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AUTHOR: *Luca Lanzoni*

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Evaluation of indoor air pollutants and new buildings' solutions to reduce them: literature review and fundamentals.

Luca Lanzoni- Orcid Id: 0009-0006-5611-7883

DA, Università degli Studi di Ferrara / Italy

Abstract- *During the past few decades various symptoms and illnesses have been increasingly attributed to nonindustrial indoor environments. In general, indoor exposure to noxious chemical, physical, and biological hazards occur at low levels, however, such indoors exposition are very common (Seltzer, 1994: pp. 318-326). Symptoms such as drowsiness, headache, fatigue, burning eyes and breathing difficulties are signs that could indicate a high percentage of pollutants in the indoor environment, although we often tend to attribute them to other causes. This phenomenon which causes disease is called - sick building syndrome - (SBS) and it is a growing problem (Carrie A Redlich, 1997: pp. 1013-1016). SBS has been reported with increasing frequency since the 1970s, as older, naturally ventilated buildings have been replaced by more energy efficient, "airtight" buildings. SBS was frequently associated with workplaces, where the employees work together and spend most of their time. However, in this pandemic and post-pandemic situation, the smart working, and the greater crowding of living spaces, could cause this problem to arise even in private homes. Now, in the framework of COVID, it has become even more necessary to look closely at the quality of the air in homes. Indeed we spend more and more time inside enclosed and shared places, where the air can be much more polluted than outside. At home and office, we are surrounded, and we daily breathe dangerous but invisible substances, which penetrate our body without being noticed. In order to propose the best house's construction and rebuilding solutions, this review considers the contamination sources that can cause diseases in the house's environment. The innovative approach, based on the complexity of the problem, it focuses attention about the different factors in order to reduce the indoor air pollutions. Finally, having identified the factors that play a significant role in environmental indoor house's contamination, a clear picture should emerge to draw conclusions and propose the best buildings solutions. Based on the complexity of the problem and the need for interdisciplinary research.*

Keywords: Pollution - SBS (sick building syndrome) - House environment - Biomaterials - Ventilation system – IAP (indoor air pollution)

Introduction- In the last ten years, the research about the air's quality began to move from external to internal specs, reflecting the people's life styles changes. Nowadays people pass over the 90% of the time in indoor environment (Ekmekcioglu D., 2007: pp. 169–176); (Leech J.A., 2002: pp. 427–432). It whose showed that the reduction of the air quality (IAQ) can affect negatively on human's health, causing illnesses associated to the building. According to the latest World Health Organization (WHO) report, 8 million people die every year globally because of air pollution. Among these, 4.3 million die because of air pollution from household sources and 3.7 million die because of Indoor Air Pollution (IAP) (WHO, 2020). COVID-19 pandemic in this last year's increase this picture, indeed air quality appears to be a critical environmental factor in the COVID-19 pandemic (Conticini et al., 2020: pp. 261). The development of technologies to mitigate indoor air pollution

is important to avoid adverse effects. In this document we give an overview of the principal sources of particular matter (PM) and volatile organic compounds (VOCs), in the developed countries', finally we show the better and trendy strategies to the control and reduce the indoor pollutant concentration in indoor environment. pp. 276-281). The semiconductor material TiO2 can be added to dry concrete or directly to binder in proportions from 0.1% to 5%, allowing, in any case to maintain the esthetic and mechanic characteristics of the concrete. The photocatalytic concrete can be used for concrete flooring, masonry coverings and houses 'walls. Indeed, this technology can be used also for coverings tiles and photocatalytic glass (Fig. 1).

Objectives and Methodology

This document aims to identify what are the new engineering and architectural solutions to reduce pollution inside homes. The scientific relevance of this review is to identify different aspects of the problem and solutions that are often studied separately. The methodology used to choose scientific evidence concerns the following aspects:

- Identify keywords and concepts to research
- Identify research databases based on objective quality criteria (impact factors, accredited scientific journals and peer-reviewed articles)
- Based on these standards, find the relevant references
- classify references for relevance and appropriateness
- Consult, read and select the references
- Rearrange references after reading compare the material and write the text.

Particulate Matters (PM) and volatile organic compounds (VOCs) emission sources in house environment

There are at least sixty sources of household air pollution, and these vary from country to country. Indoor air pollution with toxic volatile organic compounds (VOCs) and fine particulate matter (PM2.5) is a threat to human health, causing cancer, leukemia, fetal malformation, and abortion. PM and VOCs are solid or gaseous polluting substances, created by the presences of people (CO2, and corporal secretions) combustion's processes (tobacco smoke, cooking food), building and furnishing materials and chemicals products used for the sanitization. PM is defined as carbonaceous particles in association with adsorbed organic chemicals and reactive metals. PM's main components are sulfates, nitrates, endotoxin, polycyclic aromatic hydrocarbons, and heavy metals (iron, nickel, copper, zinc, and vanadium) (Hamanaka R.B., 2018: pag. 680). Depending on the particle size, PM generally is classified into coarse particles, PM10 of diameter <10 μm; fine particles, PM2.5 of diameter <2.5 μm; and ultrafine particles, PM0.1 of diameter <0.1 μm. Compared with PM10 and PM2.5, PM0.1 created by fossil fuel combustion represents a greater threat to health due to its penetrability into the small airways as well as alveoli (Miller M.R., 2012: pp. 577-602) (Brook R.D., 2010: pp. 2331–2378).

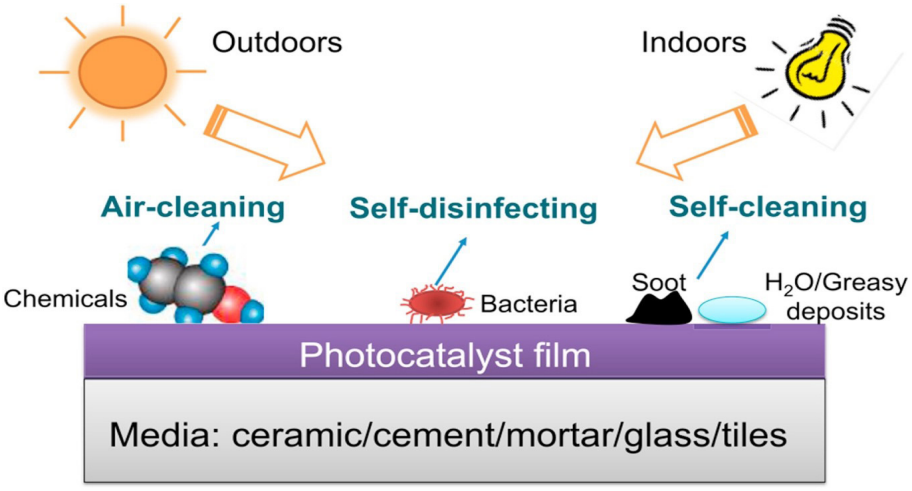

Fig.1/ Schematic diagram of multi-functional photocatalytic building materials.
Sourse/ Lexuan Zhong, Fariborz Haghighat, Photocatalytic air cleaners and materials technologies – Abilities and limitations, Building and Environment, Volume 91, 2015, Pages 191-203

Sometimes called oil-based or petroleum-based solvents, many VOCs are included in paints and cleaning products to dissolve or dilute the other ingredients. Flat (or matte) paints with fewer than 50 grams of VOCs per liter are generally considered to be low-VOC, while a zero-VOC paint is one with fewer than 5 grams per liter. Nonflat paints (such as satin and semi-gloss) are considered low-VOC if they have fewer than 100 grams of VOCs per liter.
Another VOC indoor emission source is glue, most of the synthetic adhesive are volatile organic compounds. Adhesive application in indoor decoration is an important anthropogenic volatile organic compound emission indoors source. Studies have been conducted on VOC emission factors and characteristics from indoor decorating adhesives. In this study (Gao M. et al., 2021: pag. 779), the VOC emission factors were obtained by measurement of VOCs in 210 adhesives. The results showed that the VOC emission factors were 41.23 g/L for wall and ground solidify, 33.49 g/L for tile adhesive, 76.88 g/L for white glue, 52.36 g/L for wallcovering adhesive, 132.28 g/L for sealant glue, 49.33 g/kg for foaming adhesive, 654.23 g/L for all-purpose adhesive and 152.01 g/L for marble glue. A new trend towards replacing the current chemical adhesives with bio-based adhesives for commercial interest is taking place accelerated by international legislation mainly in the US and EU that reduces the use of toxic materials in the building industries (Mathias G. I. et al, 2016: pag 104-116). These demands for green adhesive materials and sealant market is projected to reach USD 73.8 billion in 2024 compared to the global market of a few billions in 2019 (Rearch and Market, 2019).

Mitigation of indoor's air pollution
To reduce indoor air's pollution, we can adopt some strategies: some of them connected to the use of new materials, others bound to new architectural and engineering solution. We will consider the mine strategies:

Photocatalytic materials
In order to reduce the air pollution we can use self-cleaning paints and material. Adsorption and photocatalytic oxidation are the current approaches for the removal of VOCs and PM2.5 with high efficiency (Yue X., 2021: p. 124138). Catalytic technology for indoor air pollution treatment has the advantages of high elimination efficiency, low oxidation temperature, wide application range, simple equipment, and no secondary pollution (Weon et al., 2019: pp. 3185-3214). The principle behind is a photosensitive semiconductor material (e.g. TiO2) which is excited to emit electron-hole pairs under the irradiation of light of a certain wavelength that in turn converts O2 and H2O into radicals with strong oxidizing properties (Weon et al., 2019: pp. 3185-3214). Subsequently, the generated radicals cause the decomposition of VOCs. Indeed thanks to the photocatalysis, the damaging substances on materials and in the air, such as nitric oxide (NOx), or particulate matter (PM10) and VOC (Volatile Organic Compound), are easily transformed in inorganic and harmless

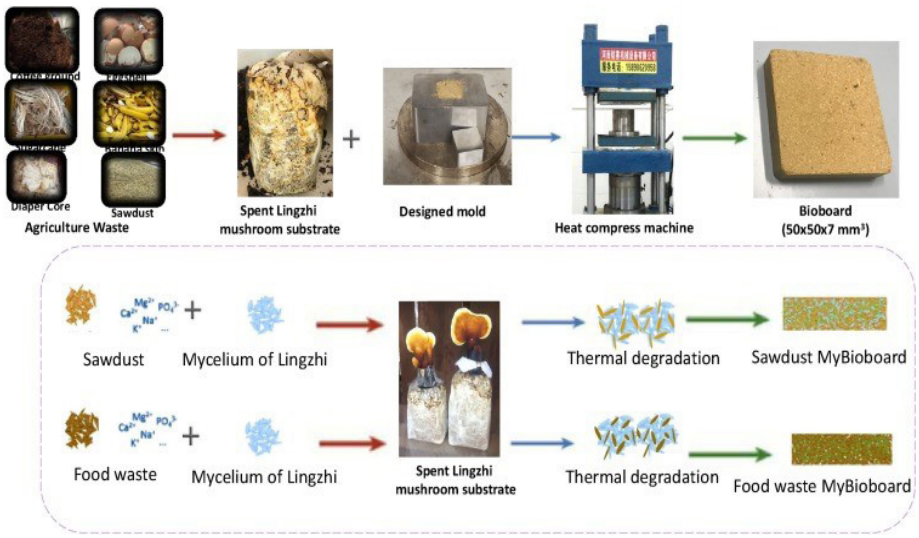

Fig.2 /The schematic overview of the Bio-board production from recycle of spent mushroom substrate (Shing Ching Khoo, et al, Volume 400, 2020, pp. 123-296.)

salts, as sodium nitrates (NaNO3), sodium carbonate (CaNO3) and limestone (CaCO3), these are substances similar to water. Studies results show that the maximum decomposition efficiency of formaldehyde is 73% and that immobilization of ZnO nanoparticles has a synergistic effect on photocatalytic degradation (Zhu et al, 2015: pp. 276-281). Il semiconductor material TiO2 can be added to dry concrete or directly to binder in proportions from 0.1% to 5%, allowing, in any case to maintain the esthetic and mechanic characteristics of the concrete. The photocatalytic contrite can be used for concrete flooring, masonry coverings and houses' walls. Indeed, this tecnology can be used also for coverings tiles and photocatalytic gals (Fig. 1).

Natural material - Sheep wool panels -
It is well known that wool carpets and upholstery permanently remove many gaseous pollutants from the air, thus improving indoor air quality, and peoples' wellbeing , this keratinous materials can absorb toxic substances such as heavy-metal ions, formaldehyde and other hazardous VOCs (volatile organic compounds), applications can also be envisaged in air cleaning (Aluigi A. 2009: pp. 311-319). For example, sheep wool is a natural material, already used for thermal insulation, in the form of soft mats or panels. The chemical composition of sheep wool is approximately 82% keratin, 17% non-keratin proteins and about 1% lipids and polysaccharides. Thanks to its high protein content, wool is able to absorb and neutralize particulate matter, heavy metals, and other hazardous gases such as nitrogen oxides, sulfur oxides and VOCs (volatile Organic Compounds) such as formaldehyde (Bosia D., 2015: pp. 315-320). In the last period are designing acoustic filtering panels for the walls' insulation, that have a high surface area of diffusion. In this panel the air can be forced to pass and can be easily recycled. The wool-based passive filters can significantly improve indoor air quality and represent a new use for wool.

Natural material - Mushroom panels -
Synthetic adhesives in the plywood industry are usually volatile compounds such as formaldehyde-based chemical which are costly and hazardous to health and the environment. This phenomenon promotes an interest in developing bio-boards without synthetic adhesives. Recent studies have proposed a novel application of natural mycelium produced during mushroom cultivation as a natural bioadhesive material that converts spent mushroom substrate into high performance bio-board material (Shing C. K. et al., 2020: pp. 123-296) (Fig. 2). This new material application is an indirect solution to reduce VOCs indoors environments.

Conclusions
Of 31 studies identified in the search, 17 met pre-specified inclusion and exclusion criteria. The compartmentation more present in the modern buildings and the increase of the time that the person spend indoor, has brought indoor air's quality problems. Ventilations systems that use filters for the particulate and

polluting substances, are surely effective to reduce the indoor air, bat in this review most recent and innovative solutions to reduce VOCs are evaluated. Alternative solutions are possible: some are in the implementation phase, other have already been present on the market. Different types of solutions are proposed in the examined studies, in any case the union of different technologies as the use of photocatalytic materials for coatings and floors, filter panels and the installation of green-walls, give an high contribution to improve the indoor air's quality.

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