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Industrial Hygiene Characterization of Automotive Wood Model Shops

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A suspicion of an excess cancer risk in automotive model shops prompted the Industrywide Studies Branch, NIOSH, to conduct a proportionate mortality study and an industrial hygiene characterization of operations in these shops. The mortality study showed a statistically significant excess proportion of deaths due to colon cancer and leukemia (for woodshops only). The materials used in the model shops include various natural woods, laminated woods, plastics, resins, varnishes, putties and paints. Personal breathing zone samples were collected for total and respirable dust, amines, various hydrocarbons (including styrene, and toluene), formaldehyde, and nitrosamines. Particle size distribution studies were conducted on the wood dust and bulk airborne samples of dusts were subjected to various mutagenicity test systems. Work practices, ventilation and general housekeeping were checked. Total wood dust samples ranged from 0.03 to 25 mg/m^3 with an average around 1.0 mg/m^3. The percent respirable dust ranged from 19 to 38% as measured with Andersen impactors. Solvent exposure samples ranged from non-detectable to about 10% of the OSHA Permissible Exposure Levels. Relevant recommendations for improvement of contaminant control were made.

Introduction

In November 1979, an article appeared in the Detroit News which suggested that workers in one of the automobile wood die and model shops had experienced excess cancers.[1] Following this article, the National Institute for Occupational Safety and Health (NIOSH) was asked by the United Auto Workers and General Motors Corp. to investigate these operations. The scope of the study was later expanded to include the model shops at the three major automobile companies and several job shops in the area. In order to quickly ascertain if there was indeed a problem, Industrywide Studies Branch (IWSB), NIOSH, conducted a proportionate mortality ratio (PMR) study of deceased white male workers in the pattern and model making trades. At the same time, an industrial hygiene characterization of the workplace was started.

The IWSB PMR study and two other studies commissioned by General Motors (GM) on overlapping groups of their own model makers all have indicated an excess incidence of cancer of the colon and other sites among automotive wood model workers. The IWSB PMR study, using the death benefit records of the Pattern Makers' League of North America, showed statistically significant excess proportions of deaths due to colon cancer and leukemia among wood workers.[2] The Michigan Cancer Foundation, using cancer incidence rates in the Detroit area for comparison, showed statistically significant excess incidence of colorectal and salivary gland cancer among GM wood workers in 7 Detroit shops.[3] The Memorial Sloan-Kettering Cancer Center, using other nonwood shop GM employees for comparison, showed statistically significant excess incidence of colon cancer and statistically significant excess mortality due to colon and bladder cancer among GM wood workers in 14 shops nationwide.[4]

Pattern and model makers and other wood and metal workers have been found in previous epidemiologic studies to experience unusual distributions of excess cancer mortality. The Registrar General's decennial supplement[5] on occupational mortality in England and Wales reported excessive but not statistically significant risks of death due to cancer of the stomach and lung among pattern makers. In a proportionate mortality ratio (PMR) study of deaths occurring in the years 1950-1971 in Washington State, it was found that pattern and model makers had experienced slightly elevated proportionate mortality due to cancer of the prostate, digestive system and respiratory system.[6] Studies in the United States and Europe of workers employed in various wood-related industries have reported excess cancer of the nasal cavity and sinuses, esophagus, stomach, small intestine, respiratory system, skin, kidney, bladder, and brain as well as leukemia, Hodgkin's disease, and multiple myeloma.[5-11] Based on these and other studies, the World Health Organization has concluded that "sufficient evidence" exists to link nasal adenocarcinomas to employment in the funiture-making industry where wood dust constituted the major source of occupational exposure.[12]

The purpose of this paper is to summarize the results of our industrial hygiene characterization of exposures in the automotive wood model shops. Although one of the study populations included both wood and metal pattern makers, the primary thrust of our exposure estimates was confined to the wood model shops since this was the occupational group most strongly associated with elevated cancer rates.

Description of the Workplace

The making of wood models is a highly skilled craft. The model maker must be able to work from engineering drawings and convert them to three dimensional wood models with overall tolerances of 10/1000 of an inch (for die models). Experimental or prototype models, used for the conceptualization of ideas, do not necessarily need to be made to such close tolerances. These experimental models are often made of soft more easily worked woods since they do not have to meet close tolerances or to retain those tolerances

TABLE I

Materials Used in Wood Model Operations and Potential Occupational Exposures

Materials Used	Potential Exposures
Natural woods	Wood dust
Laminated wood	Wood dust, formaldehyde, phenol
Paints, sealers, lacquers	Toluene, acetone, xylene, cellosolve acetate, methyl isobutyl ketone, methyl ethyl ketone, n-butyl acetate, hexane, ethanol, isopropyl alcohol, 2-ethoxyethanol, methylene chloride
Resins	Formaldehyde, epichlorohydrin, diglycidyl ether of bisphenol A, styrene
Hardeners	Diethylenetriamine, triethylenetetramine, 1,2-ethane diamine, many other assorted amines

over long periods of time. These softer woods include pine, bass, jelutong, plywood lavan and mahogany. Historically, mahogany was used for die models but today most are made of an impregnated cativo wood (Impreg or Di-Ply are the two trade name products).

The impregnated wood is 30% phenol-formaldehyde resin impregnated in and laminated between thin sheets of cativo wood. The laminated wood can be readily carved to close specifications and has superior dimensional stability under changing temperature and humidity.

The model makers use a variety of woods and wood machine tools, both stationary and hand-held, to complete the models. Pieces of wood are glued together using white glue and epoxy resins to form a large block from which the model will be made. A wide variety of machines are used: table saws, routers, planers, radial arm saws, shapers, jointers, sanders, band saws, grinders, drill presses and multi-axis numerical control mills. A wide array of hand tools also is used in the course of making a model.

The larger wood working machines, particularly the shapers, are generally grouped together in a separate mill shop. In some cases the shapers are isolated from the rest of the mill or at least from the general work areas. In all large shops, to ensure safety, the shapers are operated only by specially trained workers. A typical mill shop may include radial arm saws, table saws, large routers, planers, jointers, and shapers. Other wood working machines are generally scattered throughout the work area or grouped near the model makers into "mini-mill shops." These include routers, band saws, grinders, sanding wheels and drill presses. The multiaxis machines also usually are separated from the rest of the work area.

In addition to the many woods used, other materials used to make models include adhesive systems, from white glue to epoxy resins; plastics such as carveable putties, fiberglass and polyfoams; and a variety of paints and lacquers. Table I lists the common types of materials encountered and a fairly complete list of potential exposures which may be associated with their use.

Historical Exposures in Model Shops

At the time this study was started (1979), virtually no exposure information could be found for model shops, either through the literature or from the companies involved with the study. A wealth of information does exist on wood dust exposures in related industries, such as furniture making where nasal carcinomas have been linked to wood dust exposures. In one study of furniture making,[13] 59 results of air sampling for wood dust ranged from 1.0 to 94.6 mg/m^3 with an average of 10 mg/m^3. Area cascade sampling results ranged from 0.5 to 100 mg/m^3, with an average of 9.2 mg/m^3; a calculated mass median equivalent diameter of 8.9 μm was reported. The IARC Monograph on Wood[12] summarizes many papers on wood dust exposure studies in a variety of related industries throughout the world. Wood dust levels as high as 200 mg/m^3 with averages around 40 mg/m^3 were encountered in a Czechoslovakian furniture making shop but typical average exposure concentrations of 10-20 mb/m^3 were more commonly reported.

In 1980, the General Motors Corporation reported results of extensive sampling in the largest of their model shops.[14] The 90 wood dust samples collected ranged from 0.1 to 22.4 mg/m^3 with an average of 1.5 mg/m^3. All 32 samples collected to evaluate exposure to solvent vapors resulted in levels well below the respective OSHA Permissible Exposure Levels (PEL) for the solvents (the highest, 12 ppm of toluene, was approximately 10% of its respective PEL). Formaldehyde was non-dectectable in their samples and the highest nitrosamine levels were on the order of 5 parts per trillion.

TABLE II

Summary of Personal Sampling for Total Wood Dust Exposures

		Total Dust (mg/m^3)^A		
Job Category	N	X	σ(SD)	Range
Model makers (soft and hard wood)	23	0.79	1.66	0.16-8.33
Model makers (predominately soft wood)	4	0.34	0.14	0.2-0.51
Model makers (predominately hard wood)	12	0.64	0.39	0.16-0.25
Sweepers	5	1.62	2.55	0.1-6.1
Machine operators (shapers)	7	2.65	5.0	0.33-13.9
Plastic shop	3	0.43	0.35	0.03-0.71
Multi-axis machine operators	4	0.46	0.37	0.17-1.0
Total	58			

^{A}OSHA Standard: 15 mg/m^3 (nuisance dust). ACGIH TLV (1982): 5 mg/m^3 (soft wood), 1 mg/m^3 (hardwood).

TABLE III

Summary of Area Sampling for Total Dust

Location	Number of Samples	Average Conc. (mg/m³)	σ[A]	Range
Wood mill-general	10	0.28	0.17	0.05-0.47
Mini mill-general	4	0.37	0.15	0.27-0.6
Routers, next to or between	5	10.9 (0.44)	23.4 (0.47)	0.07-52.7[B] (0.07-1.06)[C]
Shapers, next to or between	7	2.7	6.5	0.09-17.5
Grinders	2	0.68	0.8	0.13-1.23
Multi axis machine	2	0.17	0.007	0.16-0.17
Total	30			

[A]Standard Deviation.

[B]Sample at 52.7 mg/m^3 is suspect due to large particles collected.

[C]Data in parentheses are calculated without the highest value.

Description of Survey Methods

Personal and area wood dust samples were collected with MSA Model G pumps at flow rates of 1.5 to 2.0 liters per minute (Lpm) using 37 mm Millipore matched-weight filters. Respirable dust samples were collected using a 10-mm nylon cyclone at 1.7 Lpm on 37-mm PVC filters. Dust loadings were determined by gravimetric analysis of the filters. Area samples taken for Scanning Electron Microscope (SEM) analysis of respirable dust were collected at 10 Lpm on 37-mm polycarbonate filters using a 1/2-in. stainless steel cyclone with a Gast® vacuum pump. High volume air samples (area) were collected with Staplex HiVol® samplers at about 50 CFM on either pleated paper filters or 102-mm Whatman 41 filters. The HiVol samples were weighed to determine total dust loading and then analyzed by one of two ways: 1) solvent extraction and submission to the Ames Salmonella/Microsome assay system or 2) solvent extraction and analysis of the extract by gas chromatography/ mass spectrophotometry (GC/MS). Wood dust samples for particle size distribution were collected on 102-mm PVC and glass fiber filters using an Andersen Non-Viable sampler with a Gast vacuum pump at 29 Lpm (1.0 CFM). Loadings per stage were determined by gravimetric analysis.

Samples for organic solvents were collected on standard 150-mg charcoal tubes (SKC, Inc.) with DuPont P-200 personal sampling pumps. These samples were desorbed with carbon disulfide and analyzed by a gas chromatograph equipped with a flame ionization detector.[15]

Several samples for volatile amines were collected in 150-mg silica gel tubes (SKC, Inc.) using DuPont P-200 personal sampling pumps. These samples were desorbed from the tubes with a suitable solvent and analyzed by gas chromatography. This procedure was recommended by the analytical laboratory but had not been fully evaluated. Therefore the results from this method are questionable.

Nitrosamine samples were collected on Thermosorb/N air samplers (Thermo Electron Corp.) at 1.0 Lpm with MSA Model G sampling pumps. These samples were analyzed for N-nitroso compounds with a Thermal Energy Analyzer (TEA) (Thermo Electron Corp.).

Samples were collected for formaldehyde using a new NIOSH method, P&CAM #318.[15] This method involved the collection of formaldehyde with a 150-mg impregnated charcoal tube and analysis by ion chromatography. This method also was under development at the time of this study and has since been abandoned due to questionable reproducibility in field use, blank variability and other concerns.

Results and Discussion

Total Dust

A summary of the fifty-eight personal samples for total dust is contained in Table II. The concentrations ranged from 0.03 to 13.9 mg/m^3 with an overall average of 0.96 mg/m^3. One of the samples with a total dust loading of 29.4 mg/m^3

TABLE IV

Summary of Total Versus Respirable Dust Samples

	Total Dust	Respirable Dust
Range (mg/m³)	0.05-29.4	0.01-0.6
Average (mg/m³)	3.2	0.16
Standard Deviation (mg/m³)	7.5	0.17

Ratio: Respirable Dust/Total Dust X 100%

Range	0.1-180%
Average	42.8%

TABLE V

Summary of Andersen Impactor Samples for Particle Size Distribution [A]

Location	Date Sample Collected	MMAD[B] (μm)	σ_g^C	Total Dust Conc. (mg/m^3)	% Respirable [D]
Wood Mill-Plant A	9/25/80	10	1.5	0.91	18
Wood Mill-Plant A	1/ 9/80	9.8	2.8	0.72	38
Mini Mill-Plant A	1/ 9/80	9.0	1.1	0.69	42
Mini Mill-Plant A	1/10/80	5.2	2.1	0.47	61
Shaper Room-Plant C	3/ 5/80	6.1	1.6	0.43	57
Wood Mill-Plant A	3/ 4/80	6.6	1.5	0.22	53
Shaper Room-Plant C	3/ 5/80	7.8	1.3	0.20	47
Wood Mill-Plant A	9/ 4/80	8.4	1.2	0.20	35
Wood Mill-Plant C	3/ 4/80	6.1	1.6	0.19	54

[A]Data estimated from plots of the effective cutoff diameter versus cumulative percent on logarithmic probability paper.

[B]Mass median aerodynamic diameter.

[C]Geometric standard deviation.

[D]Respirable dust fraction divided by the total dust fraction times 100%.

had, on examination, several large pieces of wood particle (>1 mm) on the filter. It was believed that particles of this size could exist on the filter only if they were projected into the cassette, most likely due to high operating speeds of the woodworking machines. Thus the sample was considered to be questionable and was not included in later statistical analysis.

Shaper operators was the job category found to have the highest exposures. This was expected due to the large amount of dust generated by these machines. The possibility of projected wood dust being collected by samplers worn by shaper operators was also large; therefore, each sample was visually inspected for unusually large particles. It was very difficult to control the dust emissions from shapers due to the speed of rotation (approximately 10 000 rpm) and the necessity that the work surface around the shaper heads be kept clear for safe operation of the machines.

The second highest exposure category included the workers who clean up the wood dust in the shops (sweepers). This was surprising because even though these workers are constantly disturbing the settled dust, they generally do not stay near the primary sources of dust generation. Since only five such samples were collected, these results may not be truly representative of sweepers' exposure.

Exposures in other job categories ranged from 0.3 to 1.0 mg/m^3. None of the conclusive samples were above the Occupational Safety and Health Administration (OSHA) Permissible Exposure Limit (PEL) for nuisance dust (15 mg/m^3) while only 3.4% (2 samples) were above the American Conference of Governmental Industrial Hygienists (ACGIH) recommended Threshold Limit Value (TLV)® for soft woods (5 mg/m^3) and 14% (8 samples) were above the ACGIH recommended TLV for hard woods (1 mg/m^3).

A summary of the 30 area samples for total dust is contained in Table III. The highest concentrations were measured near routers and shapers. This, again, is not surprising because these two machine types gave off the greatest amount of visible dust and are the most difficult to control with local exhaust ventilation. Only five samples were collected near the routers. The high concentration sample (52.7 mg/m^3) had been showered by dust projected off the router and therefore was discounted in statistical analysis. This sample is included to illustrate the problems in sampling that can occur when particles are projected at high speeds from the woodworking machines. Generally, the samples were below the ACGIH recommended TLV of 1.0 mg/m^3 for hardwood (only 13% or 4 samples were above).

Particle Size Distribution

At the start of this study, it was believed that 10-mm nylon cyclones might not work well for respirable wood dust since wood dust acquires a static charge and sticks to the nylon cyclone. The data presented in Table IV support this hypothesis. One might expect a range of percent respirable dust depending on the loading, the type of wood being used (degree of hardness, % moisture content) and the machining process. However, the results found were quite inconsistent, ranging from 0.1 to 180% respirable dust. The average (43%) was not greatly different from data collected by more reliable methods such as Andersen samplers. This is attributed more to the effect of averaging than to the validity of the samples.

A total of nine Andersen impactor samples was collected throughout this study. These data are summarized in Table V. The Andersen impactors used had nine stages including a back-up filter and a 10 μm prestage. The effective cutoff diameter and cumulative mass fraction were plotted for each sample on logarithmic-probability paper. The mass median aerodynamic diameter (MMAD), percent respirable fraction, and the geometric standard deviation (σ_g) were esti-

TABLE VI

Summary of Particle Size Analysis of Respirable Dust Samples for Scanning Electron Microscope[A]

Respirable Total Dust[B] (mg/m^3)	Median Area Equivalent Diam (μm)	Median Length (μm)	Median Width (μm)	Mass Median Diameter (μm)	Aerodynamic Diameter (μm)
0.49	0.52	0.81	0.36	1.76	1.57
0.46	0.47	0.69	0.36	1.62	1.45

[A]Sample collected on polycarbonate filter with 1/2 in. cyclone @ 9 Lpm.

[B]Sample collected on matched weight filters @ 1.7 Lpm.

mated from the plot for each sample. The MMAD ranged from 5.2 to 10 μm with an average of 7.7 μm. The percent respirable fraction and the MMAD were roughly inversely proportional to the total dust loading (the percent respirable more so) over the range of 0.3 to 0.9 mg/m^3. One might expect this to be the case. Both curves tend to flatten out at total dust loadings of 0.3 mg/m^3.

Many of the workers complained about extremely fine dust being generated when the impregnated wood was machined with a router or a shaper. In order to determine how fine the respirable dust was, three samples were collected on polycarbonate filters with 1/2-in. stainless steel cyclones for subsequent scanning electron microscope (SEM) analysis. These data are presented in Table VI and show that, indeed, the mass median diameter was quite small, approximately 1.7 μm (of respirable dust only). The question was raised as to whether the dust particles in these shops displayed any fiberlike characteristics. The SEM analysis also addressed this question; the length to width ratios of the particles (2.3:1 and 1.9:1 in two samples) were below the 3:1 ratio used to characterize fibers. This may not be the case for all woods since only the impregnated woods were investigated. It is suspected that the dusts from working softer woods may exhibit greater length to width ratios.

Organic Solvents

A total of fourteen charcoal tube samples (ten area and four personal) was collected throughout this study for a variety of organic solvents. Solvents analyzed were toluene, acetone, xylene, cellosolve acetate, methylisobutyl ketone, butyl acetate, styrene, epichlorohydrin and methylene chloride. All vapor concentrations were well below the respective OSHA PELs. In fact, in calculating the PEL for a mixture of all the solvents listed above and using the highest value obtained for each solvent, the value was 10% of the PEL.

Nitrosamines

Eight samples were collected for nitrosamines at points as close as possible to the epoxy mixing stations. None of these samples showed the presence of any N-nitroso compounds. Two of the samples were positioned immediately above two different resin systems while the resin systems reacted (large quantities of each part having just been added) and yet no N-nitroso compounds were detected.

Amines and Formaldehyde

Four area samples collected on silica gel near the epoxy mixing stations were analyzed for hexamethylenetetramine (HMTA) and diethylenetriamine (DETA), hardeners for the major epoxy resin systems used. None of the samples showed the presence of HMTA and DETA above the detection limits of 0.01 and 0.2 mg per tube, respectively. Since the sampling and analytical method used (collection on silica gel, elution with 2 mL of 0.4 N HCl in 80% methanol, analysis by GC with a nitrogen/phosphorous detector) had not been validated, the results of these samples Could not be considered conclusive. No method was available for other amines (*e.g.*, triethylenetetramine).

Since the impregnated wood used extensively by model makers is saturated with a phenol-formaldehyde resin, it was thought that formaldehyde might be released when the impregnated wood was subjected to high speed machining (*e.g.*, routers and shapers). Ten samples for formaldehyde were collected immediately above routing and shaping operations using NIOSH method P&CAM #318.[15] These samples showed levels of 0.1 to 0.3 ppm formaldehyde. However, one of the blind blanks analyzed showed formaldehyde levels approximating the highest concentration on the samples. Therefore, these data were discounted. Additional samples were collected using a 2,4-dinitrophenylhydrazine method for aldehydes and no formaldehyde was found at levels above 0.01 ppm.[14] These samples were considered to be more conclusive than those obtained with the P&CAM #318 method.

Mutagenicity Testing

Since no exposure levels were found which would explain the apparent excess of colo-rectal cancer, bulk air and bulk wood samples were collected to see if these materials demonstrated any mutagenic activity. A sample was considered to display positive activity if it had an activity (revertants per plate) at least twice the blank control (blank filters) and displayed a dose-response relationship (increasing activity with an increase of the amount of extract perplate). A total of 15 high volume (hi vol) air samples, 5 blank filters (Whatman 41) and 10 bulk wood dust samples were tested for mutagenicity with the Ames Salmonella/Microsome assay system. The samples were extracted with 250 mL of dichloromethane (DCM) followed by a similar extraction with a 1:1 mixture of methanol and acetone (M+A). Tester strains TA100 and TA98 were used with and without S9 activation. In the first round of testing two bulk wood samples (impregnated wood and mahogany) and four hi vol filter samples were submitted to the assay system. Both bulk wood samples and three of the hi vol samples showed no activity while one of the hi vol samples displayed a borderline positive activity (with TA98 test strains, with and without S9 activation).

The second round of samples included 8 bulk dust and 11 hi vol samples, including two rooftop, ambient air samples. The results were equivocal; both ambient air samples showed positive activity; while 3 of the bulks and 2 of the hi vol room samples displayed slightly positive activity. Although the hi vol room sample, and certainly the bulk wood sample, activity could not be attributed totally to ambient air, it was concluded that the activity was quite low and did not warrant further consideration.

Bulk wood and hi vol dust samples were submitted to the analytical laboratory for extraction and analysis by GC/MS to try to determine what extractable materials were in the samples. As can be seen from the results presented in Table VII, the only quantifiable material was phenol. The amount of phenol extracted from the hi vol filter samples equated to approximately 0.01 mg/m^3 which is well below the 19 mg/m^3 OSHA PEL for phenol. Since airborne levels of phenol were not measured these samples cannot be considered estimates of phenol exposure.

Samples of new impregnated wood also were tested for the presence of latent formaldehyde. The procedure involved suspending weighed portions of each bulk sample over water in sample jars, sealing the jars and placing them in an oven for 20 hours at 49°C. The solutions were analyzed spectrophotometrically after the addition of chromotropic acid and compared to a calibration curve based on known concentrations of formaldehyde. The limit of detection was 1 μg/mL of solution (5 μg per g of dust). All samples were less than the detection limit.

Conclusions

A total of 88 personal and area samples were collected for total dust in three different model shops. Of those samples considered valid, one (1%) was greater than the OSHA PEL of 15 mg/m^3 for nuisance dust, three (3%) were greater than the ACGIH recommended TLV of 5 mg/m^3 for soft woods and eleven (12.5%) were above the ACGIH recommended TLV of 1.0 mg/m^3 for hard woods. The use of 10-mm nylon cylones for collecting respirable wood dust was found to be unreliable. Estimates of the mass median aerodynamic diameter using area impactor samples ranged from 5.2 to 10.0 μm. The mass median aerodynamic diameter of respirable dust (generated by machining impregnated woods) was estimated to be 1.7 μm. None of the samples collected for organic solvents, amines, formaldehyde or nitrosamines revealed any appreciable concentrations of these contaminants. Extractable materials submitted to the Ames assay system from high volume dust and bulk wood samples were inconclusive with regard to evidence of mutagenicity. These same types of samples, when extracted with methylene chloride and analyzed by GC/MS, were found to contain small amounts of phenol. Bulk wood samples were checked for the presence of latent formaldehyde but none could be detected at a limit of detection of 1 μg/mL (5 ppm per sample).

Recommendations

Even though no significant air contamination was found in the workplace, general recommendations were made concerning work practices, housekeeping and ventilation in order to keep all exposures at the lowest possible levels because of the excess cancer incidence found at the shops involved in this study. Most of these recommendations have already been implemented in the larger shops but not in many of the smaller operations. These recommendations are general in nature and are considered prudent steps to take until a causative agent can be identified.

1. All woodworking machines should be equipped with local exhaust ventilation. This system should be checked periodically to ensure the proper air flow and capture velocity are maintained.
2. Bag or hopper type collection systems on woodworking machines should be emptied on a frequent and regular basis to ensure proper operation.

TABLE VII

Summary of Results of Analysis of Bulk and Filter Wood Dust for Organic Extractables (Phenol)^A

Type Bulk Sample Analyzed	Bulk Samples: Amount Extracted (grams)	mg Phenol per g Sample^B
Mahogany	0.3456	N.D.
Impreg® (new)	0.5556	17.39
Impreg (old)	0.6557	10.43
Mahogany	0.3261	N.D.
Impreg	0.3339	4.65

Filter Samples^C

Filter #	mg Phenol/Filter^b
GHV - 2	3.41
GHV - 4	0.24
Blank	N.D.

^{A}Both bulks and filter samples were extracted with methylene chloride and analyzed by gas chromatography (FID). The presence of phenol was verified by GC/MS.

^{B}N.D. = Not Detected.

^{C}Filters were 102-mm Whatman 41.

3. Workers should be trained in the proper operation of wood mill machines and they should avoid improper use of such machines, *e.g.,* using the upward side of a sanding disc.
4. In the case of some machines, such as shapers and routers, the generation of large quantities of dusts appears to be unavoidable even with properly designed local exhaust ventilation. Therefore, the use of NIOSH approved dust respirators is recommended for operators of shapers and routers, unless engineering controls can be developed to reduce the dust to acceptable levels.
5. Further research should be conducted on new control measures to help reduce the amount of airborne dust generated from woodworking machines, particularly shapers and routers.
6. Compressed air should not be used to blow dust off clothing. Vacuum systems should be used whenever possible to remove dust from work pieces, work areas and clothing.
7. Good work practices in the use and handling of epoxy resins should be established or augmented. These include the use of rubber or latex gloves when mixing or applying epoxies, washing hands after handling epoxies and taking care not to wipe the epoxy on work clothes where subsequent skin contact can occur.
8. Mixing and applying adhesives, glues and putties should be conducted in properly ventilated areas, preferably in an exhausted hood.
9. The spraying of primers, lacquers and paints should be conducted in a ventilated booth.
10. Any eating or storage of food, drinking or smoking in the workplace should be discouraged.

Several of the companies involved in this study started colo-rectal screening exams for all workers who have worked or are currently working in the model shops. These tests are considered to be sound preventative health measures in light of the increased incidence of colo-rectal cancer among model makers. These tests include:

1. stool guaiac test
2. colonoscopy or sigmoidoscopy exam
3. digital rectal exam

These tests are particularly worthy of consideration since approximately 70% of colon cancers are treatable if detected early enough by medical tests.

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