampling train was hanging on the wall at in the breathing zone. The area or personal samples did not exceed a calculated OSHA PEL of 3.0 mg/m³ which was based on the silica content in the sample (see formula in evaluation criteria). In this case, silica ranged in concentration from 0.4 percent to 1.3 percent, while average silica content was determined to be 1%. The NIOSH REL for respirable silica is considerably lower than the calculated OSHA PEL. The NIOSH criteria intended to prevent silicosis, however some evidence indicated that crystalline silica is a potential occupational carcinogen and NIOSH is in the process of reviewing this data.²¹⁻²³

VI. DISCUSSION

Manganese is an essential inorganic trace element in trees and plants, and is known to be present in heartwood, sapwood and in the bark of a variety of timber including fir, the principal wood used at the BC Kettle Falls plywood mill.²⁴ Manganese concentrations in wood have been shown to increase from the heartwood (inner core of the tree) to the bark.²⁴ Trees are known to translocate metals from anthropogenic emissions (man-made sources such as air pollution) from air and soil into the structural components (wood and bark) of the plant. Toxic metals such as lead, cadmium, chrome, manganese, and nickel have all been found to be present in the wood of trees.²⁵⁻²⁶ Table 5 describes a variety of metals found in Pacific Northwest industrial wood ash. Manganese is listed at 3,300 µg/g, a concentration consistent with the results found in this investigation. In another study of wood from Grand Fir (*Abies grandis*) from conifers east and west of the Cascade Mountains, Mn ranged in concentration from 2.9 to 28.6 µg/g (Figure 2). The mean Mn concentration for the trees west of the Cascades was 16.6 µg/g. Trees east of the Cascades averaged 15.4 µg/g. Samples of buttwood and bark contained 18 and 310 µg/g of Mn, respectively. Needles contained the greatest Mn concentrations at 3,423 µg/g.²⁷ This may be explained by Mn having a role in plant photosynthesis, therefore higher concentrations would be expected in the needles where photosynthesis occurs.

Concentrations of Mn in samples of sawdust and hogging fuel collected during this investigation ranged from 46 µg/g in light colored wood from the inner core of the tree to 310 µg/g in loamy brown hog fuel, containing mostly bark. A number of metals are known to be incorporated into the wood of trees through root uptake from soils and metal-containing soil solutions. A trend of increasing mobilization of many elements, including Mn, is seen in more acidic soils.

Bulk samples collected during this investigation indicate that Mn was generally present in greatest concentration in the samples of ash residues from the veneer dryers, and in fly ash (Table 2). These samples had mean Mn concentrations of 3,800 µg/g, and 2,700 µg/g, respectively. Manganese was also found in samples of IONE Grain 422 which had been used in the combustors. One sample of this grain had 3% Mn (30,000 µg/g). Manganese was not detected in samples of unused IONE Grain 422 (to a limit of 3 ppm, the LOD for the analytical method.) This suggests the source of the Mn is not IONE Grain 422. Bulk sample data are described in Table 2 and represented graphically in Figure 3. Table 2 describes the samples, where the samples were collected, the Mn concentration in micrograms per gram of sample, and where it was reasonable to make average comparisons, the mean (average) concentration is listed. A numerical sample type (using numbers 1 - 8) is given in Table 2 to reference the samples listed in Figure 3. Figure 3 is a graphical comparison of distributions of Mn in various bulk samples of fuel, dryer residues, fly ash, boiler ash, IONE Grain, and refractory brick. It is important to note that in this figure, Mn concentration is expressed on a logarithmic scale (the µg/g concentrations were converted to base 10 logarithms). For purposes of interpreting this figure, the concentration difference between a value of 1 and a value of 2, is a ten-fold increase. Converting the numbers to logarithms was necessary for graphical purposes because the concentrations of Mn in the bulk samples varied from not detected, to the tens of thousands of micrograms per gram. The analytical LOD divided by 2 was used for samples which were not detected (unused IONE Grain.)

The results of the investigation suggest that Mn is entering the fluidized bed combustors as a natural element present in the hogging fuel. The metal appears to be accumulating (adsorbing) onto the IONE Grain 422, a relatively porous material. As the fluidized beds are continually on-line, the throughput of hogging fuel is constant. This serves as a constant source of Mn. However, other sources of Mn are suspected as posing possible contamination in hogging fuel. During combustor clean-out, the NIOSH investigator noticed that in addition to rocks, pieces of metal scrap, and even tools (three crescent wrenches, a mechanics mirror, several links of roller chain and the remains of a few welding rods) came out of the combustor on the tramping screen. Rocks apparently enter the combustor attached to tree bark. Evidently, the metal parts get into the hogging fuel when swept up on the plant floor by the jitney. Welding rods in particular, may contribute some Mn to the waste stream, although the principal source is still best explained by the Mn content of wood ash.

The small white rocks which are often noticed on the tramping screen (a topic of much concern by employees regarding chemical composition) are composed predominantly of calcium oxide (CaO) which is also known as lime, quicklime, and unslaked lime. Some magnesium oxide may also be present. Mn is also adsorbed onto these rocks (140 µg/g). These rocks react vigorously and exothermically when in contact with water to form calcium hydroxide [Ca(OH)₂]. This is a strong base, with a pH of 12 or greater. Calcium hydroxide is corrosive in contact with skin or mucous membranes. These rocks are likely to be formed by the presence of calcium (from the wood being burned) under the oxidizing conditions and high heat of induced-draft combustion. These rocks appear on the tramping screen apparently because they are dense enough to migrate to the bottom of the bed and accumulate with larger stones and heavy material which is seen on the tramping screen during combustor cleanout. The rocks may pose dermal exposure hazards to unprotected employees working on the tramping screen, they may also be related to the high pH of the wood ash. It is uncertain whether inhalation exposures to CaO are occurring because this material was not evaluated during the investigation. The NIOSH REL⁴ for CaO is 2 mg/m³.

VII. CONCLUSIONS

The results of this investigation indicates that exposure to Mn is a possibility in the wood products industry, an occupational sector not commonly expected as having exposures to this metal. A potential health hazard was determined to exist at the Boise Cascade, Kettle Falls Plywood Plant for occupational exposures to Mn-containing dust during operations in which large quantities of dusts are generated, specifically during cleanout of the fluidized bed combustors. A health hazard was also determined to exist for occupational exposures to respirable dust and respirable crystalline silica (quartz). The source of the Mn exposure was determined to be from Mn-containing wood ash generated from the combustion of hogging fuel used to produce heat for the mill's veneer dryers. Manganese as total dust and respirable dust PBZ exposures to employees in the veneer plant were below the current OSHA and NIOSH criteria. It appears that combustor clean-out operations (and perhaps working inside the veneer dryers) are work activities having the greatest risk for exposures to respirable particulate, and Mn and respirable silica-containing dusts. One employee was found to be exposed to respirable dust in excess of the current OSHA criterion during the period sampled, one area sample inside the combustor was more than twice the OSHA PEL for respirable dust during the

period sampled. No exposures to Mn-containing dusts were found to exceed the current OSHA and NIOSH criteria of 5 mg/m^3 and 1 mg/m^3 , respectively. The margins of safety for these limits may be low, however, as reflected by ACGIH's notice of intended change to reduce the TLV-TWA for Mn as total dust from 5 mg/m^3 to 0.2 mg/m^3 . In two PBZ samples, Mn concentrations exceeded 0.02 mg/m^3 , while concentrations in two area samples were at 0.2 mg/m^3 or exceeded this amount during the periods sampled (Figure 1).

Three samples (two personal and one area) had respirable silica (quartz) concentrations in excess of the NIOSH REL of 0.05 mg/m^3 during the period sampled. The remainder of the samples were below or at the reported analytical limit of quantitation (LOQ) of 0.03 milligrams per sample. In area samples where quartz was reported at or above the LOQ, it was present in airborne concentrations of 0.19 mg/m^3 and 0.02 mg/m^3 . Personal samples taken on a Dryer Tender and a Laborer had concentrations of 0.08 mg/m^3 and 0.07 mg/m^3 respectively, which exceeded the NIOSH REL of 0.05 mg/m^3 during the periods which were sampled. The concentrations were below the calculated OSHA PEL (based on percent quartz) of 3.0 mg/m^3 for the sample set.

VIII. RECOMMENDATIONS

The following recommendations are based on the results and observations of the HHE. These recommendations are provided in the interests of improving health and safety conditions at the Boise Cascade, Timber and Wood Products Division, Plywood Plant in Kettle Falls, Washington.

1. To reduce occupational inhalation exposures to Mn-containing dusts from wood ash, respirable dust, and respirable silica, a complete respiratory protection program should be developed and implemented. This is particularly directed toward protection of those employees having exposure to Mn and respirable silica-containing dusts generated during cleanout and maintenance operations of the fluid beds. Work in the veneer dryers also poses a possible exposure to Mn-containing residues and fly ash. Respirators should not be worn by employees having facial hair that comes in contact with the sealing surface of the facepiece. Employees using respiratory protection during work involving possible exposure to dusts and residues from the combustors and dryers should be clean shaven to achieve the best possible fit of the facepiece. The respiratory protection program should stress employee training and should be consistent with the guidelines provided in DHHS (NIOSH) Publication No. 87-116: A NIOSH Guide to Industrial Respiratory Protection and the Washington State Department of Labor and Industries Safety and Health Standards, which address respiratory protection.

2. Respiratory protection in the form of air-purifying, full-face respirators equipped with high efficiency particulate air (HEPA) filters should be used to protect employees when exposure to dusts from the fluidized bed combustors and veneer dryers is likely. Examples of situations where exposures are likely include bi-annual clean-out operations on the fluidized bed combustors and work on or around the multi-clone or veneer dryers when dusts are generated. Dryer Tenders performing repair operations are likely to be exposed to Mn-containing dusts when servicing or working around the veneer dryers. Protective equipment such as impermeable gloves and safety glasses or shields should be used to protect the skin and eyes against fly ash and residues which are quite basic and pose hazards if skin or mucous membrane contact occurs.
3. To control dusts in the veneer plant and fluid bed control room, where ash is found to be visibly accumulating on environmental surfaces, it should be periodically removed with a vacuum equipped with a HEPA filter. This should be considered part of a general housekeeping program to reduce metal and silica-containing dusts at the facility.
4. A confined space entry program should be developed and implemented when personnel are required to enter the fluid bed combustors for bi-annual clean-out operations or any routine or emergency maintenance procedures. Guidelines for confined space entry programs can be found in: A Guide to Safety in Confined Spaces published by U. S. Department of Health and Human Services, Public Health Service, (NIOSH), July 1987, Publication # 87-113 and: Worker Deaths in Confined Spaces also published by the U. S. Department of Health and Human Services, Public Health Service, (NIOSH), January, 1994, Publication # 94-103. Other regulations pertaining to confined spaces include the Washington State Department of Labor and Industries General Occupational Health Standard, WAC 296-62-145, Part M, Confined Spaces, and the Code of Federal Regulations, 29 CFR 1910.146 [1993] which addresses permit-required confined spaces.
5. To reduce smoke and particulate haze in the plant, pressurization of the dryers should be evaluated. The dryers, particularly the Prentice dryer, appear to be over-pressurized. Blow-by accumulations on the dryer doors and a smoky haze in the plant indicate that the dryers may be inappropriately pressurized from supply fan inputs from the fluidized beds. According to engineering specifications (provided by BC) for the Coe Dryer, the plans call for the dryer to have -.1" static pressure (SP) at the wet feed end (door #2) and -.5" SP at door #19 near the dry end

of the dryer. Positive pressurization areas within the dryers are called for at doors #8 (+1.3" SP) and #9 (+1.7" SP). Visual inspection of the doors which are designed to be negatively pressurized did not indicate this was the case as confirmed by the blow-by on these doors, and from the smoke coming from the dryer in-feeds. In addition to pressurization changes to the dryers, another method to reduce smoke and haze may be to extend the bottom of the vestibule and increase the exhausting capacity of the roof-mounted exhaust fans. While the axial fans (which are currently installed) are a suitable choice considering the low static pressures under which these fans are used, an appropriately sized and installed radial-blade centrifugal fan could be used to exhaust a greater amount of air under the low static pressures encountered in the plant. Radial bladed centrifugal fans are appropriate in situations where dust-laden air passes across the fan blades, these fans are frequently used in the woodworking trades. If new fans are chosen it is best to select fans which are certified by the Air Moving and Control Association (AMCA).²⁸

6. The roof-mounted axial exhaust fans above the veneer dryers should be inspected and their current operational status confirmed. During the second site visit on July 2, 1992, the roof exhaust fan at the dry end of the new Coe dryer was not operating.
7. To reduce dustiness inside the combustor during combustor cleanout, alternatives to the use of compressed air should be investigated. While the use of compressed air to dislodge dusts from the manifold may be a quick method to accomplish this task, it is almost certain to increase dustiness (and decrease visibility) which may increase risks for inhalation exposures and dermal or mucous membrane exposure to fly ash. Suggestions to investigate include the use of a vacuum extraction, and where possible, using wet methods to decrease dustiness.
8. Employees having contact with fly ash and dryer residues should be informed of the importance of handwashing prior to eating or smoking. Manganese exposure could occur from ingesting ash-contaminated food, or inhalation of metal fume from fly ash contamination on cigarettes. Additionally, fly ash and dryer residues on clothing can present an inhalation hazard (and possibly take-home exposure hazards) when ash is brushed off or shaken from heavily contaminated work clothes (resulting from resuspension of dust). Using disposable coveralls for extremely dusty work or a work uniform laundry program are suggestions to reduce fly ash exposure from ash on heavily soiled work clothes.

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