Emissions of volatile organic compounds from wood and its derivatives

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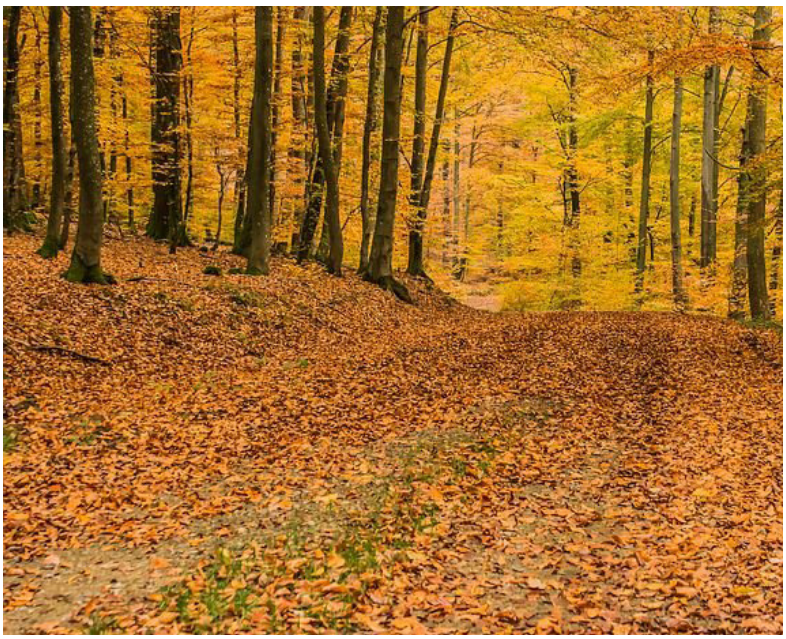


When we consider the "sensitive" characteristics of wood, in addition to its visual, noble and familiar aspect, as well as the pleasant tactile sensation it produces when we touch it, we should also properly consider its smell. The wood scent, which varies a great deal according to the species considered, normally produces pleasant sensations that suggest the unspoiled nature, the trees and the beauty of green landscapes. It can also awaken in us memories linked to the work of the old carpentries, the rooms of ancient buildings, a perfume that is therefore also a profound reference to the culture and history of humanity.
In purely scientific terms, these aromas are evidently the result of the emission of volatile organic compounds that pass from the wood into the air and then reach our nose and consequently the olfactory cells that allow us to perceive their presence.
Knowledge of the volatile substances that are emitted from wood is today a very relevant issue which, beyond the sensory and cultural aspects mentioned above, mainly concerns the quality of the air we breathe. As we all know, standards, laws, regulations of various types now focus attention on the effects of potential emissions of volatile substances from the materials that surround us, consequently imposing limitations in qualitative and quantitative terms.
Therefore, knowing which substances are emitted from a piece of wood can be useful from different points of view, first of all, that of knowing and duly considering precisely these natural emissions when proposing or defining limitations in this sense within the various national and international standardised and legislative tables. Being prepared always helps not to make mistakes.

1. The origin of the emissions

Wood emits various types of volatile organic substances and in very variable quantities depending on the wood species considered but with a significant differentiation, as we will see later, between Softwoods and Hardwoods.
However, a first important consideration concerns the subdivision between those that can be classified as primary emissions, i.e. dependent on substances that wood directly produces for its biological activities, and those that can be considered as secondary emissions. The latter derive from complex degradation phenomena (for example from oxidation or from hydrolytic processes) that occur on certain wood components. Due to the interaction with oxygen, temperature, electromagnetic radiation and other degradative factors, certain volatile substances can therefore form directly from lignin, cellulosic components and other complex substances that make up wood.

This observation already leads us to a first important consideration concerning the duration of both types of emissions previously mentioned.
The primary volatile substances are in fact no longer produced by wood after the tree has been cut and there-

fore, although their release may initially be even high, it will nevertheless progressively decrease, tending to practically zero over the course of a few months or a few years.
On the other hand, the initial emissions of secondary volatile organic substances are usually lower but can nevertheless continue for a much longer period of time since, as already mentioned, they can tend to be continuously generated inside wood due to the degradation phenomena already reported.

Still considering the differentiation between primary and secondary substances, it is clear that the processes or treatments to which wood is subjected (for example its heating in the pressing of panels or in the production of thermo treated wood), can accelerate the rapid release of volatile substances (the primary ones) and, on the other hand, promote the formation of secondary substances.
The following paragraphs examine in detail which substances belong to the primary emissions and which ones are of the secondary type, also trying to derive some important practical information.

2. Primary and secondary emissions

2.1 Primary emissions

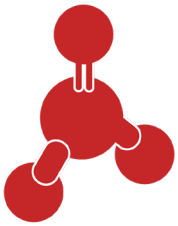
The primary emissions, those that originate as a result of the presence of substances produced directly by trees to carry out their metabolic functions (in particular the terpenes) are by far the most relevant although they almost exclusively concern wood derived from softwoods they contain, in particular , different terpenes and different terpene derivatives.

2.1.1 Terpenes and terpenoids

Terpenes, which are chemically classified as unsaturated hydrocarbons derived from isoprene, perform various functions in living plants including that of acting as repellents against possible biological aggressions.
Terpenoids, on the other hand, are terpenes modified by the presence of particular chemical groups (hydroxyl, carboxylic) or other chemical elements (for example nitrogen).
Among the most relevant terpenes related to wood emissions it is possible to mention the following compounds: pinene (alpha and beta), carene, limonene, camphene, phellandrene and terpinolene
The various wood species, basically softwoods, contain variable quantities of these substances but, with the same wood species, the concentration of terpenes is usually higher in the heartwood (the oldest inner part of the trunk) than in sapwood.
Furthermore, given that, as is known, terpenes are normally concentrated in the resin canals, the emissions of these substances can be higly variable, depending on the specific piece of wood sampled for the analysis.

2.2 Secondary emissions

As already mentioned, secondary emissions derive from the degradation of the complex macromolecular constituent of wood, which produce, as a result of various types of reactions (oxidation, hydrolysis), simpler compounds with a low molecular weight, which therefore evaporate easily in the air.



From a chemical point of view, these are normally carboxylic acids, aldehydes, alcohols and some other type of organic substance.
The emission of secondary substances is generally greater in the case of wood elements derived from Heartwoods than those from Softwoods as a result of some chemical differences that characterize their components.
The emission of acetic acid, for example, is generally more relevant in Hardwoods than in Softwoods due to the greater amount of acetyl groups (-COCH3) present in the hemi-

cellulose of these species.
Furthermore, contrary to what has been observed for the emission of terpenes from Softwoods, in this case the secondary emissions are greater for sapwood than for heartwood.

2.2.1 Acids

The carboxylic acids emitted from wood are mainly represented by acetic acid, while others such as hexanoic and formic, can be emitted in much lower concentrations. Hardwoods, such as Oak and Cherry (frequently used in the furniture sector), emit considerably higher quantities of acetic acid (which can be easily detected by their smell) than woods derived from Softwoods.
This evidence comes from the formation of acetic acid resulting from the hydrolysis of acetyl groups (deacetylation) of lignin and hemicellulose.

2.2.2 Aldehydes

Aliphatic aldehydes are mainly produced by the oxidation of acids deriving from the hydrolysis of fatty substances contained in wood and are formed especially if wood is subjected to treatments at high temperatures.
A peculiarity of aldehydes is that they are normally characterized by intense odors which can therefore strongly characterize some wood-based panels or wood itself if subjected to heat treatments. Hexanal represents the aldehyde potentially emitted in greater quantity from wood followed by acetaldehyde, propanal, butanal, pentanal, heptanal and also formaldehyde.
Even the emission of furfural can sometimes be detected although this cyclic compound is normally formed as a result of degradation phenomena that occur to cellulose and hemicellulose molecules at fairly high temperatures.
As regards the formation of formaldehyde, specific studies show that it mainly derives from the decomposition of lignin, although it can theoretically also form from the polysaccharide components of wood (hemicellulose and cellulose) and from some extractives possibly present in certain wood species.
Also for formaldehyde, the high temperature treatment of wood and the high moisture content promote its formation.

2.2.3 Other VOCs emitted from wood: alcohols, ketones, hydrocarbons, ethers and esters.

Methanol appears to represent a relative significant emission for various wood species, and mainly for Hardwoods such as Ash, Beech, Maple, Oak and Cherry.
Emissions of ethanol have been also observed for Beech and to a lesser extent for Oak and Birch.
Emissions of ketones, such as acetone, were detected by analyzing samples of Birch, Pine, Spruce, Beech and Oak.
Some alkylfurans have also been found, albeit in low concentrations, in the emissions of some Hardwoods. As already reported emissions of other substances such as aliphatic and aromatic hydrocarbons, phenols and esters were also observed in consequence to wood treatments at high temperature.

3. Conclusions

This short article, based on literature data and on direct experiences from Catas, testifies first of all how the issue of volatile organic compound emissions from wood and its derivatives is quite complex.
In any case, some of the considerations reported above can make us understand certain dynamics and certain situations detected or detectable in the wood materials used in the wood-furniture sector. For further information on these aspects, please refer to the literature reported in the bibliography.
As already mentioned in the introduction, we believe that knowledge of these issues is essential to manage

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in a rational way also the delicate issue of the limits to be imposed on the emissions of volatile organic substances from the materials that surround us. It is in fact necessary to make reference to toxicological data to establish exposure and emission thresholds. Proceeding on the basis of the emotion that safety issues always arouse, or on the basis of a mere questionable opportunism, can trigger negative consequences on the entire wood and furniture sector with the further risk of depriving us of even those pleasant and beneficial sensations that offers us wood with its delicate and fascinating scent.

Bibliography

- Bulian F., Fragassa C., (2016), *VOC Emissions From Wood Products and Furniture: a Survey About Legislation, Standards and Measures Referred to Different Materials*, FME Transactions 44, 358-364 (2016)
- Thakeow P., Holighaus G., Schultz S. (2007). *Volatile organic compounds for wood assessment*. in Kules U editor. Wood production, wood technology and biotechnological impacts. Universitatsverlag Gottingen. Gottingen pp. 197-228
- Pohleven J., Burnard M. D., Kutnar A. *Volatile Organic Compounds Emitted From Untreated And Thermally Modified Wood, A Review*, in Wood and Fiber Science, 51(3), 2019, pp. 231-254 https://doi.org/10.22382/wfs-2019-023
- Kirkeskov L., Witterseh T., Funch L. W., Kristiansen E., Mølhave L., Hansen M. K., Knudsen B. B. in Archives of Environmental Health An International Journal · September 2001

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