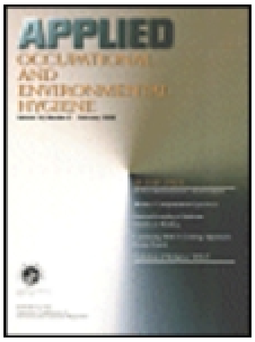

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Case Studies

Manganese Exposure in the Manufacture of Plywood: An Unsuspected Health Hazard

Dawn Tharr, Column Editor

Reported by Eric J. Esswein

Background

Exposure to manganese and the occupational disease manganism is commonly associated with exposure to dusts and fumes during extraction of manganese ore, in steelmaking operations, in welding operations, or in the manufacture of dry cell batteries. Manganese exposure has not previously been associated with manufacturing of plywood. The results of this investigation by the National Institute for Occupational Safety and Health (NIOSH) indicate that exposure to manganese-containing dust is occurring in the wood products industry, an occupation not suspected of having exposure to this metal.

Introduction

The plywood mill under study was located 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. The facility manufactures 19/32-inch (CDX grade) plywood. Felled timber is trucked to the mill from the cutting site and stored on site in the log yard. The timber consists primarily of Douglas fir (90%) and Western larch (10%). The logs are first debarked, cut to 8-ft 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 that shaves the logs into long, thin sheets of veneer. The veneer sheets are cut into 4-ft sections which then travel on a belt conveyer for inspection, sorting, and stacking. The stacks of green veneer are stored until they are manually or mechanically fed into a veneer dryer, which is essentially an oven operating at temperatures ranging from 350 to 400°F, with a series of slow-moving rollers that move the wood through the dry, hot air. The facility contains four veneer dryers.

After the sheets of veneer leave the dryers, they 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. Any knots in the wood are patched with small pieces of veneer. Glue containing water, flour, dried animal blood, and a phenol-formaldehyde resin is applied to each layer of veneer. The rough plywood is aligned and then moved to the "pre-rack" or accumulator where heat and pressure (400°F and 325 lb/inch^2) bond each layer 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 logo, and loaded onto rail cars for transport.

The health hazard evaluation 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 that are located adjacent to the plant. These 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 that can be used to heat veneer dryers or produce energy and, at the same time, avoid solid waste disposal expenses. Hot air, produced from combustion of the hogging fuel, directly supplies heat to the four 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-ft 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 online, 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° to 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° 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 with a multiclone (a number of small cyclones arranged in parallel), which can have capture efficiencies for fine particulate down to 2 μm in diameter.

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

Fluidized bed cleanout and maintenance was performed by a dryer tender and an employee with a cleanup/utility job classification. The cleanup worker essentially acted as a laborer. The NIOSH investigator observed that significant amounts of fine particulate (fly ash) are generated during cleanout operations. This may occur outside of the combustor as the sand is removed, inside the combustor as the walls and nozzles are cleaned with compressed air, or at the tramping screen where rocks, wire, and other "tramp" materials are removed from the bottom of the combustor. During the first NIOSH site visit, obvious fly ash accumulations were evident on much of the metal structural supports for the two combustors. Accumulation of fly ash on the outside of the combustors was not as evident during the second site visit. Based on the observation of the NIOSH investigator, combustor cleanout appeared to be the dustiest operation; next would be work on the multiclone, followed by 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 employees performing activities involving work inside the combustors or in the multiclone room.

Most employees who assisted with the maintenance and cleaning 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 combustors reported that they wore full-face air-purifying respirators while performing those jobs; however, other employees reported that in the past it was common to wear only a disposable dust mask. Some workers who reported wearing full-face respirators had facial hair, which can interfere with the sealing surface of those masks.

During both visits to the plant, a blue haze was noticeable above the veneer dryers. The haze appeared to be smoke coming from the dryers. The dryers appeared to be positively pressurized; this was apparent at several of the dryer doors, where a noticeable brown-gray accumulation of residue was found on the outside of the dryer doors from blow-by of material between the door and the door frame. Engineering controls in the plant consisted of roof-mounted exhaust fans and a metal curtain vestibule which is suspended from the roof and surrounds an area above the dryers. Dryer feeders interviewed by the NIOSH investigator said that installation of the curtain vestibule reduced smoke and haze in the plant but did not eliminate the problem completely. Smoke and haze on the operator's platform on the upper dryer were reported to be worse than for dryer feeders working at the floor level.

Methods

Environmental Evaluation

The industrial hygiene investigation involved collecting personal breathing zone (PBZ) samples and area samples to determine exposures to manganese. To evaluate manganese 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 the combustors. To evaluate the manganese content of wood, sawdust samples were collected at the debarker, near the "grizzly" (a wood chipper), and from hogging fuel in a storage bin near the combustors. Bulk samples of the liner from inside the combustors, AP Green, the patching cement used to repair the refractory lining, and small white rocks that were found on the tramping screen were collected and analyzed for manganese.

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.

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 regarding their contact with hazardous substances, the type of protective equipment 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.

Ten employees, eight male and two female, were interviewed. Their ages ranged from 33 to 62 years, 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.

Toxicology

Manganese 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 element in human physiology and serves as a cofactor for various enzymatic reactions. Manganese is present in all living organisms and it is found as a natural background level in urban air at concentrations of 0.02 to 0.04 $\mu g/m^3$.[1] Concentrations in soil range from 20 to 3000 ppm and average approximately 600 ppm.[2,3] The principal form of manganese intake in humans is from food, where it is present in grains, fruits, nuts, tea, and some spices. The usual daily intake can vary from 2,000 to 9,000 μg per day, depending on one's diet.[2]

Manganese poisoning (manganism) was first reported in 1837.[4] Industrial exposures generally occur through inhalation of manganese dioxide in mining, steelmaking, and the production of dry cell batteries. Manganese dioxide is the most stable oxide of manganese. Most occupational exposures to manganese have been documented in workers exposed to dusts and fumes during mining and foundry operations. The clinical effects of chronic manganese poisoning resemble symptoms of Parkinson's disease (expressionless faces, rigidity, resting tremor, stooped posture, and a shortened gait) and generally are apparent after several years of exposure. Some individuals, however, may show signs and symptoms after only 1 to 3 months of exposure.[2] Marked differences in individual susceptibility to inhaled manganese exist; these differences may be related to alcohol use (alcoholism), anemia, carbon monoxide exposure, or preexisting pulmonary disease. The lowest exposure levels for preclinical adverse effects to the central nervous system (CNS) and lungs are unknown.[5]

Acute inhalation exposures to manganese in mining and manufacturing can result in a debilitating form of lung disease known as manganese pneumonitis.[6] 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.[6] The usual form of chronic manganese poisoning primarily involves the CNS. Symptoms of poisoning include languor, sleepiness, and weakness in the legs. A stolid, masklike appearance of the face, emotional disturbances such as uncontrollable laughter, and a spastic gait with a tendency to fall in walking are found in the more advanced cases.[7] Diagnosis of manganese poisoning is based on symptomatology. Individual evaluation using biological monitoring methods is unreliable based on concentrations of manganese in blood (Mn-B) or urine (Mn-U).[5] On a group basis, however, the biological significance of Mn-U appears to reflect recent manganese exposure, as the half-life for Mn-U is less than 30 hours. Mn-B may be an indicator of a person's total body burden.[5,8]

The NIOSH recommended exposure limit (REL) for manganese compounds is 1 mg/m³ as a time-weighted average (TWA);[4] the OSHA permissible exposure limit (PEL) is 5 mg/m³ as a ceiling limit.[5] The American Conference of Governmental Industrial Hygienists (ACGIH) currently recommends a threshold limit value (TLV) of 5 mg/m³ as a TWA for manganese dust and compounds; the TLV–TWA for fume is 1 mg/m³ with a short-term exposure limit (STEL) of 3 mg/m³.[9] However, in 1992 ACGIH published a Notice of Intended Change (NIC) for manganese. The NIC recommendation is a TLV–TWA of 0.2 mg/m³ for manganese, elemental, and inorganic compounds as manganese.[10]

The ACGIH proposal considered the epidemiological studies of Roels *et al.*[5] and Lauwerys *et al.*,[11] which indicate that TWA exposures to total manganese dust at approximately 1 mg/m³ may lead to preclinical adverse pulmonary effects and effects in male reproductive capacity. The NIC documentation recognizes that uncertainty exists regarding thresholds for the lowest levels of manganese exposure and the development of preclinical pulmonary effects and adverse effects on male reproductive health.[12]

Results

Environmental

Results of personal air monitoring for all employees revealed that exposures to manganese 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 were measured on a cleanup utility worker, 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 combustors and the tramping screen (and for short times in the plant) as the IONE Grain 422 was being removed from the combustors. The laborer operated a bucket loader at the area where sand was draining from the combustors and also occasionally used a wheelbarrow to move quantities of the sand after it had drained from the combustors. 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 that 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 and the dryer tender appeared to be exposed to similar quantities of dust. Exposures to the dryer tender and the laborer exceeded the ACGIH 1992 NIC criteria of 0.2 mg/m³ 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 was considerably lower, 0.014 and 0.002 mg/m³. Full-shift exposures to dryer feeders in the plant were measured at 0.001 and 0.002 mg/m³.

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/m³. Area measurements taken during the initial site visit indicated that manganese was not detected at the wet feed work platform for dryer 3, but it was found at a concentration of 0.12 mg/m³ on the catwalk. This sample was placed close to the dryer in-feed, an area that was notably smoky during both NIOSH investigations. Smoke emitted from the dryer appeared to be due to positive pressurization of this dryer.

Bulk samples of a variety of materials were found to range widely in their manganese content. Samples of hogging fuel and sawdust ranged from 46 μg/g in samples of fine, light-colored wood dust to 310 μg/g for dark brown hogging fuel collected near the screw auger. A sample of reddish wood bark collected near the grizzly chipper was found to contain 52 μg/g. Samples of used and unused IONE Grain 422 ranged from not detected in new IONE Grain 422 to 30,000 μg/g (3% manganese) in one sample of the material after it had been used in the combustor. Samples of fly ash collected around the combustors and in the multiclone room ranged from 840 to 5200 μg/g. In the plant, samples of residues collected inside the doors of veneer dryers ranged from 3900 to 6600 μg/g. Samples of residues collected on the outsides of the veneer dryer doors (material deposited from blow-by due to pressurization) ranged from 1900 to 2800 μg/g. Boiler ash ranged from 180 to 2900 μg/g. Samples of the refractory lining from the combustor wall contained 120 μg/g manganese. AP Green, the patching cement used to repair the combustor liners, contained 40 μg/g.

Medical

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 manganese toxicity. Three individuals stated that they had submitted blood for manganese testing in 1991, and all three reported that their blood manganese level was within a range they were told was 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 which reduced the amount of fly ash in the work area.

Discussion

Manganese is an essential inorganic trace element in trees and is known to be present in heartwood (inner core of the tree) and in the bark of a variety of timber including fir, the principal wood used at the plywood mill.[13] Manganese concentrations in wood have been shown to increase from the heartwood to the bark. Trees are known to translocate metals from anthropogenic emissions (artificial sources) from air and soil into the structural components (wood and bark) of the plant. Toxic metals such as lead, cadmium, chrome, and nickel have all been found to be present in the wood of trees.[14,15] In a study of samples of wood from grand fir *(Abies grandis)* trees east and west of the Cascade Mountains, manganese ranged in concentration from 2.9 to 29 μg/g. The mean manganese concentration for trees west of the Cascades was 17 μg/g. Trees east of the Cascades averaged 15 μg/g. Samples of buttwood and bark contained 18 and 310 μg/g of manganese, respectively. Needles contained the greatest manganese concentrations at 3423 μg/g.[16]

Concentrations of manganese 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. Besides the metals mentioned previously, calcium, zinc, iron, and magnesium 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 manganese, is seen in acidic soils.

Bulk samples collected during this investigation indicate that manganese was generally present in the greatest concentration in the samples of ash residues from the veneer dryers and in fly ash. These samples had mean manganese concentrations of 3800 and 2735 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 percent manganese (30,000 μg/g). Manganese was not detected in samples of unused IONE Grain 422 (to a limit of 3 ppm, the limit of detection for the analytical method). This suggests that the source of the manganese is not IONE Grain 422.

Conclusions

The results of this investigation indicate that exposure to manganese-containing dust is a possibility in the wood products industry, an occupational sector not commonly expected to be exposed to this metal. A potential health hazard was determined to exist for occupational exposure to manganese-containing dust during operations in which large quantities of dusts are generated, specifically during cleanout of the fluidized bed combustors. The source of manganese exposure was determined to be manganese-containing wood ash generated from the combustion of hogging fuel used to produce heat for the mill's veneer dryers. No exposures to manganese-containing dusts were found to exceed the current OSHA and NIOSH criteria of 5 and 1 mg/m³, respectively. The margins of safety for these limits may be low, however, as reflected by ACGIH's NIC to a TLV-TWA for manganese, elemental, and inorganic compounds, to 0.2 mg/m³. Two PBZ samples exceeded 0.02 mg/m³ during the periods sampled, and two area samples were at or above this amount.

Recommendations

1. To reduce occupational inhalation exposures to manganese-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 manganese and respirable silica-containing dusts generated during cleanout and maintenance operations of the fluid bed combustor. Work in the veneer dryers also poses a possible exposure to manganese-containing residues and fly ash. The respiratory protection program should stress employee training and should be consistent with the guidelines provided in the Department of Health and Human Services (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. 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 to include biannual cleanout operations on the fluidized bed combustors and work on or around the multiclone or veneer dryers when dusts are generated. Dryer tenders performing repair operations are likely to be exposed to manganese-containing dusts when servicing or working around the veneer dryers.
2. Protective equipment, such as impermeable gloves and safety glasses or shields, should be used to protect against fly ash and residues that are quite basic and pose hazards if skin or mucous membrane contact occurs.
3. To control dust 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 at the facility. To reduce dustiness inside combustors during cleanout, alternatives to using compressed air should be investigated. Using compressed air to dislodge dusts is certainly a quick method to accomplish this task; however, 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 included using vacuum extraction methods and, where possible, wet methods to abate dustiness.
4. A confined space entry program should be developed and implemented when personnel are required to enter the fluid bed combustors for biannual cleanout operations or any routine or emergency maintenance procedures. Guidelines for confined space entry can be found in *A Guide to Safety in Confined Spaces* (Publication No. 87-113) published by DHHS/Public Health Service/NIOSH, in July 1987. Other regulations pertaining to confined spaces included in the Washington State Department of Labor and Industries' General Safety and Health Standards, WAC 296, may also be appropriate.
5. To reduce smoke and particulate haze in the plant, pressurization of the dryers should be evaluated. The dryers appeared to be overpressurized. Evidence of blow-by accumulations on the dryer doors and haze in the plant suggest that the dryers may be inappropriately pressurized from supply fan inputs from the fluidized beds. Engineering specifications call for the dryers to have between −0.1 inch static pressure (SP) at the wet wood feed side and −0.5 inch SP at the dry wood end. Visual inspection of the dryer doors did not confirm this to be the case, as suggested by the blow-by accumulating on dryer doors.
6. 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 inhalation hazards (and possibly take-home exposure hazards) when ash is brushed off or shaken from heavily contaminated work clothes (resulting in resuspension of dust). Using disposable coveralls for extremely dusty work or a work uniform laundry program were suggested to reduce exposures to fly ash from heavily soiled work clothes.

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Editorial Note: Eric Esswein is with the Hazard Evaluation and Technical Assistance Branch of NIOSH. More detailed information on this evaluation is contained in the Health Hazard Evaluation Report No. 92-0263 available through NIOSH, Hazard Evaluation and Technical Assistance Branch, 4676 Columbia Parkway, Cincinnati, Ohio 45226, or by telephoning 1-800-35-NIOSH.