VOC emissions: interaction with mortars

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SUMMARY
Indoor air quality can be strongly influenced by the presence of adhesives, mortars and in general all the building products in our houses, even if they are not in direct contact with indoor air. Emissions of volatile organic compounds can change in terms of quality and quantity as function of building materials applied. In our study we compared three different mortar substrates in terms of contribution in indoor air quality. The traditional stainless steel chambers have been modified and dressed with three different mortars; some of typical pollutants have been introduced into the chambers and their time decay has been studied.

KEYWORDS
VOC, mortars, emission chambers

INTRODUCTION
Indoor air quality can be strongly influenced by the presence of VOC coming from adhesives, paints, furniture, tobacco smoking, and also can be affected by the presence of pollutants coming from the environment. As described by Hoshi in 2008, typical VOC coming from atmospheric environment nowadays are aromatic compounds, above all benzene, toluene and xylene, but also some aliphatic compounds and terpenes have been detected in town air.
Several studies tried to evaluate the effectiveness of some sorptive building materials in decreasing VOC in air (Seo, 2007). In our study we applied our experience in the evaluation of low-VOC building materials, following ISO 16000, and we considered the “sorptive” aspect of materials. In fact we detected the air into large emission chambers dressed with three different low-VOC mortars, after the injection of some organic markers. We observed that all the mortars can adsorb VOC for a “sink effect” due to physical characteristics as porosity, but we identified also a chemical interaction between the different mortars and the considered VOC , depending from the hydrated products of the materials.

METHODS
Emission test chambers have been used for years in our analytical laboratory, in order to evaluate the content of volatile organic compounds emitted by building products and adhesives used for flooring installations. The chambers, made of stainless steel and glass, have a volume of 210 l, controlled relative humidity and temperature (T=23 $\pm$ 2°C; RH= 50 $\pm$ 5%), and loading factor 0.45 m^2/m^3. The chamber is fluxed by dry nitrogen, with a flow rate of 0.5 h^{-1}, which allows a complete change of the air in the chamber every two hours. Usually the sample is mixed uniformly, weighed and applied on a glass non adsorbent surface; the test specimen is transferred into the chamber immediately after preparation, and sampling of air for testing should start 24 hours after the application of the adhesive. In our experiment, panels made by different mortars have been applied into the chambers. 100 µl of a 2000 ppm methanol solution composed by some VOC (benzene, heptene, heptane, o-m-p xylene, toluene, ethyl benzene, cumene, ethylene glycol monobutyl ether and diethylene glycol mono butyl ether acetate, carene, isolongifolene) have been injected with the auxiliary of an injector

fluxed by nitrogen, into the three chambers with mortars and in an empty one, while the flow into the chamber has been decreased to 20 cc/h.
After 1h, 2h, 3h, 4h, 5h, 6h and 24h the injection, exhaust air is passed trough a sample tube filled with a suitable adsorbent material (Tenax TA®). Tenax tubes are then desorbed by a thermo-desorber; volatile organic compounds are separated by gas-chromatography, identified by MS detector and quantified by FID detector. Mortars tested in emission chambers have been the same superficial area (2700 cm^2), bottom and borders covered with a aluminium sheet in order to allow only a superficial adsorption of VOC. In our study a common mortar (mortar 1), a prepacked dehumidifying salt resistant mortar (mortar 2) and a cement free-pozzolanic binder one (mortar 3) have been compared.

RESULTS

Next graphs (fig. 1-a, 1-b, 1-c) show results obtained in terms of emissions detected in the chambers contained the three different mortars. Graphs have been built considering 100 % the concentration of the injected solution, and have been joined in chemical groups (aromatic compounds, hydrocarbons, terpenes and glycols).

Aromatic compounds

Benzene, toluene, o-m-p xylene, ethylbenzene, cumene emissions have been summed, since their trend in the three chambers have been similar (Figure 1-a).After one hour an appreciable difference from the three mortars have been observed: we detected after one hour the injection 21.3% of aromatic VOC with mortar 1, 26.2% in presence of mortar 2 and 14.6% in mortar 3.

Hydrocarbons

Heptane and heptene are the hydrocarbons considered (Figure 1-b): mortar 1 and mortar 2 have similar behaviors (24.6% of emissions detected after one hour in chamber 1, and 27.5%. in chamber 3) , while mortar 3 shows the lowest concentrations (19.1% of hydrocarbon detected after one hour). After 24 hours, no hydrocarbons can be detected in chamber 3.

Terpenes

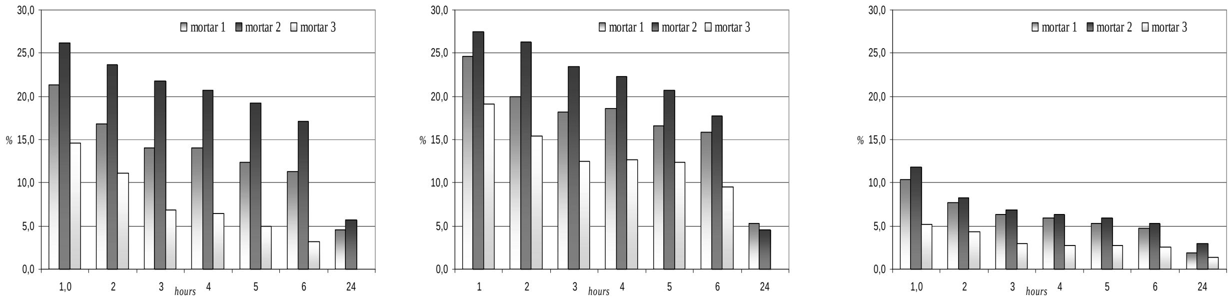
3-Carene and isolongifolene have been detected into the chambers after the injection (Figure 1-c): mortar 3 seems to adsorb the higher amount of these compounds. After one hour the injection of the solution, we detected 10.4% of terpenes in chamber 1, 11.8% in chamber 2 and 5.2% in chamber 3.

Glycols

Ethylene glycol monobutyl ether and diethylene glycol mono butyl ether acetate, have not been detected into chambers 1 and 3. Next table shows results obtained into chamber 2, since we detected low glycol emissions only in presence of mortar 2.

Table 1. Glycol concentration (μg/m^3)

Sample	Mortar 1	Mortar 2	Mortar 3
1 hour	-	31.4	-
2 hour	-	18.5	-
3 hour	-	12.5	-
4 hour	-	11.6	-
5 hour	-	11.3	-
6 hour	-	10.2	-



a) b) c)

Figure 1. Cumulative graphs of emissions a) aromatics, b) hydrocarbons, c) terpenes

TVOC (Total Volatile Organic Compound)

Next graph (fig. 2) shows the decrease of TVOC in the three chambers. After 24 hours the injection of the solution, all organic markers completely disappeared in the presence of the innovative mortar. An initial concentration of 5000 µg/m³ is related to standard injected, and it is not necessarily indoor linked.

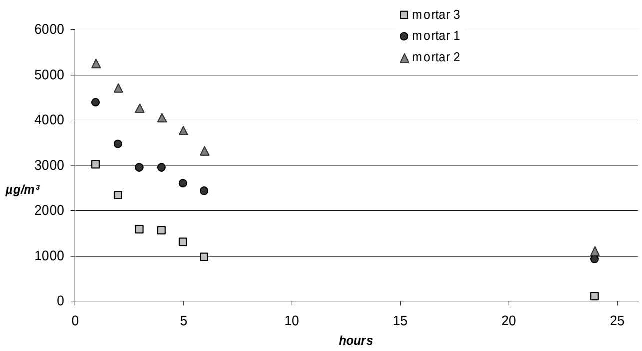
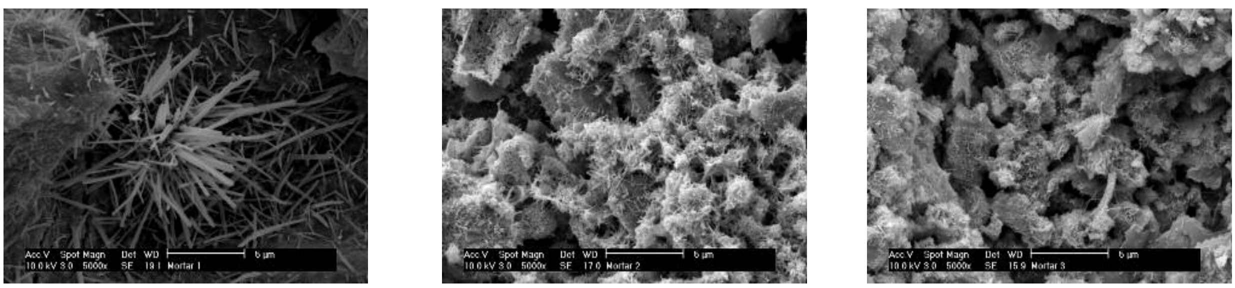


Figure 2. TVOC

Differences in TVOC can be due to physical characteristics in the three mortars after hydration: next figures (fig. 3-a, 3-b, 3-c) show the morphological aspect of the mortars collected by Environmental Scanning Electron Microscope. In the first mortar niddles of calcium silicate hydrates can be observed, while in mortar 2 silicate hydrates with different shape can be identified. At a first glance mortar 3 can be similar to the previous one, but some foil-like structure of hydration products coming from pozzolanic binder could give a higher surface disposable to interact with VOC.



a) b) c)

Figure 3. ESEM pictures a) mortar 1, b) mortar 2, c) mortar 3

DISCUSSION

Aim of this study is to highlight possible interactions between some VOC and mortars. We considered three mortars, different from a chemical point of view, since the three systems give different hydration products, due to their binders. In particular, mortar 3 is a cement-free one, that means the binder is a pozzolanic one, culture inherits by our roman forefathers. According to our test into the emission chambers, the innovative mortar can adsorb a higher amount of considered VOC rather than the other traditional ones. This effect can be due to a physical effect mortar 3, for its formula and raw materials, has a high porosity, available for a penetration of VOC. As shown in pictures collected by ESEM technique, mortar 1 and 3 have a superficial area disposable for an adsorption of organic compounds higher than mortar 2. TVOC detected from 1 hour to 24 hours the injection of the solution in chambers containing mortar 1 and 3 are in fact lower than the one detected in chamber 2. We also noticed that, depending to the class of VOC, differences of their emissions in the air are detectable. Glycols for example cannot be detected even after one hour the injection in chambers 1and 3. A reasonable distinction can be seen when detecting aromatic compounds. Mortar 3 seems to have a higher affinity for polar compounds. Mortar 1 and 2 after hydration produce Calcium Silicate Hydrates (C-S-H), while mortar 3 produces other amorphous hydration products, which in our opinion could give a stronger interaction with organic compounds. Furthermore, pozzolanic binder is rich of chemical elements which could catalyze organic compounds in smaller molecules which can easily penetrate into the mortar. Future works will deeply investigate on chemical interactions.

CONCLUSIONS

We use to think about VOC as emissions, we all try to find new materials which can guarantee a good quality of indoor air, materials which have low VOC emissions. This work shows another aspect: a mortar with low emissions of VOC, which can also adsorb, for its chemical and morphological characteristics, the considered VOC coming from pollution, smoking, paints. Mortars considered have been manufactured with different binders, and showed different behaviors in terms of VOC adsorption. From the first hours of our experiment, air in chamber 3 was always the cleanest. The interaction between VOC and mortars can be due not only for porosity and physical characteristic (sink effect), but also for a chemical interaction, enhanced in our study by the strong difference of VOC detected in presence of mortar 3.It is well known that some materials, such zeolites for instance, have an adsorption capacity. Our special eco mortar, applied in a house for restoration, can improve the quality of indoor air in terms of strong decrease of chemical pollutants due to high adsorption of VOC for both physical and chemical interaction.Results obtained in the first 24 hours enhance that chemical pollutant emissions have been strongly reduced by the three mortars, mainly due to the porosity of the surface, while the chemical composition of the three mortars can affect the “quality” of emissions. Porosity of surface can have an effect on the amount of volatile organic compounds emissions, while chemical composition of the three mortars can affect the species of volatile organic compounds in indoor air.

ACKNOWLEDGEMENT

We would like to thank Mrs Laura Villa, Mr. Marco Gariboldi for their precious contribution and Mr. Davide Salvioni for ESEM images.

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