Furniture Manufacture

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Contents

Keywords
Nasal adenocarcinoma · Airborne contact dermatitis · Beech · Oak · Mahagony · Rosewood · Wood dust · Varnish · Lacquer · Glue · Acrylates · Organic solvents · Dimethyl fumerate

1 Core Messages

- Occupational dermatoses are rare among furniture manufacturers (prevalence among sanders in Singapore 3.8%). The incidence of occupational hand dermatitis per 10,000 workers per year was 2.6 cases among wood processors.
- Occupational deafness, nasal adenocarcinoma from beech and oak wood, asthma, and allergic rhinitis due to immediate-type hypersensitivity to wood dust are the most important occupational diseases among furniture manufacturers.
- Occupational marks, abrasions, and contact dermatitis, particularly in an airborne pattern, are the most common skin lesions.
- Wood dust, soap and detergents, varnishes, lacquer, and organic solvents represent the most relevant irritant hazards to the skin.
- Synthetic and natural resins, quinones and other natural ingredients in sawdust, preservatives in glues, and acrylates in adhesives are the most frequent contact allergens.
- Dimethyl fumarate is a novel potent contact allergen identified as the cause of the Chinese sofa dermatitis.

Wood has been used as a material for furniture from ancient times until now. Due to its nature, objects used in everyday life are made of wood. Modern furniture is manufactured from various materials beside wood, including metals, and polymers. Furniture manufacturers need to have knowledge and skill in woodworking. They

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Table 1 Different occupations in furniture manufacture

Job title	Occupation
Assembly inspector	Inspects unfinished furniture for defects, makes minor repairs
Cabinet assembler	Uses hand tools to assemble cabinets, sands, installs hardware
Caner (wicket, rattan)	Weaves wet strips of twine or cane to form seats and panels
Case fitter	Fits doors and drawers into unfinished wood furniture, installs hardware
Drawer liner	Glues lining material to bottom/inside of drawers
Finishing	
Cleaner	Cleans surfaces of furniture using cloth, prior to finishing
Decorator	Applies stencils or decals onto furniture with paint, spray, or shellac
Finisher	Applies wood putty or lacquer stick. Sands, mixes finish ingredients, and brushes or sprays on coats of stain, shellac, lacquer, and varnish. Polishes and waxes finished surface
Finish patcher	Repairs defects in finishes with wax, varnish, or stain. Smoothes with sandpaper
Finished-stock inspector	Inspects completed furniture for defects. May repair minor defects in finish
Furniture assembler	Assembles wooden parts to form frames or sections of furniture, using glue, drilled screws, staples, or other fastening
Hardware assembler (upfitter)	Attaches hardware, such as latches, locks metal ornaments, drawer pulls, moldings. May use electric iron to "brand" name on product
Lag screwer (pin machine operator)	Inserts bolts into table legs using pin machine; pushes table leg against rotating drill
Laminator (plastic-top assembler)	Cements precut laminated plastic covering to plywood panels for desktops, countertops, etc., uses solvent to remove excess cement
Leather tooler	Cuts patterns on leather, applies adhesive to desk or table to attach leather. May apply gold leaf or spray lacquer over leather
Upholstery	
Cutting and sewing	Marks, cuts, and sews fabric or leather pieces used in upholstered furniture
Cushion maker	Stuffing material may be foam rubber, loose fibers, down, polyester, kapok
Padder	Shapes and assembles padded articles such as cushions, pillows. May use adhesive to fasten to frame
Spring setter	Places webbing and ties springs
Upholsterer	Tacks material onto frame and over springs. May handle foam rubber padding material

should also be gifted artists with a sense for both the traditional and the contemporary. Therefore, they are designers as well as technicians. Private, public, and industrial customers expect functional and convenient solutions for interior architecture matching their lifestyle and philosophy. Single pieces of furniture wardrobes, windows, doors, coverings for floors, panels on ceilings, and many other items are designed and produced on demand. Furthermore, conservation and restoration of furniture are core occupations.

Two types of wood are harvested for furniture manufacturing: softwoods are derived from evergreens such as pine and birch. Hardwoods are derived from deciduous trees such as beech, maple, oak, and rosewood. Hardwoods are considered to be more durable than softwoods. Regardless of the type of wood used, chemical treatment is necessary to protect the lumber from discoloration, pests, and rot. In addition to wood, particle board is often used to form a core over which the hard- or softwood veneer is attached using resins. These products may release formaldehyde vapors long after they are finished (Munday 2010).

Furniture manufacturers are craftsmen. The majority of their products are handmade. However, mass production – e.g., for windows – necessitates the use of mechanical tools, machinery, and even assembly lines. Novel materials like steel or plastics demand special technologies. Diversification of different workplaces results in specialized occupations. Table 1 lists the most important job titles used in furniture manufacture.

Fig. 1 Extraction machinery minimizing exposure to wood dust

Furniture production starts with sawing, cutting, shaping, and sanding wood using pneumatically or electronically controlled machinery. Exposure to wood dust can be minimized by extraction machinery which is mandatory at all workplaces by law (see Fig. 1). Furniture manufacturers handle wood, laminates, metal, synthetics, plastics, resins, rattan, upholstery fabric, leather, adhesives, and finishing products. Working with wood brings exposure to varnish, lacquer, stains, shellac, and glues. Most of these products contain considerable quantities of preservatives. Manufacturing furniture made of steel may involve exposure to heat, water, cutting oils, epoxy resin, and welding materials. When handling irritant materials, protective gloves should be used. Wearing gloves for several hours per day increases sweating by occlusion. This physical effect – together with the material of the gloves (rubber, leather) – is a hazard to the skin of the hands.

The most common occupational skin lesions of furniture manufacturers are small abrasions and stinging wounds from splinters on the palms and the fingers, due to rough-surfaced wood and sharp edges. Hyperkeratoses develop at sites where mechanical tools provide pressure (see Fig. 2). Occupational marks due to repetitive use of the hands are common. Contact dermatitis does occur in furniture manufacturers, but it is rare. Irritation to the skin may occur from organic solvents, varnish, and other finishing materials. Airborne patterns are common, particularly if a spray process is used. Dermatitis due to woodworking is mainly seen on the face, neck, chest, and armpits which can be explained by procedures that produce fine dust like sanding and shaving. Wood dust can lead to both contact urticaria and contact dermatitis (see ▶ Chap. 134, "Carpenters").

Fig. 2 Occupational marks on the right hand of a furniture manufacturer

Skin lesions represent a minor health problem compared to occupational deafness and diseases of the upper airways like allergic rhinitis to wood dust or nasal adenocarcinoma caused by wood dust from beeches (Macbeth 1965). Furthermore, immediate-type hypersensitivity to woods, such as to obeche (African maple, *Triplochiton scleroxylon*), is a well-known cause of asthma and contact urticaria (Hausen 1982a; Ibsen et al. 1987; Jacobsen et al. 1987).

The prevalence of occupational dermatoses among furniture manufacturers is not known. Until now no epidemiological study in this field has been performed. In Singapore, the prevalence of occupational skin diseases among sanders was found to be 3.8% (Gan et al. 1987). A population-based study on occupational skin diseases in Northern Bavaria was performed between 1990 and 1999. The incidence of occupational hand dermatitis per 10,000 workers per year was 2.6 cases among wood processors. This was the second lowest rate of all professions examined compared with 22 other professions. In the same study, the incidence was 97.4 cases among hairdressers and barbers, 33.2 among bakers, and 23.9 among florists (Dickel et al. 2001). The Holz-Berufsgenossenschaft, the German Workman's Compensation Insurance, compensated 16 cases of severe skin diseases among furniture manufacturers between 2002 and 2005 and 4 cases between 2006 and 2009, indicating a reduction of 75%. During the period of 2002–2005, 61 workers had to give up their job because of their skin disease. This number decreased to eight between 2006 and 2009. These data show the benefit of the improved prevention measures taken at the specific workplaces supported by the Holz-Berufsgenossenschaft (Hammel 2010).

2 Contact Irritants

Soaps and detergents
Wood dust (sawdust)
Rough-surfaced wood
Stains, azo dyes, shellac, lacquer, varnish
Glues
Fabric
Pentachlorophenol (wood preservative)

3 Contact Allergens

Ammoniated mercury, 1% petrolatum (pet) (wood preservatives)
Balsam of Peru, 25% pet (wood gums)
Beeswax, 30% pet (adhesives and waxes)
4-*tert*-butylphenol formaldehyde resin 1% pet (glues, preservatives)
p-*tert*-butylphenol-formaldehyde resin, 1% pet (adhesives)
Cobalt chloride, 1% pet (dryers in stains and varnishes)
Colophony (rosin), 20% pet (varnishes, adhesives)
Diaminodiphenyl methane, 0.5% pet (monomer of resin)
Dimethyl fumarate, 0.1% pet (volatile leather and upholstery preservative)
Epoxy resin, 1% pet (adhesives)
Formaldehyde, 1% aqueous solution (aq) (solvents, adhesives, preservatives)
Melamine-formaldehyde resin, 7% pet (adhesives)
2-Mercaptobenzothiazole, 1% pet (rubber)
Mercapto mix, 1% pet (rubber)
Methyl methacrylate, 2% pet (adhesives)
MCI/MI = 5-Chloro-2-methyl-4-isothiazolin-3-one +2-methyl-4-isothiazolin-3-one (3:1 in water), 0.01% aq (adhesives, paints, glues, cleansing agents)
Methylisothiazolinone 0.05% aq (preservative)
Nickel sulfate, 2.5% pet
Phenol-formaldehyde resin, 5% pet (adhesives)
p-phenylenediamine, 1% pet (dye)
o-phenylphenol, 1% pet (preservative adhesives)
Polyurethane resin, 1% pet (adhesives)
Potassium dichromate, 0.5% pet (leather preservative)
Propylene glycol, 5% pet (varnishes)
Resorcinol, 2% pet (adhesives and glues)
Solvent blue 36 (1,4-bis [isopropylamino] anthraquinone), 5% olive oil (a dye used in wood stains and varnishes and felt-tipped pens)
Tetrachloroisophthalonitrile (Daconil, Chlorothalonil), 0.01% aq
Thiuram mix, 1% pet (rubber)
Tricresyl phosphate, 5% pet (plasticizer in adhesives)

Triethylenetetramine, 0.5% pet (epoxy catalyst)
Turpentine, 10% pet (furniture polishes)
Urea-formaldehyde resin, 10% pet (glues)
Various wood dusts, 1–10% pet, depending on wood

4 Specific Aspects

Furniture manufacturers are hardworking craftsmen. The most common skin lesions derive from friction on rough surfaces and injuries from splinters (Bannikov et al. 1990; Ometov 1978; Shamugiia-Tolordava and Selisskiĭ 1972). At the end of the shift, patches of wood dust, stains, and other dirt remain on the skin and must be removed by proper cleansing agents like industrial hand cleansers containing granules instead of inadequate irritant fluids (see ▶ Chap. 65, "Organic Solvents"). Occupational koilonychia from organic solvents may occur (Ancona-Alayón 1975). Barrier creams are not recommended, since they tend to trap the irritants and allergens and hold them next to the skin. To prevent dryness of the skin, it is crucial to apply ointments containing moisturizers regularly at the end of the work shift to the skin of the hands (Kozulin et al. 1985). Due to the use of safety shoes at the workplace, mycoses of the feet are quite common among furniture manufacturers (Anton'ev et al. 1978).

Wood contains a lot of contact allergens (see ▶ Chap. 74, "Woods"). Allergic contact dermatitis typically causes a pruritic rash on the exposed body parts that occurs during work with the offending wood and is relieved with the end of the exposure. A cabinet maker who had been sensitized to white pine wood noted the same symptoms while camping near some pine trees on vacation (Mackey and Marks 1992). Pau ferro (Holst et al. 1976; Ibsen et al. 1987; Jacobsen et al. 1987; Roed-Petersen et al. 1987), Brazilian rosewood (Guanche and Prawer 2003; Holst et al. 1976; Rojas-Hijazo et al. 2007; Woods 1987), and *Grevillea robusta* (Derraik and Rademaker 2009) are potent sensitizers. The chemical structure of the dalbergiones, the sensitizing constituents of their woods, corresponds to quinones.

In nature, the quinones have antimicrobial effects. They protect the trees from termites (Hausen 1982a). Airborne contact dermatitis is the common pattern of contact allergy due to sawdust (Cook and Freeman 1997; Stingeni et al. 2008). Delayed-type sensitizations against wood are rare. They are reported in individuals exposed to sawdust occupationally (Chieregato et al. 1993; Rackett and Zug 1997). If wooden products have direct and permanent contact to unprotected skin, e.g., by wearing wooden jewelry (Hausen 1982b) or by playing wooden instruments (Hausen 1985; Pföhler and Tilgen 2010), sensitization of the individual may be induced. *Dalbergia melanoxylon* – named as grenadilla in Germany and as African blackwood in Anglo-American countries – and rosewood contain (S)-4′-hydroxy-4-methoxydalbergione and (S)-4-methoxydalbergione (Hausen 1982a). Due to similar chemical structures, cross-reactions between different woods occur. There is no other wood which is denser and more resistant to humidity and temperature changes than tropical hardwood. Therefore it is the most used material for manufacturing musical instruments like flutes, clarinets, or violins (Pföhler and Tilgen 2010).

Rietschel and Fowler (2008) recommend five steps for patch testing workers suspected of allergy to sawdust:

1. Obtain botanical identification if possible from the wood (not the dust).
2. Place no reliance on trade (lumber) names.
3. Patch test with dry and then with damp sawdust. (Damp sawdust may release formic acid and other irritants.)
4. It is best to test with freshly ground sawdust 10% in petrolatum and test controls.
5. Care must be taken not to actively sensitize workers by using allergens in too strong a concentration.

Advice number 5 is the most important. Active sensitization occurred in two nurses who had been used as controls and patch tested with sawdust from Pau ferro. The responsible contact allergen is (R)-3,4-dimethoxydalbergion, the strongest

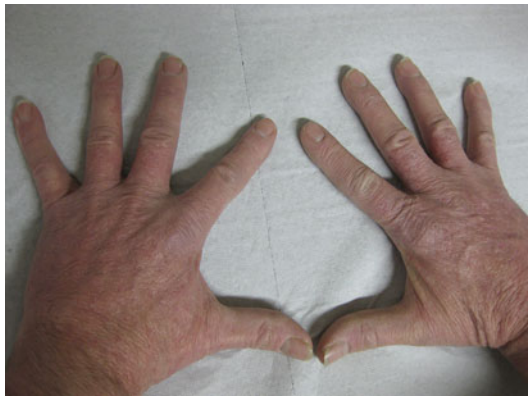

Fig. 3 Allergic contact dermatitis due to MCI/MI in a furniture manufacturer

sensitizer among dalbergiones. Its safe patch test concentration is 0.01% (Schulz et al. 1979).

Preservatives in glues and in varnishes are the most important contact allergens (Brookstein 2009; Ido et al. 2008; Inoue et al. 2008). Figure 3 shows the hands of a furniture manufacturer suffering from allergic contact dermatitis due to delayed-type hypersensitivity to MCI/MI. This was detected by patch testing in my dermatological office. The rash worsened after handling glue which contained (chloro)-methylisothiazolinone. A similar case was published in Portugal (Pereira et al. 1999). Another preservative, 2-(thiocyanomethylthio)-benzothiazole, is used as a fungicide in sawmills and may cause dry, pruritic, and peeling skin, rashes, and nosebleeds (Teschke et al. 1992). Methylisothiazolinone and benzisothiazolinone are widely used in paint and can affect painters as well as furniture manufacturers (Schwensen et al. 2015). Methylisothiazolinone in wall paint is an important occupational hazard, causing airborne allergic contact dermatitis among craftsmen. As the contact allergen is volatile, protective clothing cannot prevent the rash (Goodier et al. 2017).

Wood is often preserved by fungicides like tetrachloroisophthalonitrile (brand names: Daconil, Chlorothalonil, Forturf, Termil, Nopocide) (Bach and Pedersen 1980; Johnsson et al. 1983). This substance was introduced to replace the toxic and cancerogenic pentachlorophenol (Randerath et al. 1996). Arsenic is a fungicide, too, known to cause dermatitis with chronic exposure. However, sampling for this substance in a wood joinery shop showed that its level was not elevated (Nygren et al. 1992). Pentachlorophenol may be absorbed through human skin. It is irritating to the skin and has been reported to cause chloracne, probably due to dioxin and furan contaminants (Horstman et al. 1989). Chromated copper arsenate is another commonly used preservative and insecticide. Beside its irritating effect to the skin, it may pose a risk of skin cancer (Huff 2001). Creosotes used for wood preservatives are composed of polycyclic aromatic hydrocarbons. They irritate to the skin and may elicit phototoxic reactions (Kaidbey and Kligman 1977). Chromate is an important contact sensitizer for leather workers among the furniture manufacturers (Patel et al. 2006).

Natural resins of untreated pine wood contain colophony and turpentine (Booken et al. 2006; Hausen et al. 1982). Colophony (rosin) is part of standard patch test series in order to detect a contact allergy due to adhesives (Downs and Sansom 1999). Stains and paints often contain colophony in order to prevent corrosion or fouling. Abietic acid is the most sensitizing component of colophony. Timber is often covered by lichens containing usnic acid, the sensitizing agent of oak moss, a potential source of airborne contact dermatitis (Aalto-Korte et al. 2005). Lichens are plants composed of fungi living in symbiosis with algae. Usnic acid accumulates in these plants up to 5% of their dry weight (Mitchell 1965). Lichens can cause immediate allergy, contact urticaria, rhinitis, contact dermatitis, and probably also photoallergic contact dermatitis (Thune et al. 1988). Balsam of Peru (*Myroxylon pereirae*), a viscous fluid with a smell like cinnamon and vanilla, may be a constituent of soaps, but it is no hazard for woodwork. The balsam is not found preformed in the wood of the tree from which it is obtained, but it is produced by inflicting wounds on the tree's bark. The balsam then seeps out as a sort of granulation tissue to heal the bark's lesions. Therefore, exotic timber does not contain balsam of Peru (Rietschel and Fowler 2008).

Natural resins are derived from many sources and have diverse properties. Shellac is a resinous

excretion of the insect *Coccus lacca* exuded as a protective cover onto certain host trees, primarily in India and Thailand. Shellac may cause allergic cheilitis as an ingredient of lipsticks (Rademaker et al. 1986). Yet shellac has no occupational relevance. Urushiol is the sensitizing agent in Japanese lacquer. This substance is well-known as the responsible allergen in poison ivy. Only few cases of occupational contact dermatitis have been reported (Kullavanijaya and Ophaswongse 1997).

Since natural resins are very expensive, they have been replaced by synthetic resins in the furniture industry (Geraut et al. 2009). As a potent volatile sensitizing agent, formaldehyde should not be missed in patch testing furniture manufacturers (Imbus 1985). Melamine-formaldehyde resin (Aalto-Korte et al. 2003; García Gavin et al. 2008), phenol-formaldehyde resin (Bruze and Almgren 1988), epoxy resin (Rademaker 2000), polyester (Iatskevichiute 1979), and urea-formaldehyde resin (Shamardin and Maripuu 1963; Vale and Rycroft 1988) are the most important constituents of commercial glues and may cause allergic contact dermatitis, even with negative patch test reactions to formaldehyde. An airborne contact dermatitis in two plywood factory workers due to phenol-formaldehyde resin was reported to mimic contact dermatitis caused by sawdust. These two spreaders placed sheets of plywood, coated with a fine glue film, together, passed them through rollers, and heated them. Within a few weeks of starting as a spreader, they developed an acute dermatitis on the sites of their necks and faces. Wood dust was the initially suspected allergen. Patch tests showed a 2+ reaction to phenol-formaldehyde resin, but no reaction to wood dust or formaldehyde (Rademaker 2002).

In a Swedish plant the produced fiber-resin composite by impregnation of cellulose fiber with phenol-formaldehyde and melamine-formaldehyde resins, a new manufacturing technique was introduced that resulted in problems in the handling of uncured products. Subsequently, 6 out of 88 workers developed contact allergy to phenol-formaldehyde and 5 to melamine-formaldehyde resin (Isaksson et al. 1999). Resol resin based on phenol and formaldehyde is recommended to be included into the international baseline series for patch testing due to a multicenter study (Isaksson et al. 2015). Other glues used in particle-board manufacturing which have been reported to cause allergy include epoxy resin (Goulden and Wilkinson 1996). In a large series of occupational contact dermatitis to plastics and glues from Finland, 3.1% of 360 patients patch tested were allergic to phenol-formaldehyde resin. This was the second highest reaction rate, others being epoxy (5.1%), 4-tert-butylcatechol (2.6%), phenyl-glycidylether (2.6%), diaminodiphenyl methane (2.2%), benzoyl peroxide (2.2%), hexamethylenetetramine (2.0%), and *o*-cresylglycidylether (1.6%). At least 14 contact sensitizers had been identified, with the most potent being 4,4′-dihydroxy(hydroxymethyl)-diphenyl methanes (Kanerva et al. 1999).

Acrylates are constituents of many glues because of their strong adhesive capacities. They are well-known sensitizers in dentistry, orthopedic surgery, sculptured nails, inks, paints, and printing plates. So it is not surprising that acrylates in glues are responsible for contact dermatitis in furniture manufacturers (Aalto-Korte et al. 2008; Surakka et al. 2001).

Figure 4 shows structural similarities between compounds derived from acrylic acid and fumaric acid (Lammintausta et al. 2010a, b). Since 2006 an outbreak of dermatitis elicited by imported furniture upholstery materials has been reported in the United Kingdom (Williams et al. 2008), in Finland (Zimerson et al. 2008; Susitaival et al. 2010), and in France (Imbert et al. 2008). In each case of the epidemic, the dermatitis had started on the backs of the thighs and on the buttocks of the consumers sitting on the contaminated furniture. The degree of the rash varied from redness and itching to edema, bullous eruptions, and painful dermatitis. The extent of the dermatitis varied from half-hand-sized patches to extensive skin areas depending on the style and habits of the patients when sitting on the sofas and the armchairs. The period between the purchase of the new piece of furniture and the appearance of the skin symptoms ranged from few weeks to several months (Lammintausta et al. 2010a, b).

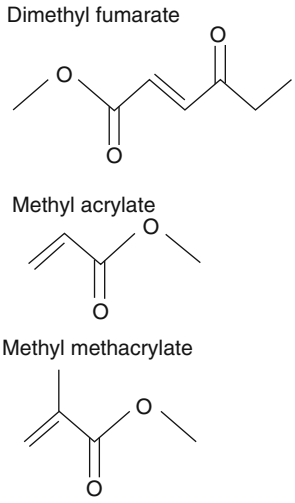

Fig. 4 Structural similarities between fumarates and acrylates

Dimethyl fumarate is a novel potent contact sensitizer. It has a broad spectrum biocide activity. During the manufacturing process in China, it was put inside sachets under the covering textile of the sofa or armchair. So it could progressively evaporate and contaminate the leather and fabric of the furniture (Rantanen 2008; Mercader et al. 2009; Darné and Horne 2008; Doumit et al. 2012). Recently, even boots were treated with dimethyl fumarate causing allergic contact dermatitis on the feet (Fraga et al. 2010). The sensitizing potential of dimethyl fumarate and diethyl fumarate is well-known (Lahti and Maibach 1985; Zhu and Mrowietz 2001). Sensitization to (meth)acrylates was seen in many patients before dimethyl fumarate was detected as the cause of their dermatitis. Cross-reactivity between these substances is frequent (Lammintausta et al. 2010a, b). No consensus has been achieved about the proper test concentration for dimethyl fumarate. In order not to miss a sensitization, M. Bruze suggested 0.1% pet instead of 0.01% pet (Bruze 2010). Until now only case reports about furniture-related contact dermatitis among consumers have been published. There is no information available about possible adverse effects of dimethyl fumarate on furniture manufacturers in China.

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