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Introduction

A study to assess Michigan wood product manufacturers' ability to comply with Occupational Safety and Health Administration (OSHA) workplace exposure limits for wood dust examined 55 wood product manufacturing facilities between October 22, 1989, and October 12, 1990. The study was part of the Michigan Energy Conservation Program's (MECP) wood dust monitoring program, a statewide service provided to forest product producers by MECP in cooperation with the Michigan State University Cooperative Extension Service, the MSU Department of Forestry, and the Michigan Association of Timbermen. This bulletin presents the results of the study and summarizes the principal findings.

Health effects of wood dust

OSHA has found evidence that clearly indicates that occupational exposure to high levels of wood dust poses a significant health risk. Therefore, OSHA has set permissible exposure levels for airborne wood dust – 5 milligrams per cubic meter (5 mg/m^3) of air on a time-weighted average over 8 hours. The short-term exposure limit is 10 mg/m^3 of air over 15 minutes for all softwoods and hardwoods except western red cedar. Western red cedar has a lower permissible exposure level – 2.5 mg/m^3 for a time-weighted average over 8 hours.

OSHA set the new limits on wood dust not on the basis of any single study, but on the basis of dozens of studies reporting on the respiratory, irritant, allergenic, and carcinogenic properties of wood dust (Occupational Safety and Health Administration, 1989).

The wood dust limit of 5 mg/m^3 set by OSHA has been challenged by woodworking unions as being too high. The unions are petitioning for a standard of 1 mg/m^3 for wood dust. The unions' position is that a 1 mg/m^3 limit would better protect workers' health. This study compared actual exposures to the 1 mg/m^3 limit as well as the current OSHA 5 mg/m^3 limit.

Dust particles irritate the mucous membranes of the nose, throat, and eyes, and even affect the inner regions of the respiratory tract. Cancer of the nasopharynx may develop in woodworkers after several decades of steady contact with fine wood dust (Woods Injurious to Human Health, 1981).

The Inter-Industry Committee on Wood Dust contests the evidence on the carcinogenicity of wood dust and supports the OSHA regulation for limiting the irritant effects of wood dust. The committee recommends the 5 mg/m^3 exposure level as a matter of good housekeeping practice and to promote worker comfort, and it will continue to identify and support needed health research related to wood dust.

Methods

This study involved on-site sampling in wood processing facilities throughout Michigan. Through informational mailings and personal invitations, wood product companies were offered the opportunity to have their employees' exposure to wood dust measured at their facility for a nominal charge. The companies were told the data collected would be used by researchers at Michigan State University in compiling group information on wood dust, and that the researchers would not know the identities of the companies.

MECP is a cooperative effort of the:
Michigan Department of Agriculture - Michigan Soil Conservation Districts - USDA Soil Conservation Service
Michigan State University's Agricultural Experiment Station and Cooperative Extension Service

Twenty industry segments were surveyed (Table 1). A total of 55 companies were tested; at each company, four or five stations were tested in work areas where wood dust was assumed to be a problem. A total of 267 work station samples were taken.

Table 1. Type of wood product manufacturers tested for wood dust exposure.

Number tested	Type of manufacturer
6	Furniture
14	Sawmill
4	Pallet
9	Sawmill and pallet
2	Veneer
1	Reel manufacturer
1	Planing mill
1	Dimension mill
1	Molding & picture frames
1	Utility pole
5	Cabinet
1	Truss manufacturer
2	Window
1	Pattern maker
1	Architectural millwork
1	Log home manufacturer
1	Wood souvenirs
1	Fence
1	Snowshoe manufacturer
1	Cutting board
55 Total	

The sizes of plants in the study ranged from small plants employing fewer than 10 workers to several employing more than 100. The majority of the plants tested employed between 15 and 30 workers.

Testing Procedure

The OSHA-approved procedure for determining wood dust exposure is to conduct gravimetric measurements by using a battery-operated personal air sampler attached to a cassette with a preweighed filter. The cassette is attached to the pump by flexible tubing, which is placed over the employee's shoulder so the air intake of the cassette is within 12 inches of the nose. After the air pump has been calibrated to a constant air flow, the air sampler draws a measured amount of air from the worker's breathing zone through the filter. Wood dust is deposited on the filter during the time it takes to draw that amount of air. Samples to be analyzed for this study were collected with Staplex PST-5 Personal Air Samplers.

In each field study, the plant manager and the monitoring technician jointly selected the work stations to be tested. The manager was asked to select the work areas he or she most suspected of having wood dust problems. The technicians conducting the wood dust monitoring were trained in the wood dust monitoring procedures recommended by OSHA.

At each site, the technician calibrated the air samplers before beginning the test. The delicate nature of the sampling equipment and the benefits of the testing were explained to the workers. Workers wore the samplers on belts around their waists, and intake tubes were attached to their shirt collars. The monitoring technician recorded the time each test began and ended. Worker's breaks and extraordinary occurrences were noted. At lunchtime, technicians removed the sampling machines and cassettes, plugging all intake openings. Testing resumed after lunch. The technician also made periodic observations of the workers and inspected the sampling machines during the course of the test.

After the monitoring period, the cassettes were removed from the samplers, sealed, and sent back to Michigan State University for gravimetric analysis.

The weight of wood dust collected on each filter was determined as the difference between the conditioned filter's weight before and its weight after sampling.

Results

The results of the study are presented in Tables 2 and 3. Table 2 shows the types of work stations tested, the number of samples taken at each station, the number of samples over 5 mg/m^3, the number over 1 mg/m^3, and the percent of the samples in compliance with the OSHA standard. Table 3 shows the range of variation in these measurements. This table shows the minimum, the maximum, and the average time-weighted average for each category of work station and the standard deviation from the mean for each category of work station.

Thirty-seven types of work stations were tested. The work stations were chosen by the plant manager at each site. This resulted in some work stations being tested more than others. For example, the most samples – 25 – were taken from cutoff saws, while only one sample was taken from a number of other machines. Statistical inferences drawn from work stations with a small number of samples are less valid than those with a greater number of samples.

The study found a wide range of exposure levels. For example, the average exposure of the 12 head saw areas tested was 1.09 mg/m^3. The lowest sample showed no measurable wood dust; the highest exposure was 2 mg/m^3. In contrast, the six maintenance people tested were ex-

Table 2. Dust monitoring results from 55 wood product manufacturers.

Work station type	Number of samples	More than 5 mg	More than 1 mg	Percent compliance with OSHA regulations
Head saw	12	0	6	100%
Edgesaw	16	2	11	88%
Chipper	4	0	3	100%
Trimsaw	17	4	11	76%
Grader	7	0	6	100%
Debarker	16	1	10	94%
Tailer	2	0	1	100%
Resaw	5	2	4	60%
Molder	9	2	6	78%
Planer	8	0	4	100%
Bolt gangsaw	9	1	6	89%
Cutoff saw	25	3	20	88%
Shaper	3	2	2	33%
Router	8	4	8	50%
Panel saw	3	0	2	100%
Gang rip	7	1	4	86%
Nailer	4	1	4	75%
Sander	21	6	13	71%
Ripsaw	19	2	13	89%
Drilling	4	0	2	100%
Maintenance	6	5	5	17%
Dry kiln	1	0	0	100%
Bandsaw	6	2	5	67%
Material handling	9	1	4	89%
Bagger	4	3	4	25%
Misc. wood tools	21	0	10	100%
Foreman	2	0	1	100%
Dowel finisher	1	0	1	100%
Notcher	3	0	2	100%
Veneer jointer	2	1	1	50%
Veneer sander	1	0	0	100%
Veneer splicer	3	0	1	100%
Veneer welder	1	0	1	100%
Veneer drier	1	0	1	100%
Veneer clipper	1	0	1	100%
Mult. carver	1	0	0	100%
Pattern maker	5	1	5	80%
Totals	267	44	178	84%

Table 3. Dust monitoring results from 55 wood product manufacturers from 10-22-89 to 10-12-90.

Work station type	Range of variation: airborne wood dust, mg/m^3 of air				Number of samples
	Min	Max	Avg	Std	
Head saw	0.0	2.0	1.1	0.6	12
Edgesaw	0.5	56.4*	6.3	13.3	16
Chipper	0.7	2.4	1.7	0.7	4
Trimsaw	0.3	58.3*	6.5	13.4	17
Grader	0.6	3.9	2.0	1.2	7
Debarker	0.2	8.0	1.9	2.0	16
Tailer	0.5	2.4	1.4	1.0	2
Resaw	0.5	13.1	4.7	4.5	5
Molder	0.3	10.7	3.0	3.1	9
Planer	0.5	1.9	1.1	0.5	8
Bolt gangsaw	0.2	6.2	2.2	2.0	9
Cutoff saw	0.3	52.7*	4.7	10.9	25
Shaper	0.5	6.5	4.4	2.7	3
Router	2.4	8.1	4.8	1.9	8
Panel saw	0.4	3.4	1.7	1.3	3
Gang rip	0.9	8.1	2.4	2.4	7
Nailer	2.3	5.4	3.9	1.3	4
Sander	0.5	028.9*	4.8	7.6	21
Ripsaw	0.2	45.3*	4.4	9.9	19
Drilling	0.5	2.2	1.3	0.7	4
Maintenance	0.8	88.0*	19.7	30.7	6
Dry kiln	1.0	1.0	1.0	na	1
Bandsaw	0.9	74.5*	22.0	30.1	6
Material handling	0.3	7.8	2.1	2.3	9
Bagger	4.9	8.0	6.5	na	4
Misc. wood tools	0.2	4.2	1.3	0.9	21
Foreman	0.8	2.0	1.4	0.6	2
Dowel finisher	1.2	1.2	1.2	na	1
Notcher	0.5	2.1	1.5	0.7	3
Veneer jointer	0.5	6.5	3.5	3.0	2
Veneer sander	0.6	0.6	0.6	na	1
Veneer splicer	0.3	2.1	1.0	0.8	3
Veneer welder	1.7	1.7	1.7	na	1
Veneer drier	3.7	3.7	3.7	na	1
Veneer clipper	1.3	1.3	1.3	na	1
Mult. carver	0.5	0.5	0.5	na	1
Pattern maker	1.2	5.4	2.5	1.5	5

* Note: Some high exposure levels occurred because of one -time exposure under unusual conditions.

posed to dust concentrations averaging 19.55 mg/m^3. The highest reading for the maintenance personnel was 87.98 mg/m^3; the lowest was 0.75 mg/m^3.

Forty-four (16 percent) of the 267 samples exceeded the 5 mg/m^3 limit established by OSHA; 178 (64 percent) of the 267 samples exceeded 1 mg/m^3.

Twenty-two of the 55 plants (40 percent) sampled had at least one sample indicating wood dust concentration above 5 mg/m^3. Fifty companies (90 percent) had at least one sample indicating wood dust concentration above 1 mg/m^3. Only five (9 percent) of the companies tested had no tests indicating dust levels above 1 mg/m^3. Of these five companies, three were sawmills tested in the summer while it was raining. (The effect of weather on test results will be discussed below.)

The on-site sampling occurred from October 22, 1989, through October 12, 1990. The testing procedures remained consistent throughout this time, but the results differed with the time of year the testing occurred (Tables 4-7). No testing was done from April 20 through June 27, 1990.

Summary of wood dust exposure data by company.

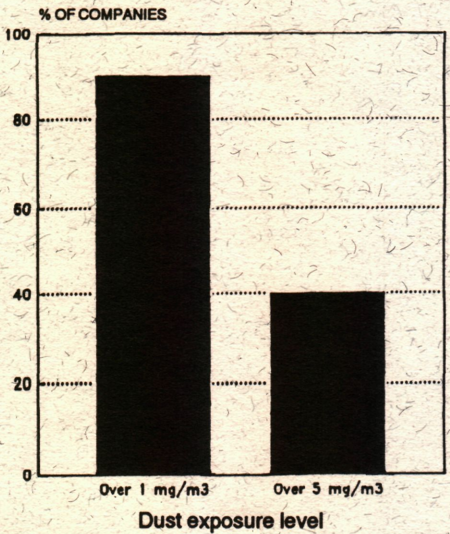

Figure 1. The percentage of the 55 companies tested having at least one station exceeding 1 mg/m^3 or 5 mg/m^3.

Seventy-seven percent (104 out of 136) of the work stations tested during the winter were under the 5 mg/m^3 limit (Table 4). During the summer, 90 percent (118 of the 131 of the work stations tested)were under the 5 mg/m^3 limit (Tables 6 and 7). In almost every case, the samples taken in the summer were lower than their winter counterparts.

During the winter testing, 70 percent (19 out of 27) of the companies had at least one work area with levels over 5 mg/m^3 (Figure 2). All of the companies tested at this time had at least one station over 1 mg/m^3.

Summary of wood dust exposure data by season.

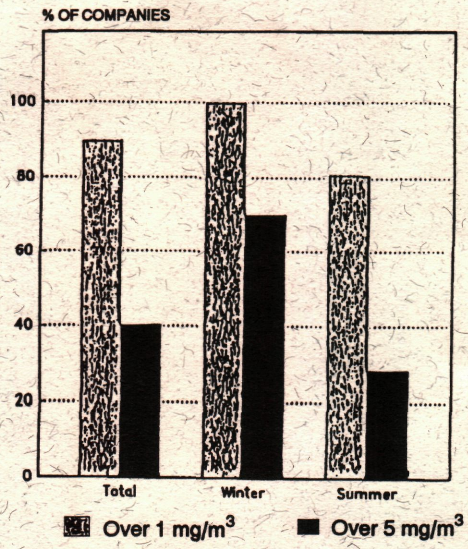

Figure 2. The percentage of the 28 companies tested during the summer and the 27 companies tested during the winter with at least one work station that exceeded 1 mg/m^3 or 5 mg/m^3.

During the summer, 28 percent (8 out of 28) of the companies had at least one station over 5 mg/m^3. Eighty-two percent (23 out of 28) had at least one station over 1 mg/m^3. During the summer, 17.8 percent (5 out of 28) had all stations in their facilities test under 1 mg/m^3.

In general, three factors contributed to reduced exposure rates during the summer: the opening of doors and windows, higher humidity, and the use of individual fans for cooling.

On rainy days, work stations usually had dust levels much lower than expected, based on other tests of similar machines on dry days. The workers indicated that they believed that the higher the humidity, the lower the apparent dust levels. No precise data on humidity were collected during this study, but the technicians did observe lower wood dust levels during days of apparent high humidity or rain.

Variation in wood dust exposure

A number of variables could be responsible for the wide variation in wood dust exposure rates of similar work stations. The total amount of wood dust found at a specific work station is the result of a combination of many components, including the dust collection system used, worker experience, work methods, weather, the species of wood being processed, tool maintenance, and the type of

Table 4. Wood dust exposure sampling results from 27 Michigan wood product manufacturers from 10-22-89 to 4-19-90 (winter testing).

Work station type	Number of samples: Total	More than 5 mg	More than 1 mg	Percent compliance with current OSHA regulations
Head saw	10	0	6	100%
Edgesaw	11	2	8	82%
Chipper	2	0	1	100%
Trimsaw	10	3	7	70%
Grader	6	0	5	100%
Debarker	7	0	5	100%
Tailer	1	0	1	100%
Resaw	4	2	4	50%
Molder	3	2	3	33%
Planer	6	0	4	100%
Bolt gangsaw	5	1	5	80%
Cutoff saw	11	3	9	73%
Shaper				
Router	4	2	4	50%
Panel saw	1	0	1	100%
Gang rip	5	1	4	80%
Nailer	4	1	4	75%
Sander	7	4	6	43%
Ripsaw	6	0	4	100%
Drilling	1	0	0	100%
Maintenance	5	4	4	20%
Dry kiln	1	0	0	100%
Bandsaw	3	1	3	67%
Material handling	4	1	2	75%
Bagger	4	3	4	25%
Misc. wood tools	1	0	1	100%
Foreman	2	0	1	100%
Dowel finisher	1	0	1	100%
Notcher	2	0	2	100%
Veneer jointer	2	1	1	50%
Veneer sander	1	0	0	100%
Veneer splicer	3	0	1	100%
Veneer welder	1	0	1	100%
Veneer drier	1	0	1	100%
Veneer clipper	1	0	1	100%
Mult. carver				
Pattern maker				
Totals	136	31	104	77%

Table 5. Wood dust exposure from 27 wood product manufacturers from 10-22-89 to 4-19-90 (winter testing).

Work station type	Range of variation: airborne wood dust, mg/m^3 of air: Min	Max	Avg	STD	Number of samples
Head saw	0.0	2.0	1.1	0.7	10
Edgesaw	0.6	56.4	8.1	15.7	11
Chipper	0.7	2.2	1.5	0.7	2
Trimsaw	0.3	58.3	9.6	16.7	10
Grader	0.6	3.9	2.0	1.3	6
Debarker	0.3	3.7	1.5	1.0	7
Tailer	2.4	2.4	2.4	0.0	1
Resaw	2.2	13.1	5.8	4.4	4
Molder	1.6	10.7	6.1	3.7	3
Planer	0.5	1.9	1.2	0.5	6
Bolt gangsaw	1.1	6.2	3.4	1.9	5
Cutoff saw	0.3	52.7	8.4	15.6	11
Shaper					
Router	2.6	8.1	5.3	2.1	4
Panel saw	3.4	3.4	3.4		1
Gang rip	0.9	8.1	3.0	2.6	5
Nailer	2.3	5.4	3.9	1.3	4
Sander	0.7	28.9	9.9	11.1	7
Ripsaw	0.7	3.6	1.8	1.0	6
Drilling	0.5	0.5	0.5	0.0	1
Maintenance	0.8	8.8	6.0	2.8	5
Dry kiln	1.0	1.0	1.0		1
Bandsaw	1.0	52.7	18.3	24.3	3
Material handling	0.3	7.8	2.6	3.1	4
Bagger	4.9	8.0	6.5	1.4	4
Misc. wood tools	2.9	2.9	2.9		1
Foreman	0.8	2.0	1.4	0.6	2
Dowel finisher	1.2	1.2	1.2	0.0	1
Notcher	1.8	2.1	2.0	0.1	2
Veneer jointer	0.5	6.5	3.5	3.0	2
Veneer sander	0.6	0.6	0.6	0.0	1
Veneer splicer	0.3	2.1	1.0	0.8	3
Veneer welder	1.7	1.7	1.7		1
Veneer drier	3.7	3.7	3.7		1
Veneer clipper	1.3	1.3	1.3	0.0	1
Mult. carver					
Pattern maker					

* Note: Some high exposure levels occurred because of one time exposure under unusual conditions.

Table 6. Wood dust exposure sampling results from 28 Michigan wood product manufacturers from 6-28-90 to 10-12-90 (summer testing).

Work station type	Number of samples: Total	More than 5 mg	More than 1 mg	Percent compliance with current OSHA regulations
Head saw	2	0	0	100%
Edgesaw	5	0	3	100%
Chipper	2	0	2	100%
Trimsaw	7	1	4	86%
Grader	1	0	1	100%
Debarker	9	1	5	89%
Tailer	1	0	0	100%
Resaw	1	0	0	100%
Molder	6	0	3	100%
Planer	2	0	0	100%
Bolt gangsaw	4	0	1	100%
Cutoff saw	14	0	11	100%
Shaper	3	2	2	33%
Router	4	2	4	50%
Panel saw	2	0	1	100%
Gang rip	2	0	0	100%
Nailer				
Sander	14	2	7	86%
Ripsaw	13	2	9	85%
Drilling	3	0	2	100%
Maintenance	1	1	1	0%
Dry kiln				
Bandsaw	3	1	2	67%
Material handling	5	0	2	100%
Bagger				
Misc. wood tools	20	0	9	100%
Foreman				
Dowel finisher				
Notcher	1	0	0	100%
Veneer jointer				
Veneer sander				
Veneer splicer				
Veneer welder				
100%Veneer drier				
Veneer clipper				
Mult. carver	1	0	0	100%
Pattern maker	5	1	5	80%
Totals	131	13	74	90%

Table 7. Wood dust exposure from 28 Michigan wood product manufacturers from 6-28-90 to 10-12-90 (summer testing).

Work station type	Range of variation: airborne wood dust, mg/m^3 of air: Min	Max	Avg	STD	Number of samples
Head saw	0.7	0.9	0.8	0.1	2
Edgesaw	0.5	4.1	2.2	1.3	5
Chipper	1.3	2.4	1.8	0.5	2
Trimsaw	0.5	5.3	2.0	1.6	7
Grader	1.7	1.7	1.7	0.0	1
Debarker	0.2	8.0	2.1	2.4	9
Tailer	0.4	0.4	0.4		1
Resaw	0.4	0.4	0.4	0.0	1
Molder	0.2	2.9	1.5	1.0	6
Planer	0.4	0.8	0.6	0.2	2
Bolt gangsaw	0.2	1.2	0.7	0.3	4
Cutoff saw	0.2	4.7	1.7	1.0	14
Shaper	0.5	6.5	4.3	2.7	3
Router	2.3	6.2	4.3	1.5	4
Panel saw	0.3	1.4	0.9	0.5	2
Gang rip	0.9	0.9	0.9	0.0	2
Nailer					
Sander	0.4	9.3	2.3	2.5	14
Ripsaw	0.2	45.2	5.5	11.8	13
Drilling	0.7	2.2	1.6	0.6	3
Maintenance	87.9	87.9	87.9		1
Dry kiln					
Bandsaw	0.8	74.4	25.5	34.5	3
Material handling	0.2	3.3	1.6	1.3	5
Bagger					
Misc. wood tools	0.2	4.1	1.2	0.8	20
Foreman					
Dowel finisher					
Notcher	0.4	0.4	0.4		1
Veneer jointer					
Veneer sander					
Veneer splicer					
Veneer welder					
Veneer drier					
Veneer clipper					
Mult. carver	0.4	0.4	0.4	0.0	1
Pattern maker	1.2	5.4	2.4	1.5	5

manufacturing that takes place at and around that work station. Though no two manufacturing facilities or no two work stations were identical in all respects, factors that may have contributed to the variations in exposure rates for similar work areas were observed by the technicians doing the on-site sampling. These on-site observations are the basis for the following comments.

Systematic study of a wood products manufacturer's dust control system could suggest means of improvement. Improving the hood design, attaching ducts at 60 degrees or less and closing the shutoffs on unused machinery have been reported to reduce wood dust exposure (OSHA's Wood Dust Regulation, William McCredie). Several dust collection systems observed by the technicians during this study could have been improved by using these methods.

Initial purchases of dust collection systems are often made without giving sufficient thought to the design or the future needs of the companies (Furniture Design and Manufacturing, July 1989). This appeared to be the case in some of the manufacturing sites in this study.

Modifying a company's dust collection system after installation can make the system inadequate. Whenever an air line is added or taken out of service, the entire system is affected. Adding a line to an existing system increases resistance and reduces the system's total effectiveness.

Modifications of ductwork were noticed during the on-site sampling. Some of the modifications were held together with duct tape, which is not recommended as a primary method of joining because the fabric deteriorates and has no elasticity. Leakage wastes energy and costs money. A 10 percent leakage in a 50,000 cfm system will lose a volume of air equal to the amount needed to provide air exhaust for five or six machines (Air Handling Systems, Manufacturer's Service, 1990).

Another problem associated with tapping into existing ductwork is that joining one line to another at the wrong angle creates a dead air space where dust accumulates. This reduces the effective diameter of the pipe and creates a potential fire hazard.

Hood design at the woodworking tool is also important in improving wood dust control. If dust cannot enter a hood, the system will not pick it up. It will then accumulate in the air around the worker.

Dust collection is the final answer to any dust exposure problem. Consideration should be given to reducing the amount of work the system must do by reducing the amount of dust generated. Proper tool geometry can affect the type and amount of wood dust generated. As the rake angle and depth of cut increase, the sizes of the particles increase, there is better chip formation, and the surface quality of the work piece is improved. As the wood particles get larger, they are more easily controlled, and tool wear is reduced. Adjusting machining conditions such as depth of cut, feed rate, tool speed, and tool geometry can help reduce tool wear and wood dust problems (FDM, June 1989).

Reducing static electricity can also make the collection of wood dust easier. Static electricity sometimes causes wood dust to accumulate on machinery, work pieces, and even the workers.

Electrostatic charges occur whenever two materials come in contact and then separate. For example, when a sanding belt on a sanding machine separates from the idlers and from the piece being sanded, the dust particles that arise have the same static charge, so they are repelled from one another. They are attracted and adhere to anything that has the opposite charge--that could be the worker, the work piece, or the machine. This makes the collection of this dust very difficult.

Static charges can be reduced in a processing plant by increasing the humidity of the air during the winter heating season.

Work practice controls include housekeeping practices, materials handling, and personal hygiene. In many cases, judicious application of such practices can reduce employee wood dust exposure (Wood and Wood Products, July 1989).

Observations made during this study concur with those in a previous study done by Clayton Environmental Consultants, Inc., on the primary work practice that contributes significantly to employee exposure to wood dust: using compressed air to clean dust off equipment and workplace areas. This study and the Clayton study suggest that using compressed air for cleaning is a major source of exposure to the person doing the cleaning and to the employees in adjacent areas.

Alternatives to using compressed air include sweeping or vacuum cleaning. For controlling wood dust, vacuuming is preferred. Available information suggests that it may not be practical to replace compressed air with these methods in all applications because of the efficiency and effectiveness of the compressed air (Wood and Wood Products, July 1989).

Conclusions

The results and observations of this study indicate that most, if not all, machines and processes tested could achieve exposure levels below 5 mg/m^3 if reasonable local exhaust ventilation were used and the exhaust system was properly designed and maintained.

Sixty-six percent (178 out of 267) of the work stations tested had dust levels above 1 mg/m^3. This suggests it would take considerable effort and expense to comply with the wood dust limits suggested by the woodworking unions.

Only two of the 55 companies tested were able to achieve exposure levels below 1 mg/m^3 at all the work stations tested. It appears, from the observations of the technicians, that these companies would do so regardless of the time of year or the weather. Both of these companies emphasized maintenance on all levels and had more than sufficient dust collection systems. These two plants were moderately aged, established companies that had initially well designed dust collection systems.

Managers of the companies with the higher exposure readings should focus energy and resources to reduce wood dust levels at their facilities. To obtain optimum benefit from the efforts toward this end, managers need to find expert help before making any equipment expenditures.

Implications of the Study

This study identified many factors – weather, dust collection systems, and machine setups – that seemed to influence the wood dust exposure levels in the companies tested. Large variations in exposure rates in similar work stations could not be explained entirely by the factors considered in this study. The following factors need further study: air flow rates of the dust collection systems, effect of tool setup, feed rate, horsepower, revolutions per minute of cutter heads, and geometry of cutter heads. The influence of weather needs further study: for example, a direct comparison of dust levels during winter and summer and a study of the effect of humidity on exposure levels.

Further studies in these areas could help reduce workplace wood dust exposure levels and help make work areas safer and more comfortable.

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