WOOD DUST*

First Listed in the ***Tenth Report on Carcinogens***

CARCINOGENICITY

Wood dust is *known to be a human carcinogen*, based on sufficient evidence of carcinogenicity from studies in humans. An association between wood dust exposure and cancer of the nose has been observed in many case reports, cohort studies, and case-control studies that specifically addressed nasal cancer. Strong and consistent associations with cancer of the nasal cavities and paranasal sinuses were observed both in studies of people whose occupations are associated with wood dust exposure and in studies that directly estimated wood dust exposure. Risks were highest for adenocarcinoma, particularly among European populations. Studies of U.S. populations showed similar significant positive associations. A pooled analysis of 12 case-control studies showed that the estimated relative risk of adenocarcinoma was very high (45.5) among men with the greatest exposure, and that the risk increased with duration of exposure (Demers *et al*. 1995). The association between wood dust exposure and elevated nasal cancer risk in a large number of independent studies and with many different occupations in many countries strongly supports the conclusion that the increased risk is caused by wood dust rather than by simultaneous exposure(s) to other substances, such as formaldehyde or wood preservatives. Other types of nasal cancer (squamous-cell carcinoma of the nasal cavity) and cancer at other sites, including cancer of nasopharynx and larynx and Hodgkin's disease, have been associated with exposure to wood dust in several epidemiologic studies. However, these findings were positive in some, but not all, studies and the overall epidemiologic evidence is not strong enough or consistent enough to allow firm conclusions about the role of wood dust exposure in the development of cancer at these other sites.

There is inadequate evidence for the carcinogenicity of wood dust from studies in experimental animals. No tumors attributable to beech wood dust exposure were found in inhalation studies in female Sprague-Dawley rats, female Wistar rats, or male Syrian golden hamsters or in intraperitoneal injection studies in female Wistar rats. Similarly, inhalation exposure to wood dust did not significantly affect the incidence of tumors induced by simultaneous exposure to other compounds, including formaldehyde in female Sprague-Dawley rats, sidestream cigarette smoke in female Wistar rats, or *N*-nitrosodiethylamine in male Syrian golden hamsters. However, each of these studies suffers from various limitations, such as small numbers of animals or dose groups, short study duration, or inadequate data reporting.

ADDITIONAL INFORMATION RELEVANT TO CARCINOGENESIS OR POSSIBLE MECHANISMS OF CARCINOGENESIS

Dermal exposure to a methanol extract of beech wood dust resulted in a significant dose-related increase in the incidence of skin tumors (squamous-cell carcinoma and papilloma) and mammary tumors (adenocarcinoma, adenoacanthoma, and mixed tumors) in female NMRI mice.

Studies using polar organic solvent extracts of some hardwood dusts have reported weak positive results for reverse mutations in *Salmonella typhimurium.* In addition, two chemicals found in wood, Δ^3 carene and quercetin, were found to be mutagenic in *Salmonella*. *In vitro* and *in vivo* tests in mammals, using polar organic solvent extracts of some wood dusts (beech and oak) have shown positive results for DNA damage, micronucleus induction, and chromosomal aberrations (primarily chromatid breaks). A higher rate of DNA damage (primarily single-strand breaks and DNA repair) and micronucleus induction has been observed in peripheral blood lymphocytes from people who are occupationally exposed to wood dust.

The roles of specific chemicals found in wood dust (either naturally in the wood or added to it in processing) in inducing cancer are not clear. The particulate nature of wood dust also may contribute to wood dust-associated carcinogenesis, because dust generated by woodworking typically consists of a high proportion of particles that are deposited in the nasal cavity. Some studies of people with long-term exposure to wood dust have found decreased mucociliary clearance and enhanced inflammatory reactions in the nasal cavity. Also, cellular changes (metaplasia and dysplasia) observed in the nasal mucosa of woodworkers and of laboratory animals may be precancerous.

PROPERTIES

Wood is an important worldwide renewable natural resource. Forests extend over approximately one-third of the earth's total landmass (about 3.4 million km^2). There are an estimated 12,000 species of trees, each producing a characteristic type of wood; therefore, the species of trees harvested vary considerably among different countries and even among different parts of a single country. However, even in countries with high domestic production of wood, some wood may be imported for specific uses, such as furniture production (IARC 1995).

In the plant kingdom, trees belong to the division of spermatophytes and are subdivided into two classes based on seed type: gymnosperms (which have exposed seeds) and angiosperms (which have encapsulated seeds). Most of the 12,000 tree species are broad-leaved deciduous trees, or hardwoods, principally angiosperms. Only approximately 800 species are pines, firs, and other coniferous trees, or softwoods, principally gymnosperms (IARC 1995).

The terms "hardwood" and "softwood" refer to the species, and not necessarily the hardness of the wood. Although hardwoods generally are denser than softwoods, the density varies greatly within each group, and the hardness of the two groups overlaps somewhat (IARC 1995). Although most trees harvested worldwide are hardwoods (58% of volume), much of the hardwood is used for fuel. For industrial purposes, softwood is the major wood used (69%), although this varies from region to region (IARC 1995).

Wood dust is a complex mixture generated when timber is processed, such as when it is chipped, sawed, turned, drilled, or sanded. Its chemical composition depends on the species of tree and consists mainly of cellulose, polyoses, and lignin, with a large and variable number of substances with lower relative molecular mass. Cellulose is the major component of both softwood and hardwood. Polyoses (hemicelluloses) are present in larger amounts in hardwood than in softwood. They contain five neutral sugar units: three hexoses (glucose, mannose, and galactose) and two pentoses (xylose and arabinose). The lignin content of softwood is higher than that of hardwood. The monomers of lignin are phenylpropane units joined by various linkages.

The lower-molecular-mass substances significantly affect the properties of wood; these include substances extracted with nonpolar organic solvents (fatty acids, resin acids, waxes, alcohols, terpenes, sterols, steryl esters, and glycerols), substances extracted with polar organic solvents (tannins, flavonoids, quinones, and lignans), and watersoluble substances (carbohydrates, alkaloids, proteins, and inorganic material). Hardwood tends to have a higher percentage of polar-soluble substances than does softwood.

Wood dust is a light brown or tan fibrous powder. Its specific gravity is reported as 0.56 by the National Toxicology Program (NTP) (2001), but it also is described as variable and dependent on wood species and moisture content. The composition of softwood tissue is simpler than that of hardwood. The bulk of softwood consists of just one type of cell, tracheids. Tracheids are elongated fiber-like cells with a square or polygonal cross-section. Less than 10% of softwood consists of short, brick-like parenchymal cells arranged radially. Softwoods also contain epithelial cells that secrete resin into canals, which run horizontally and radially through the wood.

In hardwoods, there is more detailed differentiation between stabilizing, conducting, and storage tissue. Stabilizing tissues contain libriform fibers and fiber tracheids, which are elongated cells with thick polygonal walls and small lumina. The conducting system is composed of vessel elements fitted together to form long tubes of up to several meters. Hardwoods that contain resin canals also have a secretory system of epithelial cells (IARC 1995).

The walls of wood cells consist of various layers that differ in structure and chemical composition. The individual cells of wood tissue are glued together in the middle lamella (which consists mainly of lignin, polyoses, and pectins). The outer cell wall layer (the primary wall) is formed by a net-like arrangement of cellulose fibrils embedded in a matrix of lignin and polyoses. The next layer is the secondary wall, which is further subdivided into secondary walls 1 (S1) and 2 (S2). S1 and S2 contain densely packed cellulose fibrils arranged in parallel. At the inner border of the cell wall, there is a final layer (the tertiary wall). The lignin content decreases from the compounded middle lamella through S2, and the cellulose content increases in the same direction. The organic matter of wood (extractives) is found in the resin canals and parenchymal cells (IARC 1995).

No flash-point data are available for wood dust; however, wood dust is flammable and will ignite in the environment. It may present a strong to severe explosion hazard if a dust cloud contacts an ignition source. Wood dust is stable under normal laboratory conditions. No information about decomposition in the environment was found in the literature (NTP 2001).

USE

Wood dust has limited commercial uses, but wood is one of the world's most important renewable resources. Forests are estimated to cover more than one-third of the world's total land area, with a total biomass of one trillion cubic meters, of which approximately 3.5 billion cubic meters are harvested annually. "Industrial roundwood" refers to categories of wood not used for fuel, which include sawn wood (54%), pulpwood (21%), poles and pit props (14%), and wood used for other purposes, such as particle board and fiberboard (11%) (IARC 1995).

Wood dust is used to prepare charcoal, as an absorbent for nitroglycerin, as a filler in plastics, and in linoleum and paperboard (NTP 2001). Another commercial use for wood dust is in wood composts (Weber *et al.* 1993).

PRODUCTION

Wood dust is created when machines or tools are used to cut or shape wood materials. Industries in which large amounts of wood dust are produced include sawmills, dimension mills, furniture industries, cabinetmaking, and carpentry (IARC 1995).

Total estimated production values for wood used in industry in the United States for 1990 was 311.9 million cubic meters of softwood and 115 million cubic meters of hardwood (Demers *et al.* 1997).

EXPOSURE

The National Occupational Exposure Survey, conducted from 1981 to 1983 by NIOSH, estimated that approximately 600,000 workers were exposed to wood dust in the United States (NIOSH 1990). Wood dust usually is measured as airborne dust concentrations, by particle size distribution, by type of wood, and by other characteristics of wood (IARC 1995). Backlighting with a dust lamp, or Tyndall beam, is useful for identifying sources of dust emission (Hamill *et al*. 1991).

Exposure to wood dust occurs when individuals use machinery or tools to cut or shape wood. Breathing in the dust causes it to deposit in the nose, throat, and other airways. The amount of dust deposited within the airways depends on the size, shape, and density of the dust particles and the strength (turbulence and velocity) of the airflow (IARC 1981). Particles with a diameter larger than 5 µm ("inspirable" particles) are deposited almost completely in the nose. Particles 0.5 µm to 5 µm ("respirable" particles) are deposited in the lower airways (IARC 1981, 1995).

Total airborne dust concentrations are described as mass per unit volume (usually milligrams per cubic meter). Wood dust generally is collected by a standard gravimetric method that involves using a sampling pump to collect a known volume of air through a special membrane filter contained in a plastic cassette. The detection limit for personal sampling of wood dust is approximately 0.1 mg/m^3. Polyvinyl chloride (PVC) filters are preferred, because of the highly variable moisture content of wood dusts (IARC 1995).

Inspirable dust includes large particles that may deposit in the respiratory system. Finer, respirable dust is sampled through a 10-mm nylon cyclone (centrifugal separator) that is designed to accept 50% of unit density spherical particles of 3.5-µm aerodynamic diameter. Samplers that measure inspirable wood dust concentrations must maintain a sampling efficiency of greater than 50% for particles up to 100 µm in aerodynamic diameter (IARC 1995, Weber *et al.* 1993).

The National Institute for Occupational Safety and Health (NIOSH) sampling method (NIOSH Method 0500) for total airborne dust consists of collecting dusts on tared 37-mm hydrophobic filters (PVC, 2-µm to 5-µm pore size or equivalent). Sampling rates of 1 to 2 L/min are recommended, with a recommended filter maximum dust loading of 2 mg of total dusts. Dust weights are determined with a microbalance capable of weighing to 0.001 mg, and dust concentrations are expressed as milligrams per cubic meter of total dust (NIOSH 1994).

Some studies reported that the particle size distribution varied according to the woodworking operation, with sanding producing smaller particles than sawing, but others found no consistent differences (IARC 1995). The majority of the wood dust mass was reported to be contributed by particles larger than 10 μm in aerodynamic diameter, and between 61% and 65% of the particles measured between 1 and 5 μm in diameter (IARC 1995).

Several organizations, including the American Conference of Governmental Industrial Hygienists (ACGIH) and the International Standards Organization, have proposed particle-size-selective sampling methods. For wood dusts, the appropriate exposure measure is the inspirable or inhalable mass, which is defined as those materials that are deposited anywhere in the respiratory tract. The ACGIH has defined the sampling characteristics of inhalable mass samplers to have a sampling efficiency of 50% for particles of 100-μm aerodynamic diameter. Sampling devices that meet these criteria have been developed and used for sampling wood dusts (Hinds 1988, IARC 1995, Weber *et al.* 1993).

Particle size distribution is determined with a multistage cascade impactor device. The impactor separates the particles by mass, allowing dust collected at various stages to be weighed and a particle size (mass) distribution to be determined. Wood dust samples also can be analyzed by optical microscopy that classifies particles by equivalent circular diameters. A particle-size frequency distribution can then be determined (IARC 1995).

Several other characteristics of wood may be reported. Irregular shapes of wood dust particles can be recorded in photomicrographs or by scanning electron microscopy. Chemical substances that occur naturally or have been added to wood sometimes are described. There is no standard procedure, however, for measuring the extractable fraction in wood dust (IARC 1995).

Use of hand-held electric sanders has been identified as a particularly dusty process that will lead to dust exposure. Wood dust concentrations vary with type of dust extraction, amount of wood removed, and type of sander (Thorpe and Brown 1994). For electric belt sanders used to sand dowels, total dust concentrations ranged from 0.22 mg/m^3 with external dust extraction to 3.740 mg/m^3 without, and concentrations of respirable dust (0.5 to 5 μm) ranged from 0.003 to 0.936 mg/m^3 under the same conditions. Rotary sanders tested with flat wood samples produced total dust concentrations ranging from 0.002 (with extraction) to 0.699 mg/m^3 (without extraction) and concentrations of respirable dust from 0.001 (with) to 0.088 mg/m^3 (without). Comparable decreases in dust concentrations were observed for electrical orbital sanders used with dust extraction.

Environmental exposure to wood dust also occurs through handling of compost containing wood dust. Wood compost materials consist of successive layers of chopped leaves, bark, and wood stored outdoors during spring where high rainfall is expected. Visible clouds of fine particulates are easily generated when the compost materials are agitated. Inspirable and respirable dust concentrations during compost handling were measured with portable sampling pumps. Background concentrations of 0.32 mg/m^3 of respirable dust were obtained from samplers upwind from the compost pile (Weber *et al.* 1993). Routine exposures of 0.74 mg/m^3 of inspirable dust (>5 μm) and 0.42 mg/m^3 of respirable dust (0.5 to 5 μm) were determined with samplers at breathing zone level during loading and unloading of compost. The worst-case exposures were collected directly from the visible clouds generated by compost agitation and contained 149 mg/m^3 of inspirable and 83 mg/m^3 of respirable dust.

Teschke *et al*. (1999) analyzed 1,632 measurements of personal time-weighted-average airborne wood dust concentrations in 609 establishments on 634 inspection visits that were reported to the Occupational Safety and Health Administration (OSHA) Integrated Management Information System between 1979 and 1997. Exposures ranged from less than 0.03 to 604 mg/m^3, with an arithmetic mean of 7.93 mg/m^3 and a geometric mean of 1.86 mg/m^3. Exposure levels have decreased significantly over time (the unadjusted geometric mean was 4.59 mg/m^3 in 1979 and 0.14 mg/m^3 in 1997).

Jobs with high exposure to wood dust include sanders in the transportation equipment industry (unadjusted geometric mean = 17.5 mg/m^3), press operators in the wood products industry (12.3 mg/m^3), lathe operators in the furniture industry (7.46 mg/m^3), and sanders in the wood cabinet industry (5.83 mg/m^3). Industries with high geometric means include chemical and petroleum products and rubber and plastics products, in which exposures occur in sanding, pattern making, and mill and saw operation. Industries with the lowest exposures include industrial patterns, paper and paperboard mills, schools and institutional training facilities, and veneer and plywood mills.

Teschke *et al*. (1999) used a multiple regression model to predict wood dust exposure levels by such factors as year, state, job, and industry. Values predicted by the model fell in the range of 0.015 to 36.0 mg/m^3, with a geometric mean of 1.85 ± 2.95 mg/m^3.

REGULATIONS

The ACGIH assigned threshold limit values of 1 mg/m^3 for certain hardwoods, such as beech and oak, and 5 mg/m^3 for softwoods except western red cedar, as time-weighted averages (TWAs) for a normal 8-hour workday and a 40-hour workweek. It also established a short-term exposure limit (STEL) of 10 mg/m^3 for softwood, for periods not to exceed 15 minutes. Exposures at the STEL concentration should not be repeated more than four times a day and should be separated by intervals of at least 60 minutes. NIOSH recommends that wood dust (soft, hard, and western red cedar) be considered a potential occupational carcinogen and that exposure be limited to 1 mg/m3 as a TWA exposure up to a 10-hour workday during a 40-hour workweek. OSHA regulations that apply to workplaces where wood dust is present primarily control safety hazards of the environment (e.g., in sawmills). OSHA also established a permissible exposure limit of 15 mg/m^3 for the total dust and 5 mg/m^3 for the respirable fraction of wood dust. OSHA also regulates wood dust under the Hazard Communication Standard and as a chemical hazard in laboratories. Regulations are summarized in Volume II, Table 189.1

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1 No separate CAS registry number assigned to wood dust.

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