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THE INFLUENCE OF WOOD-BASED COMPOSITE MATERIALS ON INDOOR AIR QUALITY IN BUILDINGS

Andrea NEUPAUEROVÁ

Abstract
Wood-based composites encompass a range of products from fiberboard to laminated beams. Wood-based composites are used for a number of nonstructural and structural applications in product lines ranging from panels for interior covering purposes to panels for exterior uses and in furniture and support structures in buildings. Wood-based composite products are potential long-time source of indoor air pollution. The problem products may include particleboard flooring, paneling, cabinetry, furniture and hardwood plywood paneling use urea-formaldehyde resins in their manufacture. Volatile organic compounds emitted by building materials are recognized as major problems affecting human comfort, health and productivity.

Key words
indoor air quality, wood-based composites, VOCs

INTRODUCTION

The kind of used material to individual types of building constructions and procedure their realization have significant influence on climate of indoor environment. The emission of volatile organic compounds (VOCs) from building materials and building products used indoors is an important parameter for the chemical impact on the indoor air quality [1]. Building products have been shown to affect the perceived indoor air quality in buildings. Consequently, there is a need for characterizing the emissions from building products in sensory terms to evaluate their impact on the perceived air quality as well as the characterization the other indoor odor production. Determining the exposure-response relationship between concentration of the emission from a building product and human response is recommended.

Volatile organic compounds are partly responsible for reduced indoor air quality. They are frequent indoor air pollutants found at concentrations that are often higher indoors than outdoors. VOCs consist of a large number of organic substances which will volatilise at normal room temperatures. A number of VOCs sources exist in homes, offices and other public places. These include building materials and furnishings, paints, cleaners, cosmetics, printed materials and dry-cleaned clothes as well as smoking. VOCs can be emitted by materials such as wood-based products, carpets, paints, wallpapers or PVC, they may enter a room from outdoors or they are emitted or generated during human activities such as cooking or tobacco smoking. These compounds can have a negative effect on the occupant´s health, since they can act for example as irritants. Moreover, many VOCs with low odor threshold values can provoke odor annoyance [2].

BUILDING MATERIALS AS A SOURCE OF VOLATILE ORGANIC COMPOUNDS INDOORS

Building materials belong to significant indoor sources of chemical odors. A practical measuring method is needed to characterize the VOCs emissions from building products in sensory terms. The method should make it possible to rationally and economically evaluate the impact of building products on the perceived air quality. Only sensory methods using human subjects are available for measurements of perceived air quality. One of the relations that were analyzed is the relation between the perceived indoor air quality and air change rates. It was found that the perceived air quality assessed by the sensory panels concerning to VOCs odors (without human odors) was on the average slightly better in the room that had a higher air change rates. Standards are based on the hypothesis that a higher air change rate results in better perceived air quality because of the dilution of pollutants.

The concentrations of metabolic carbon dioxide (CO_2) as well as total volatile organic compounds (TVOC) have been considered as parameters of perceived indoor air quality. Carbon dioxide (CO_2) has been used as an indicator of human odors loading which depends on number of occupants. The TVOC concentrations were considered as indicator of chemical odors loading, which depends on the scale of building materials presence [2].

Many volatile organic compounds as formaldehyde, toluene, benzene, n-decane, xylenes, 4-phenylcyclohexane, isoalkanes etc. are emitted of flooring constructions. Wood products and wood-based products such as laminate floorings and parquets are a potential long-term source of indoor air pollution [3]. The floor construction is composed of walkway layer created top surface of flooring, than layer which can transfer tax from flooring and finally insulating layer having

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protective function (insulating thermical, insulating sound - proof and insulating function against damp). The kind of used material to individual types of flooring constructions and procedure their realization have significant influence on climate of indoor environment [4].

The sink effect, i.e. adsorption and desorption of VOCs by indoor materials like building structures or furniture can have a significant impact on indoor air quality by changing their dynamic behaviour. Adsorption in this context means accumulation of gaseous organic substances on material surfaces. The amount of adsorbed mass depends on several parameters, such as temperature, relative humidity, chemical nature and gas phase concentration of the VOCs and material properties like chemical structure pore size or specific surface area [5].

All indoor material surfaces interact with the air pollutants. Therefore, these materials can act as sorbents or sources of VOCs emission. Adsorption may lower the peak concentrations but later, during reemission phase, will prolong the presence of indoor air pollutants. Even though the concentrations are low, multiple exposures to low concentrations of carcinogenic VOCs could be more harmful than exposure to isolated peak concentrations. Adsorption increases with the boiling point of the compounds and it depends on the other physicochemical properties and the type of the material. VOCs typically have boiling points in the range 50 - 250 °C. All materials showed that adsorption increases as the boiling point of the compound increases and the vapor pressure decreases [6]. The objective performance of the environment can be measured in terms of physical quantities. The subjective performance of indoor environment can be measured in term of sensory panel. The human perception and assessment can be expressed by a person with so called subjective environmental performance indicators, such as acceptability of indoor air (perceived air quality, perceived thermal comfort) [2]. Some of the VOCs emitted by building materials are given in Tab. 1.

Tab. 1 Sources of the VOCs [7]

Source	**VOCs**
furniture, fabric, particleboard, carpet, cleaning fluids, adhesives	formaldehyde
paint, adhesive, gasoline, combustion sources, liquid process photocopier, carpet, linoleum, caulking compound	aliphatic hydrocarbons (octane, decane, isodecan, etc.)
combustion sources, paint, adhesive, gasoline, linoleum, wall coating	aromatic hydrocarbons (toluene, ethyl benzene, benzene)
upholstery and carpet cleaner or protector, paint, paint remover, lacquers, solvents, dry-cleaned clothes	chlorinated solvents (dichloromethane or methylene chloride)
acoustic ceiling tile, linoleum, caulking compound	n-butyl acetate
carpet, moth crystals, air fresheners	dichlorobenzene
paint, coatings, finishers, paint remover, thinner, caulking	acetone

WOOD-BASED COMPOSITE MATERIALS

The term composite is being used to describe any wood material adhesively bonded together. The classification system to logically categorize the array of wood-based composites is given in Tab. 2.

Tab. 2 Classification of wood-based composites [9]

	Veneer-based material	**Laminates**	**Composite material**	**Wood–nonwood composites**
WOOD-BASED COMPOSITES	Plywood	Glue-laminated timbers	Fiberboard (low, medium, high density)	Wood fiber–polymer composites
	Laminated veneer lumber (LVL)	Overlayed materials	Cellulosic fiberboard	Inorganic-bonded composites
	Parallel-strand lumber (PSL)	Laminated wood–nonwood composites	Hardboard	
		Multiwood composites (COM-PLY)	Particleboard	
			Waferboard	
			Flakeboard	
			Oriented strandboard (OSB)	
			Laminated strand lumber (LSL)	
			Oriented strand lumber (OSL)	

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The basic element for wood-based composites is the fiber, with larger particles composed of many fibers. Elements used in the production of wood-based composites can be made in a variety of sizes and shapes. Typical elements include fibers, particles, flakes, veneers, laminates, or lumber.

Conventional wood-based composites are manufactured products made primarily from wood with only a few percent resin and other additives. A useful way to classify conventional wood-based composites based on specific gravity, density, raw material and processing methods is shown in Fig.1 which presents an overview of the most common types of commercial panel products and a quick reference to how these composite materials compare with solid wood from the standpoint of density and general processing considerations. The raw material classifications of fibers, particles, and veneers are shown on the left y-axis. Specific gravity and density are shown on the top and bottom horizontal axes (x-axes), respectively. The right y-axis, wet and dry processes, describes in general terms the processing method used to produce a particular product [8].

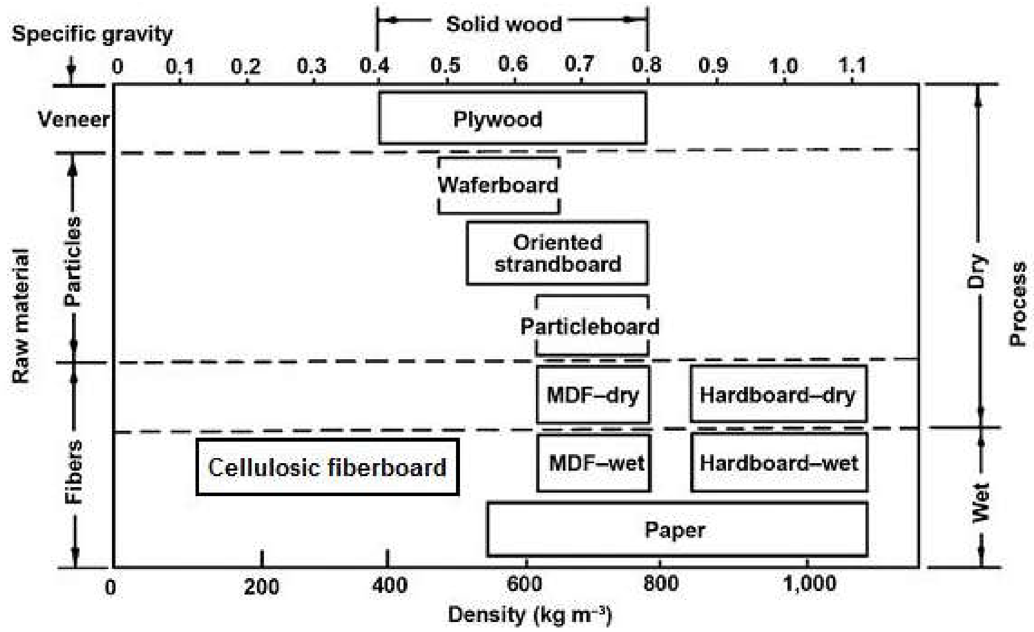

Fig.1 Classification of wood composite panels by particle size, density and process [8]

Selection of wood elements, adhesives, and processing techniques all contribute to product performance. Fig.2 shows examples of some commercial wood-based composites. The primary component of wood-based composites is the wood element, often 94 % or more by mass. Common elements for conventional wood-based composites include veneers, strands, particles and fibers. Properties of composite materials can be changed by changing the size and geometry of the elements and by combining, reorganizing or stratifying elements [8].

Bonding in most conventional wood-based composites is provided by thermosetting (heat-curing) adhesive resins. Commonly used resin–binder systems include:

- *phenol-formaldehyde,*
- *urea-formaldehyde,*
- *melamine-formaldehyde,*
- *isocyanate.*

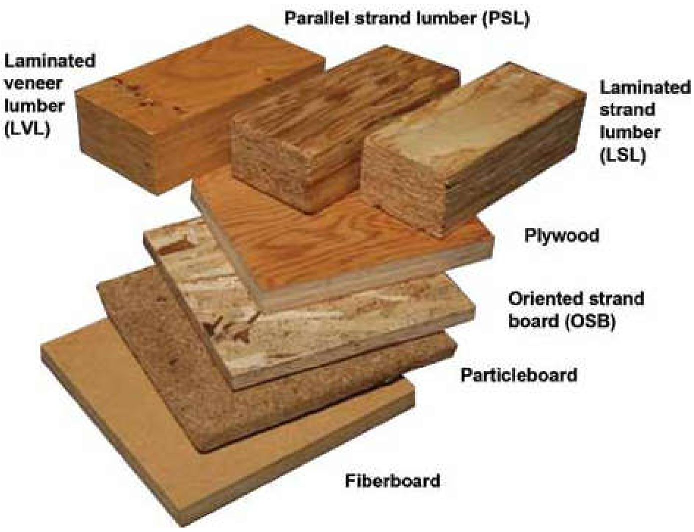

Fig.2 Examples of various wood-based composite products [8]

Phenol-formaldehyde (PF) resins are typically used in the manufacture of construction plywood and oriented strandboard where exposure to weather during construction is a concern. Other moisture exposure situations, such as temporary weather exposure, occasional plumbing leaks or wet foot traffic may also necessitate the use of PF resins.

PF resins are commonly referred to as *phenolic resins*. *Phenolic resins* are relatively slow-curing compared with other thermosetting resins. In hot-pressed wood-based composites use of phenolic resin necessitates longer press times and higher press temperatures. Hot-stacking of pressed material shortly after emergence from the press is a fairly common industrial practice used to attain adequate resin cure without greatly extending press time. Significant heat exposure associated with pressing of phenolic-bonded composites commonly results in a noticeable reduction in their hygroscopicity. Cured phenolic resins remain chemically stable at elevated temperatures. Their bonds also are sometimes referred to as being “boil-proof” because of their ability to maintain composite dimensional and mechanical properties under wet conditions. The inherently darker color of PF resin compared with other resins may make them aesthetically unsuitable for product applications such as interior paneling and furniture [8].

Urea-formaldehyde (UF) resins are typically used in the manufacture of products used in interior applications, primarily particleboard and medium-density fiberboard (MDF), because moisture exposure leads to a breakdown of the bond-forming reactions. Excessive heat exposure will also result in chemical breakdown of cured UF resins, therefore UF-bonded panels are typically cooled after emergence from the press. Advantages of UF resins include lower curing temperatures than PF resins and ease of use under a variety of curing conditions. UF resins are the lowest cost thermosetting adhesive resins. They offer light color, which often is a requirement in the manufacture of decorative products. However, the release of formaldehyde from products bonded with UF is a growing health concern.

Melamine-formaldehyde (MF) resins are used primarily for decorative laminates, paper treating and paper coating. They are typically more expensive than PF resins. MF resins may, despite their high cost, be used in bonding conventional wood-based composites. MF resins are often used in combination with UF. MF–UF resins are used when an inconspicuous (light color) adhesive is needed and when greater water resistance than can be attained with UF resin is required.

The isocyanate wood adhesive is a polymeric methylene diisocyanate (pMDI). It is used as an alternative to PF resin, primarily in composite products fabricated from strands. pMDI resins are typically more costly than PF resins but have more rapid cure rates and will tolerate higher moisture contents in the wood source. pMDI resin is sometimes used in core layers of strand-based composites, with slowercuring PF resin used in surface layers. Facilities that use pMDI are required to take special precautionary protective measures because the uncured resin can result in chemical sensitization of persons exposed to it. Cured pMDI resin poses no recognized health concerns.

Often a particular resin will dominate for a particular product, but each has its advantages. Factors taken into account include materials to be bonded together, moisture content at time of bonding, mechanical property and durability requirements of the composite products, anticipated end-use of the product, and resin system costs. PF, UF and pMDI resins systems are expected to remain the dominant adhesives used for bonded wood-based composites. However, cost and reliable availability of petrochemicals may affect the relative predominance of PF, UF and pMDI adhesives versus bio-based adhesives. More stringent regulation concerning emissions from formaldehyde-containing products (driven by concern over indoor air quality) may affect the continued commercial predominance of UF resin in interior products [8].

THE FORMALDEHYDE EMISSION FROM WOOD-BASED PRODUCTS

The formaldehyde emission from building materials used indoors markedly influences indoor air quality. The most significant source of formaldehyde are wood-based products such as particleboard (used as subflooring and shelving and in cabinetry and furniture), hardwood plywood paneling (used for decorative wall covering and used in cabinets and furniture) and medium density fiberboard (used for drawer fronts, cabinets and furniture tops) [10].

Formaldehyde emission from materials can be primary and secondary. The primary emission is the highest immediately after manufacture. Secondary emission denotes the emission of formaldehyde, which is mainly caused by actions on the material. Factors that affect on material may be moisture and alkali in the building structure, high surface temperatures or different types of treatment with chemicals such as floor cleaners, waxing etc. Secondary emission of formaldehyde may increase in time and may last for a very long period and today is regarded as being of greater significance for health because formaldehyde was classified as *carcinogenic to humans* (IARC, Group 1).

Wood products for the building and furniture industry are often a combination of wood and the materials added e.g. adhesive resins. The chemical constitution of the binding resin has an important effect upon the formaldehyde release from the wood-based panel. For a particular type of resin the molar ratio of urea to formaldehyde is an important variable [11]. Within a certain range of molar ratios there is an almost linear relationship between the molar ratio, the formaldehyde release and the extractable formaldehyde content determined by the perforator test. The “free formaldehyde” is present in various forms in the manufactured board [12]. The formaldehyde emission of the wood-based panel is not limited to the emission of the free formaldehyde content of the board. The release of free formaldehyde from wood-based panels is influenced by a number of factors including: binder type, temperature, humidity, panel thickness and percentage concentration. The majority of the formaldehyde first emitted from a new wood-based board comes from the free formaldehyde present in the material.

Formaldehyde emission from wood-based products can be influenced by exogenous and endogenous factors [12]. The exogenous factors include temperature, humidity, air movement over the panel surface, air change rate and the local formaldehyde concentration within the space where the material is placed. The endogenous factors include the wood species, moisture content of the wood flakes, the type and the chemical composition of the adhesive binder used, the additives, e.g. catalysts and formaldehyde scavengers added, the arrangement of the multi-layer board, the surface treatment, the density of the board and the manufacturing conditions, e.g. temperature and duration of the hot pressing process. The chemical constitution of the binding resin has an important effect upon the formaldehyde release from the wood-based panel [11].

CONCLUSION

Levels of formaldehyde concentration in the indoor air depend mainly upon the source, temperature, humidity and the exchange rate of air. As temperature rises, greater amounts of formaldehyde are emitted. Formaldehyde levels can change with the season and vary from day-to-day and day-to-night. Levels may also increase on a hot and humid day and decrease on a cool, dry day. During warmer months problems with formaldehyde can be especially serious as an increase in temperature of 5 to 6 degrees Celsius can double the gas's concentration. Further, an increase in relative humidity from 30 % to 70 % can also cause the gas concentration to nearly double. If both temperature and humidity increase, the concentration of gas can rise to five times its original amount. Based on the published data [13] the increase of indoor surface temperature and relative humidity influence an effect of undesirable emissions from building products.

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CONTACT ADDRESS

Author:	Ing. Andrea NEUPAUEROVÁ, PhD.
Workplace:	Department of Environmental and Forestry Machinery, Faculty of Environmental and Manufacturing Technology, Technical University in Zvolen
Address:	Študentská 26, 960 53 Zvolen, Slovak Republic
E-mail:	andrea.neupauerova@tuzvo.sk