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Impact of Wood Treatments on Indoor Air Quality: A Comparative Review of Chemical and Sustainable Coatings

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Why Indoor Air Quality (IAQ) Matters?

- People spend ~90% of their time indoors;
- Indoor VOC concentrations often higher than outdoors (*building materials, flooring, composite wood products, adhesives, as primary sources*);

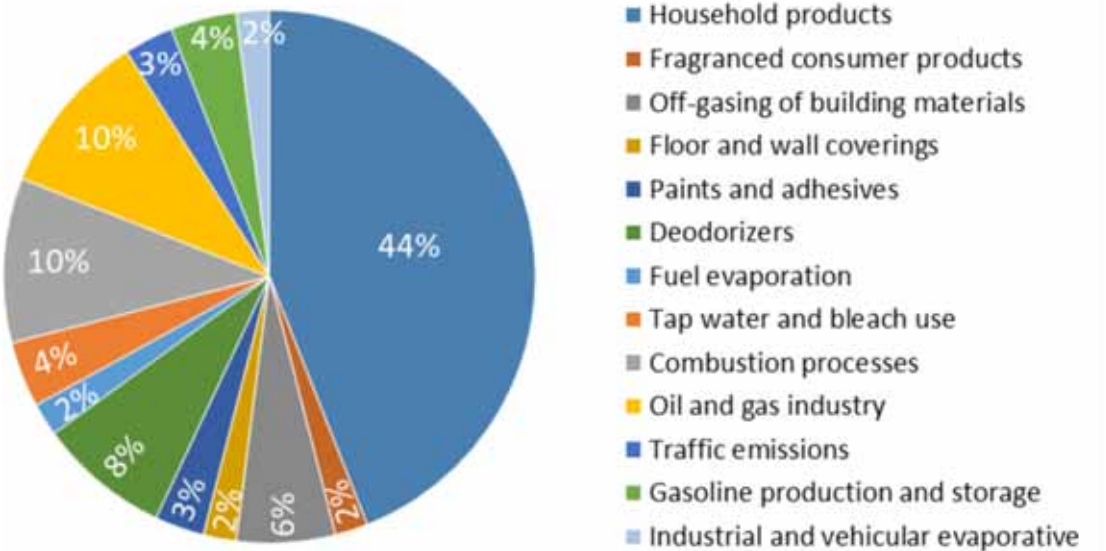


Figure 1 Percentage representation of VOCs in individual internal sources in Edmonton, Alberta

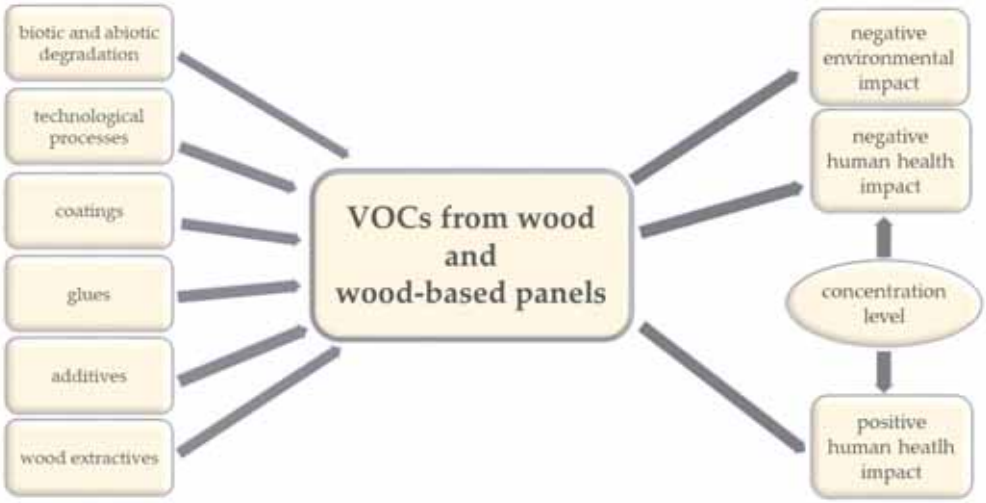


Figure 2 Graphical Abstract by Adamová, T., Hradecký, J., & Pánek, M. (2020)

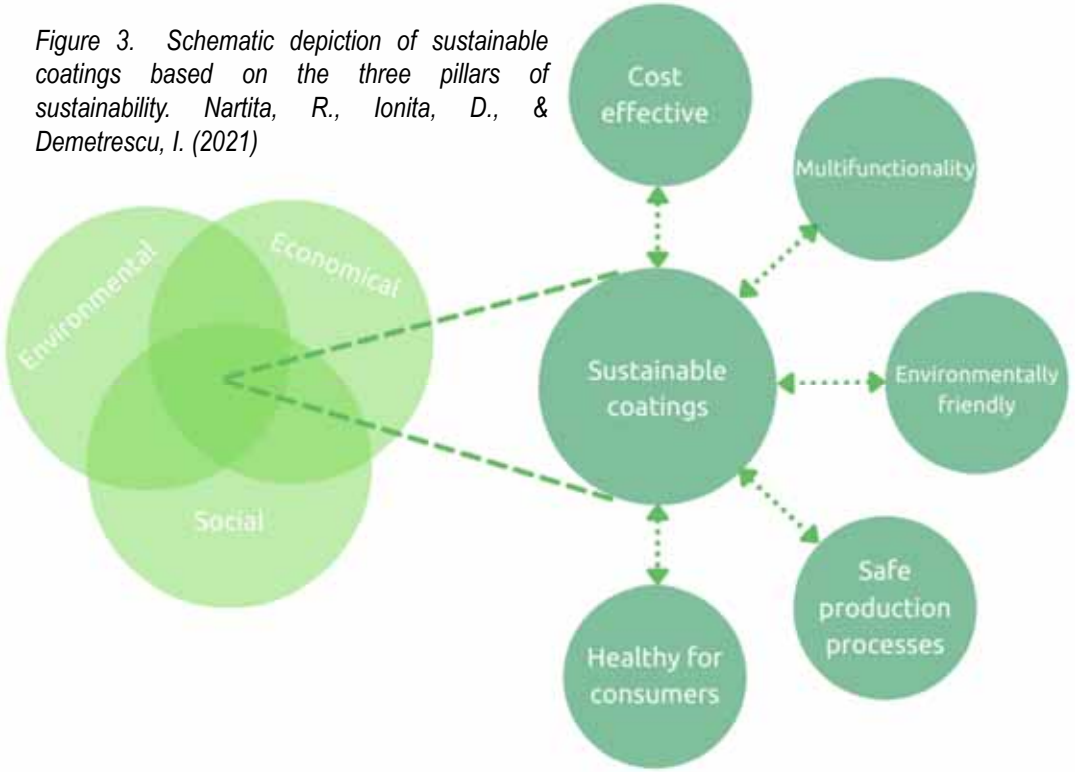
- Linked to respiratory, neurological, and carcinogenic effects;
- Sick building syndrome (SBS);
- WHO identifies IAQ as a major environmental health risk;

VOC Sources in Wood Products

- Natural emissions from wood *(terpenes, aldehydes)*
- Adhesives and resins in wood-based panels

Figure 3. Source: www.plyonline.com.au

Figure 3. Schematic depiction of sustainable coatings based on the three pillars of sustainability. Nartita, R., Ionita, D., & Demetrescu, I. (2021)



- Surface finishes and coatings as major VOC sources *(secondary emissions by reacting with indoor ozone to produce toxic byproducts such carbonyl compounds)*

Why coatings matter?

- coatings are of vital importance in the protection of wood against environmental factors, such as humidity, solar light irradiation, temperature variations, biological decay, and damage of structural integrity that occurs through mechanical or chemical processes.

Figure 3. Source: www.abodowood.co.uk

Figure 3. Thermopine® Cladding factory coated with Teknos® paint system | Fife Architects | GH Cook & Son Ltd

Conventional Chemical Coatings

- Still commonly used: Polyurethane, nitrocellulose lacquer, alkyd-based finishes
- High VOC emissions, including formaldehyde, benzene, toluene *(up to 1,200 µg/m³)*
- Why are they still used? Strong durability and aesthetic appeal but poor IAQ impact

Figure 7. Source: https://doxuchem.com/industry/woodfurniture/

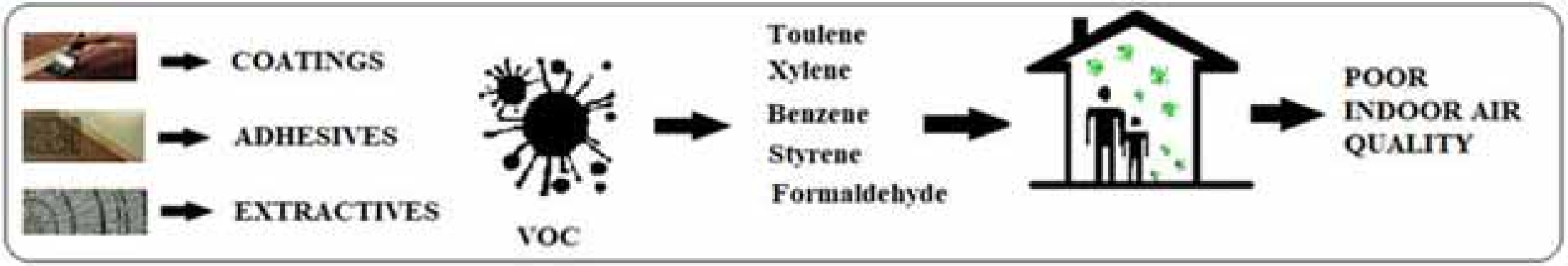


Figure 2 Graphical Abstract by Adamová, T., Hradecký, J., & Pánek, M. (2020)

Sustainable / Low-VOC Coatings

- Plant oils (linseed, tung), waxes, waterborne acrylics, UV-cured resins
- Generally lower VOC emissions compared to chemical coatings
- Durability and abrasion resistance remain a challenge *(Even after few days of application, some coatings have kept off-gassing)*

- aqueous acrylic coatings emitted 150–400 µg/m³ of total volatile organic compounds (TVOCs) after 28 days in controlled experiments
- frequently less than 100 µg/m³, were released by UV-cured coatings, which harden by photopolymerization and don't require solvents

* However, biogenic volatile organic compounds (VOCs) such terpenes (limonene, pinene) and aldehydes (hexanal, nonanal) were created by plant-based oils and waxes.

Figure 7. Source: https://www.furnitureclinic.co.uk/boiled-linseed-oil /

Environmental & Performance Factors

- Humidity and temperature influence emission rates
- Ozone reactions generate secondary VOCs indoors
- In heated, poorly ventilated spaces the TVOC concentrations increased significantly, speeding up the off-gassing process
- Relative humidity (RH) *Aldehyde release from chemical and bio-based coating was shown to increase with elevated relative humidity (>60%)*
- Wood moisture content (MC) *Higher moisture levels decreased VOC emissions, presumably by absorbing certain volatiles during drying or diminishing solvent diffusion*

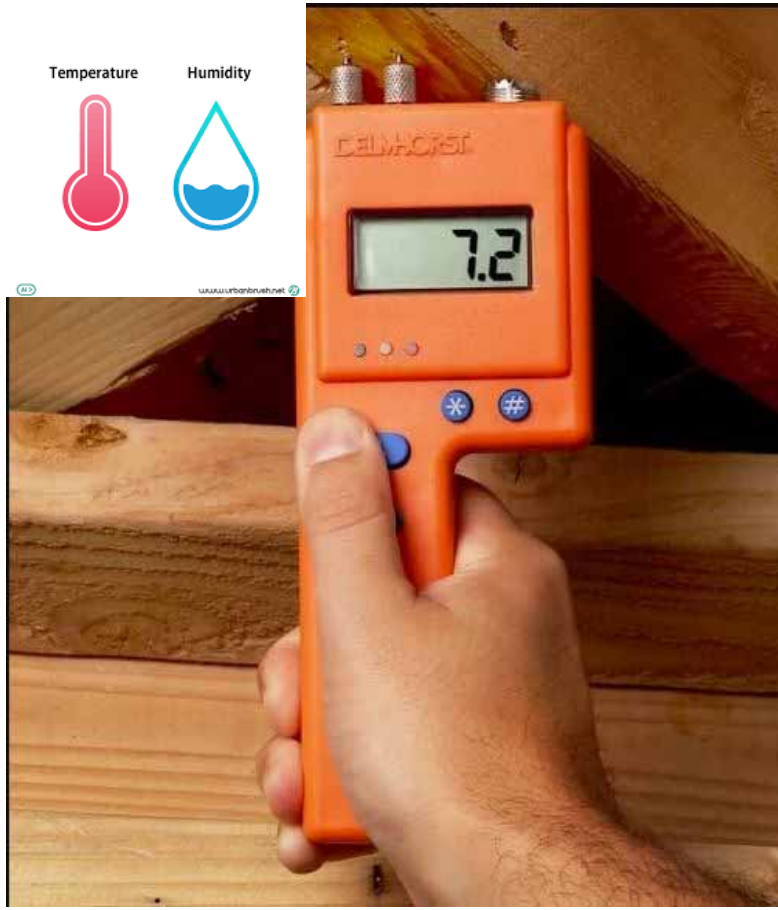


Figure 10. Source: https://moisturemeters.com.au/

Comparative Results: Chemical vs Sustainable-Key findings

- Conventional chemical coatings consistently emit higher levels of VOCs compared to sustainable alternatives. Greater risk to indoor air quality.
- Sustainable coatings do show clear benefits in terms of lower emissions. However, they have limitations in terms of durability and consistency. Their performance depends on many variables, and more evidence is needed before they can fully replace conventional coatings in all applications.
- Environmental factors such as humidity, temperature, and ventilation significantly influence VOC emissions for both types of coatings.

Feature	Chemical Coatings	Sustainable Coatings
Common Types	Polyurethane, nitrocellulose lacquer, alkyd varnish	Waterborne acrylics, UV-cured bio-resins, plant oils (linseed, tung), natural waxes
Main VOCs Emitted	Formaldehyde, benzene, toluene, xylene, acetaldehyde	Aldehydes (hexanal, nonanal), terpenes (limonene, pinene)
Total VOC Range (7–28 days)	800–1,200 µg/m³ (Adamová et al., 2020)	100–400 µg/m³ (Jabbari et al., 2025)
Secondary Emissions	High (e.g., carbonyls from ozone reactions)	Moderate to Low (ozone reactions with terpenes possible)
Health Concerns	Respiratory irritation, carcinogenicity (formaldehyde, benzene)	Mild irritation in sensitive individuals
Durability	High abrasion and water resistance	Variable; may need reapplication or blending
Cost and Accessibility	Widely available; cheaper	Slightly more expensive; growing market
Environmental Impact	High (petrochemical base, persistent emissions)	Lower (bio-based, often biodegradable)

- Limited field studies:

Few long-term, real-world comparisons of VOC emissions and performance.

- Lack of standardised testing → Standardized VOC measurement protocols required

Variability in chamber size, duration, temperature, and humidity complicates comparisons.

- Durability concerns:

Insufficient data on long-term maintenance, reapplication needs, and cost-effectiveness of sustainable coatings.

- VOC–indoor air interactions:

Secondary emissions from reactions with ozone (e.g., terpenes → aldehydes) underexplored.

- Need for hybrid solutions:

Combining conventional durability with low-emission sustainable materials for better balance in architecture and design.

Conclusions

- Indoor air quality is a major public health issue, and wood coatings are an important source of VOCs indoors.
- Conventional chemical coatings offer excellent performance but at the cost of high emissions and health risks.
- Sustainable coatings are promising, but their long-term durability and real-world performance remain under-researched.
- This calls for more rigorous testing, standardized measurement, and innovation in hybrid solutions.
- The message is clear: **material choices matter**. By selecting safer, more sustainable coatings, we can create healthier and more sustainable indoor environments for everyone.