Indoor Environmental Quality of Selected Flooring Materials

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Abstract

This study investigates the influence of various flooring materials on indoor environmental quality (IEQ) through a comparative analysis based on in-situ measurements. The primary objective was to assess the concentration of total volatile organic compounds (TVOCs), perceived air acceptability, and odor intensity associated with selected flooring types, specifically wooden flooring, floating flooring, and carpet. The results demonstrated that the highest TVOC concentrations were consistently observed with carpet. However, the lowest air acceptability was recorded for wooden flooring. Notably, when wooden flooring was combined with other materials, improved sorption efficiency resulted in more favorable air acceptability outcomes than the standalone materials. Sensory evaluation of material combinations under in-situ conditions produced more favorable results than those obtained in controlled chamber tests. This suggests that real indoor environments may reduce or moderate the perceived effects of chemical emissions. Over a 36-hour monitoring period, TVOC concentrations from in-situ measurements exhibited a decreasing trend, whereas chamber test concentrations stabilized at higher levels after approximately 18 hours. After 36 hours, TVOC levels from in-situ measurements were lower than those from chamber tests for both standalone and combined flooring materials. Floating flooring demonstrated the lowest TVOC emissions and the most favorable air acceptability and odor intensity, suggesting that it provides an optimal balance between chemical emissions and sensory comfort. The findings underscore the need to complement chamber-based assessments within in-situ evaluations. Real indoor environments introduce variables—such as ventilation rates, humidity levels, and material interactions—that can significantly influence the emission behavior of materials and how these emissions are perceived. Without considering these contextual factors, indoor environmental quality assessments may overlook key aspects of real-world performance.

Keywords: *Flooring materials; Indoor Environmental Quality; TVOC emissions; Sensory evaluation; In-situ measurements*

1. Introduction

Indoor Air Quality (IAQ) is a crucial factor that significantly affects building users' health, comfort, and overall well-being [1, 2]. Acceptable indoor air quality is associated with higher productivity, improved cognitive function, and a lower incidence of health issues such as headaches, respiratory irritation, fatigue, or allergic reactions. Conversely, poor indoor air quality can lead to the so-called Sick Building Syndrome (SBS), which manifests as various health problems linked to staying in enclosed spaces. For this reason, ensuring high indoor air quality is essential for designing healthy and sustainable interiors of buildings. [3, 4]

The most significant sources of indoor air pollution include Total Volatile Organic Compounds (TVOCs). TVOCs encompass a broad group of organic chemical compounds that easily evaporate into the air at normal temperatures. These substances primarily originate from several sources. Floor coverings are a significant source of TVOCs, which are released from adhesives, surface treatments, and the materials themselves, such as vinyl, laminate, or carpets. Building materials also contribute to the release of TVOCs. This includes particleboard, plywood, paints, varnishes, sealants, and other products that often contain formaldehyde, benzene, toluene, or xylene. Surface treatments are another major source of TVOCs. These include coatings, varnishes, impregnations, and waxes used to protect and finish floors and furniture.

TVOCs represent a chemical burden and can directly impact human health. health and comfort. Short-term exposure to high concentrations of TVOCs can cause eye, nose, and throat irritation, headaches, nausea, and impaired respiratory function. Long-term exposure is associated with the development of allergies, asthma, and an increased risk of cancer. Therefore, it is essential not only to monitor TVOC concentrations but also to analyze their impact on the subjective perception of the indoor environment.

The importance of indoor environmental quality has been highlighted in previous research, which focused on the emissions and odors from different interior surface materials and their impact on perceived indoor air quality [5]. In a preceding study, the influence of various common indoor materials, including oriented strand boards (OSB), high-density fiberboard (HDF), polyamide carpet (PA), polyvinyl chloride flooring (PVC), cork, concrete/marble-based flooring (CM), cotton carpet, modern linoleum, wooden parquet, and acrylic-based flooring, was analyzed under controlled chamber conditions. Painted gypsum boards (PGB) were used as a wall and ceiling coating material for studied combinations.

The previous published research [5, 6] demonstrated that building materials could act as both sources and sinks for volatile organic compounds (VOCs). The re-emission of sorbed VOCs significantly influenced the long-term concentration levels in indoor air. Flooring surfaces such as PVC and OSB exhibited high VOC emissions, whereas natural materials like wood and linoleum demonstrated lower emission levels. Furthermore, it was established that sorption effects between flooring materials and gypsum board coatings could influence

both chemical and sensory outcomes, affecting odor intensity and air acceptability.

Multi-layer installation is a standard practice for building materials [7]. The findings indicated that modern acrylic-based flooring, cork, and linoleum combinations offered the most favorable outcomes in terms of TVOC concentration, odor intensity, and air acceptability. In contrast, OSB and HDF-based flooring materials consistently exhibited the highest levels of VOC emissions and the least favorable sensory results. The role of sorption as a mechanism for reducing indoor pollutant levels was identified as a key factor in improving indoor air quality and occupant comfort [5].

This study builds on these previous insights by conducting in-situ measurements to evaluate the real-world behavior of different flooring materials under actual operating conditions. Unlike chamber tests, which provide controlled but artificial results, in-situ measurements reflect the complex interactions between building materials and environmental factors such as ventilation, humidity, and airflow patterns. By comparing in-situ data with chamber test outcomes, this research aims to provide a more comprehensive understanding of the role of flooring materials in shaping indoor environmental quality.

2. Basic Characteristics of Experimental Indoor Flooring Materials

This section of the study explores the fundamental characteristics of selected flooring materials and their impact on indoor environmental quality. The current research focuses on comparing several types of floor coverings—specifically wooden floors, laminate (floating) floors, and carpets—including combinations of these coverings with interior cladding made of gypsum boards. The selected materials were evaluated based on the concentration of total volatile organic compounds (TVOCs), indoor air acceptability, and odor intensity, both under controlled laboratory conditions and in real-life settings (in-situ).

This research builds [5,6] on a previous study that examined a broader range of interior flooring and cladding materials. These included OSB boards, laminate floors with HDF cores, synthetic (polyamide) and natural (cotton) carpets, PVC flooring, cork, concrete and marble surfaces, traditional linoleum, wooden parquet, and two types of acrylic-based floors. The earlier findings highlighted the significance of the sorptive properties of surfaces and demonstrated that the combination of flooring with wall and ceiling cladding made of painted gypsum board (PGB) can significantly influence both the level of TVOC emissions and the sensory perception of indoor air quality.

Wood and wood-based materials constitute a significant portion of the studied flooring types. Wooden floors (e.g., solid wood parquet) represent a traditional renewable material with favorable sustainability and indoor humidity regulation properties—wood can absorb moisture in a humid environment and release it when the air becomes dry. Solid wood typically emits only small amounts of VOCs, primarily composed of naturally occurring terpenes and aldehydes in the wood. However, surface treatments or adhesives used during installation can be a potential source of emissions; nevertheless, modern products of this type no longer contain formaldehyde-based resins, thereby limiting their emission potential.

In addition to solid wood, composite wood-based materials such as OSB boards and high-density fiberboards (HDF) used in the construction of laminate floors were also examined. OSB (Oriented Strand Board) is a multilayered board made of large wood strands bonded together with synthetic resin, commonly used in construction (e.g., as a subfloor or structural material for walls, ceilings, and floors). This material is known for its relatively high VOC emissions due to the adhesive used. OSB boards can release a wide range of volatile compounds, including aromatic hydrocarbons (e.g., benzene, toluene, xylenes), carbonyl compounds (e.g., pentanal, hexanal), and terpenes (e.g., α-pinene, limonene).

Laminate (floating) flooring with an HDF core is a multilayered system in which the supporting HDF board, made of wood fibers with a homogeneous structure and non-porous surface, is coated with a decorative paper layer impregnated with melamine resin and a protective wear-resistant film. During the manufacturing of laminate floors, adhesives and resins are used, which may contain volatile components (e.g., residual solvents); typical VOCs emitted from these materials include benzene, ethyl acetate, lower alcohols, and toluene. Emission intensity tends to be highest in the initial period following the production or installation of laminate and decreases over time as volatile compounds gradually evaporate into the surrounding environment.

Textile Floor Coverings (Carpets) represent another significant category of floor coverings included in the experiments. Synthetic carpets are made from artificial fibers (most commonly polyamide, polypropylene, polyester, or acrylic) and are typically constructed with primary and secondary backing, often based on latex or PVC [8]. Various additives and chemical agents (e.g., dyes, solvents, flame retardants) are used during their manufacturing, which can contribute to subsequent VOC emissions. The typical emission profile of new synthetic carpets includes aromatic hydrocarbons (such as benzene, toluene, ethylbenzene, and xylenes) and esters (such as ethyl acetate), with the concentrations of these compounds generally declining over time after the carpet is installed.

The emission profile of a carpet also depends on the fiber and backing materials. Carpets made from natural fibers (e.g., cotton or wool) typically do not contain synthetic solvents or monomers; however, they may release specific odor compounds of biological origin or residues of cleaning and impregnation agents.

In addition to direct emissions, textile materials in indoor environments can also act as passive sorbents of certain pollutants. The fibrous structure of the carpet allows for the temporary adsorption of VOCs from the surrounding air and their subsequent gradual release, making carpets a secondary source of VOCs over time or under changing environmental conditions (e.g., increased temperature).

The previous study [5, 6]] also evaluated elastic floor coverings based on synthetic polymers and natural raw materials. A representative of plastic flooring was polyvinyl chloride (PVC), which is a widely used material, particularly in commercial and industrial interiors. However, PVC can be a source of various undesirable organic pollutants—typically residual solvents from manufacturing (e.g., trichloroethylene), monomeric vinyl and styrene compounds, and especially plasticizers (phthalates), which are released from PVC slowly over an extended period.

As a more environmentally friendly alternative, traditional linoleum flooring was examined. Linoleum is manufactured from natural raw materials (linseed oil as a binder, along with resins, cork granules, wood flour, and limestone). Due to its natural composition, modern linoleum releases almost no intrinsic VOCs. However, adhesives used during installation may contain volatile compounds, contributing to indoor emissions.

Another evaluated material was cork, which stands out for its very low emissions and favorable acoustic and thermal insulation properties. Cork flooring is often recommended for interiors occupied by allergy sufferers or sensitive individuals due to its minimal dust production and low emissions.

In contrast, hard mineral surfaces such as concrete screeds or polished marble have very low porosity and are considered essentially inert in terms of VOC emissions. For these materials, the impact on indoor air quality is more likely to result from substances used during installation or surface finishing (e.g., primers, sealants, coatings), with emissions occurring primarily in the initial period following application.

3. Material and Methods

When evaluating floor covering emissions, it is crucial to consider interactions with the surrounding environment, particularly the sorption capacity of building materials within the room. The experiments used gypsum boards with a standard interior paint finish as a model sorption surface on the walls and ceiling. Due to its porous structure, gypsum board can absorb (adsorb) VOCs from the air to some extent, thereby reducing their concentration in the indoor environment, which generally improves the perceived air quality.

Previous research [5] has shown that adding sorptive surfaces to highly emitting floor coverings can significantly mitigate the increase in pollutant concentrations. For example, in the case of OSB boards, the presence of gypsum board cladding resulted in a substantial reduction in measured TVOC concentrations and odor intensity. Conversely, for materials with inherently low emissions, the effect of sorption may be less pronounced or may manifest as the release of previously absorbed compounds from the walls back into the air—especially under changing conditions such as surface heating or reduced relative humidity. Thus, materials' sorption and desorption behavior play a key role in interpreting the final VOC concentrations in enclosed spaces.

An important aspect of the methodology used in this study is the comparison of results obtained under laboratory conditions with measurements conducted in-situ. In the controlled environment of a small-volume test chamber, emissions from the tested flooring samples accumulate within a confined space, allowing for accurate quantification and direct comparison of materials shortly after installation.

However, real-world indoor environments differ significantly—air volume is larger, natural or forced ventilation occurs, and various other surfaces are present, which may further sorb VOCs or chemically interact with them. As a result, measured TVOC concentrations in occupied interiors are typically lower than those recorded in sealed laboratory chambers, and the perceived odor intensity tends to be lower in real environments.

Nevertheless, comparing laboratory and in-situ data is essential for verifying how accurately laboratory-derived emission characteristics reflect the actual impact of a particular floor covering on indoor air quality. In this study, combining both approaches allowed for identifying specific behaviours of individual flooring types under both controlled conditions and everyday use.

Based on the composition and properties of the materials, it can be expected that floor coverings containing higher amounts of organic binders or plasticizers (e.g., OSB boards or PVC) will have the highest impact on indoor TVOC concentrations. In contrast, natural and modern low-emission materials (e.g., solid wood, cork) will result in significantly lower VOC release levels. The presence of porous sorptive surfaces, such as gypsum board or textiles, can further dampen the final concentrations to some extent. A comprehensive assessment of all these factors provides a complete understanding of the impact of different flooring systems on indoor air quality, which will be further explored in the following sections of the study.

Emissions of TVOCs and odors from various common indoor flooring materials (solid wood flooring, laminate flooring, carpet) and their combinations were examined in a test chamber under standardized conditions – temperature of 23 °C, relative humidity of 50%, surface air velocity of v = 0.1–0.2 m/s, and air exchange rate n = 0.5 1/h. Chemical measurements (TVOC) and sensory evaluations (odor intensity, perceived air quality) were conducted after exposure of the building materials to the standardized conditions.

The chemical measurement methodology was based on gas chromatographic analysis of the absorbed TVOCs. Measurements were conducted in a glass test chamber with a volume of 190 liters. Before starting the tests, the chamber was cleaned, the baseline concentration of pollutants was determined, and a sensory evaluation was conducted in the empty chamber under the same conditions as during the emission test. Emission surfaces were oriented parallel to the direction of airflow. The average air velocity and airflow rate were measured using a thermal anemometer (TESTO 425). Measurements were performed two days after the building products were placed in the chamber. Active sampling of TVOCs was carried out using a pump (Aircheck 2000) with an air flow rate of 400 ml/min onto ORBO 32S charcoal tubes (Supelco) for 24 hours. The absorbed TVOCs were analyzed using gas chromatography (GC Varian 3 300) after extraction into CS_2. The total TVOCs were calculated based on the concentrations of individual TVOCs, including unidentified peaks converted to decane equivalents.

The test chambers were visually concealed using aluminum foil to ensure unbiased sensory evaluation, preventing the panellists from identifying the assessed materials. This blinding technique was critical to eliminate visual cues that could influence perception and maintain the objectivity of the sensory data. Prior to the initial assessment, all panel participants underwent standardized training, during which they were thoroughly instructed on how to use the continuous rating scales and operate the exposure apparatus. This preparatory session was designed to ensure consistency in the evaluation process and minimize inter-individual perception variability.

The experiment supervisor conducted a brief pre-assessment screening to evaluate each participant's attitude and motivation toward the experiment and their adherence to personal hygiene standards, given the sensitivity of odor perception to extraneous factors. No restrictions were imposed regarding participants' gender or smoking habits, thereby allowing for a representative and heterogeneous panel. The panel comprised individuals aged between 20 and 38 years, with an average age of 30 years. Notably, 35% of the participants were smokers, ensuring that the dataset reflected a realistic cross-section of potential indoor occupants.

For the sensory evaluation itself, the exhaust air from each test chamber was funneled through a diffuser to deliver a consistent and uniform airflow to the participants. Each subject was asked to provide an immediate, instinctive rating using two continuous scales: one for odor intensity (ranging from 0 = no odor to 5 = unbearable odor) and another for air acceptability (ranging from –1 = completely unacceptable to +1 = completely acceptable). These scales were chosen for their sensitivity and ability to capture nuanced perceptual responses. Based on the collected acceptability scores, the percentage of dissatisfied individuals (PD) was calculated using an established empirical relationship between mean acceptability and perceived dissatisfaction. This approach provided a robust, quantifiable indicator of indoor air quality as experienced by occupants, bridging objective emission data with subjective human perception.

4. Results & Discussion

The combination incorporating carpet as the surface layer of the flooring exhibited the highest TVOC concentration values, both in the case of in-situ chemical assessment and chamber tests. From the perspective of air acceptability, the least favorable results were observed for the wooden flooring. However, due to the advantageous sorption efficiency of the material combination, the overall acceptability of this configuration surpassed that of its individual constituent materials. Notably, the in-situ sensory evaluation of the material combination yielded the most favorable results, meeting indoor air quality assessment criteria more effectively than chamber tests (Table 1). TVOC concentration values (expressed in $\mu g/m^3$) were measured at five-time intervals: 6 hours, 12 hours, 18 hours, 24 hours, and 36 hours. The decking floor alone exhibited relatively high TVOC emissions, with the initial concentration at 2163 $\mu g/m^3$ after 6 hours, which progressively declined to 751 $\mu g/m^3$ at the 36-hour mark. Similarly, the gypsum board released lower levels of TVOCs, starting at 718 $\mu g/m^3$ at 6 hours and decreasing to 94 $\mu g/m^3$ at 36 hours. The combination of decking floor and gypsum board resulted in higher initial emissions than the individual materials, with a concentration of 2577 $\mu g/m^3$ at 6 hours, which gradually decreased to 872 $\mu g/m^3$ at 36 hours. However, the in-

situ measurement of the combination recorded even higher initial TVOC values (2830 µg/m³), but these emissions also declined over time, reaching 732 µg/m³ at 36 hours. The higher initial emissions in the combined configuration suggest that the material interaction or installation-related factors could have contributed to the increased release of VOCs.

Air acceptability was evaluated using a scale from -1 (clearly unacceptable) to +1 (clearly acceptable) at the 36-hour mark. The decking floor alone had the lowest acceptability score of -0.13, indicating poor perceived air quality. In contrast, the gypsum board exhibited a more favorable acceptability score of +0.10. The combination of materials under chamber test conditions showed a slightly improved acceptability score of +0.12, suggesting that the sorptive properties of the gypsum board helped mitigate the negative impact of the decking floor's emissions. The in-situ combination, however, demonstrated the highest air acceptability score of +0.13, indicating that real-world conditions such as ventilation and surface interactions contributed to a more favorable perception of air quality.

Odor intensity was rated on a scale from 0 (no odor) to 5 (overwhelming odor) at the 36-hour mark. The decking floor exhibited an odor intensity of 1.81, reflecting a moderate odor perception. The gypsum board had a slightly higher odor intensity rating of 2.00, indicating that although the TVOC emissions from the gypsum board were lower, the odor perception was more pronounced. The combined configuration under chamber test conditions resulted in a reduced odor intensity of 1.48, suggesting that the combination of materials had a balancing effect on perceived odor. The in-situ combination showed the lowest odor intensity of 1.40, further supporting the hypothesis that real-world environmental factors such as ventilation and humidity positively influenced odor perception.

Tab. 1. Chemical evaluation and in-situ measurement of the combination (deck flooring)

	TVOCs concentration (µg/m³)					**Air acceptability (-1/+1)**	**Odor intensity (0/5)**
Time interval (h)	***6 h***	***12 h***	***18 h***	***24 h***	***36 h***	***36 h***	***36 h***
Decking floor*	2163	1305	1190	990	751	-0.13	1.81
Gypsum board*	718	255	213	161	94	0.10	2.00
Combination* (Decking floor)	2577	1516	1383	1150	872	0.12	1.48
Combination (in-situ measurement)	2830	1815	1407	1061	732	0.13	1.40

* Chamber test.

During the 36-hour period, the initially higher concentration of TVOCs (measured in-situ) decreased, in contrast to the concentration of TVOCs from chamber tests, which reached higher levels after approximately 18 hours (Figure 1). The concentration of TVOCs (measured in-situ) at 36 hours dropped below the concentration levels of both the flooring material (chamber tests) and the combination (chamber tests). Therefore, it can be concluded that, in the context of comparing sensory and chemical evaluation, the concentration of TVOCs had a direct impact on the outcomes of the sensory evaluation in this case.

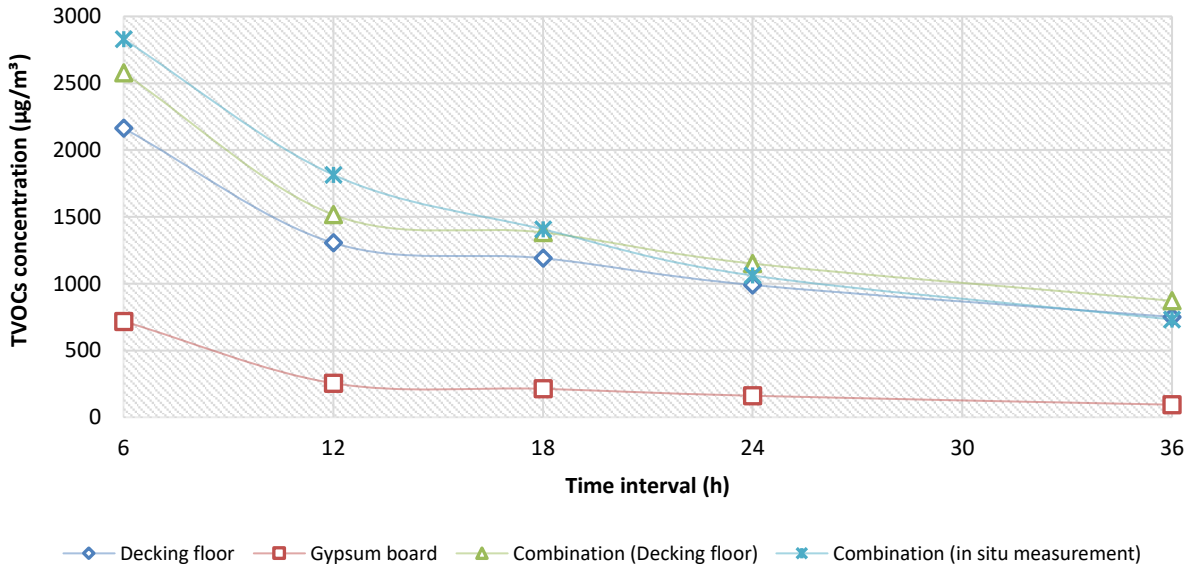

Fig. 1. Trend of TVOC concentration in the combination (deck flooring)

In the case of the combination with floating flooring, the lowest TVOC concentrations were recorded among all three evaluated combinations. The combination (chamber tests) achieved the most acceptable results in terms of air acceptability and, during the observed 36-hour period, did not exceed the TVOC concentrations of the combination (measured in-situ) (Table 2). Regarding odor intensity, the combination (measured in-situ) also achieved the best results, like the previous combination. The floating floor alone exhibited moderate emissions, starting at 1029 µg/m³ and decreasing to 154 µg/m³ at 36 hours, while the gypsum board again showed significantly lower emissions (from 718 to 94 µg/m³). When combined, the materials displayed higher initial TVOC concentrations—1219 µg/m³ in chamber tests and 1347 µg/m³ under in-situ conditions—yet both configurations showed a continuous decrease over time. In terms of air acceptability, the combination performed best under chamber conditions (+0.16), followed closely by the in-situ evaluation (+0.15), both improving upon the individual materials. Odor intensity was also lowest for the combined configurations, especially in the in-situ case (1.37), suggesting that the interplay between materials and real-world environmental factors, such as ventilation, contributes to a more favorable sensory perception despite the higher initial emission levels.

Tab. 2. Chemical evaluation and in-situ measurement of the combination (Floating flooring)

	TVOCs concentration (µg/m³)					Air acceptability (-1/+1)	Odor intensity (0/5)
Time interval (h)	***6 h***	***12 h***	***18 h***	***24 h***	***36 h***	***36 h***	***36 h***
Floating floor*	1029	730	527	335	154	0.11	1.56
Gypsum board*	718	255	213	161	94	0.10	2.00
Combination* (Floating floor)	1219	915	634	371	201	0.16	1.42
Combination (in-situ measurement)	1347	1063	755	607	421	0.15	1.37

* Chamber test.

Within the observed time interval, no significant changes were recorded, and the highest TVOC concentration was thus measured in-situ in the actual building interior (Figure 2). Therefore, it can be concluded that, in this case, the TVOC concentration does not have a direct impact on the results of the sensory evaluation.

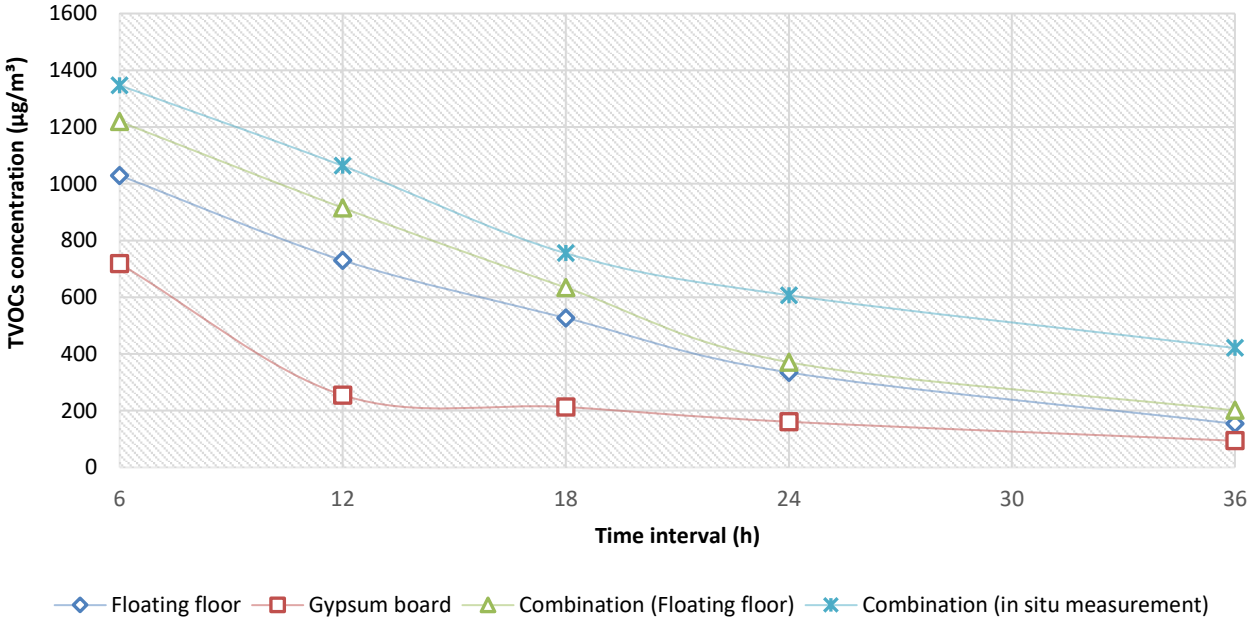

Fig. 2. Trend of TVOC concentration in the combination (Floating flooring)

In the last monitored interior, moderate TVOC concentration values were recorded; however, the most acceptable values for sensory evaluation were achieved. The combination (measured in-situ) achieved the best air acceptability and odor intensity values despite the highest TVOC concentration values at 36 hours (Table 3). The carpet alone exhibited relatively high TVOC emissions, starting at 1754 µg/m³ and decreasing to 713 µg/m³ after 36 hours, while the accompanying gypsum board again showed low emissions, dropping from 718 to 94 µg/m³. When combined, the materials demonstrated even higher initial concentrations—1933 µg/m³ in chamber conditions and 1845 µg/m³ in-situ measurements—though both configurations showed a steady decline over time. Despite these elevated emission levels, the combination performed well in terms of sensory indicators: air acceptability improved to +0.21 (chamber) and further to +0.26 (in-situ), the highest among all tested combinations. Odor intensity was also the lowest in the in-situ setting (1.32), indicating that, despite relatively high VOC concentrations, the combined carpet system benefitted from environmental sorption effects and possibly improved ventilation, resulting in favorable perceived indoor air quality.

Tab. 3. Chemical evaluation and in-situ measurement of the combination (carpet)

	TVOCs concentration (µg/m³)					Air acceptability (-1/+1)	Odor intensity (0/5)
Time interval (h)	***6 h***	***12 h***	***18 h***	***24 h***	***36 h***	***36 h***	***36 h***
Carpet*	1754	1372	998	842	713	0.17	1.35
Gypsum board*	718	255	213	161	94	0.10	2.00
Combination* (Carpet)	1933	1497	1084	897	756	0.21	1.40
Combination (in-situ measurement)	1845	1412	1124	935	862	0.26	1.32

* Chamber test.

Within the monitored 36-hour time interval, it can be stated that the combination of in-situ measurements exceeded the TVOC concentration values obtained from chamber tests at approximately 16 hours, despite initially lower TVOC concentration levels (Figure 3).

In conclusion, it can be stated that despite higher TVOC concentrations in-situ measurements, more favorable results were recorded in the sensory evaluation of indoor environmental quality. Therefore, sensory assessment in a chamber represents a more stringent evaluation approach compared to in-situ measurements.

Based on the progression of individual concentration levels, it has been demonstrated that using a computational model of concentration and values from the test chamber, we can almost accurately predict the course of TVOC concentrations in building interiors. Deviations may be caused by differences in evaluation using gas chromatography and in-situ assessment with a measuring device. The smallest deviations between in-situ measurements and chamber tests with the computed progression were recorded at approximately 17 to 18 hours.

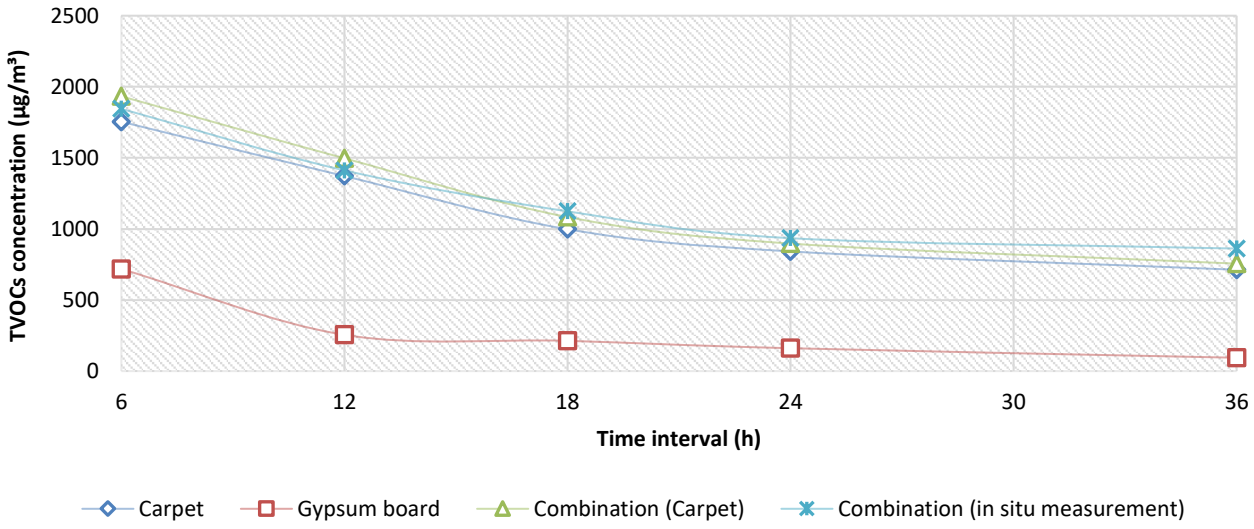

Fig. 3. Trend of TVOC concentration in the combination (Carpet)

5. Conclusion

These findings clearly show that in-site measurements under real conditions are essential if we truly want to understand how building materials affect the quality of the indoor environment where people live and work. Unlike chamber tests, which offer controlled and reproducible conditions ideal for initial material screening, in-situ assessments capture the complex dynamics of real-world environments—ventilation patterns, surface interactions, temperature and humidity fluctuations, and occupant presence. The study highlights that material combinations interact chemically and physically with their surroundings, influencing emissions and sensory perceptions in ways that are not fully captured by chamber testing alone.

Despite showing the highest TVOC concentrations, the carpet combination consistently achieved the best sensory acceptability ratings, particularly under in-situ conditions. This outcome points to the potential of carpet materials to act as passive sorbents that moderate odor perception and contribute to occupant comfort. Conversely, the floating floor combination demonstrated the lowest overall TVOC emissions and odor intensity, confirming its suitability for environments where minimal chemical exposure is a priority, such as in spaces for sensitive individuals or healthcare settings. The wooden plank floor combination, which produced intermediate TVOC levels and favorable but more neutral sensory outcomes, may represent a balanced choice for general-purpose interiors, combining sustainability, aesthetic appeal, and reasonable indoor air quality performance.

These results underscore the importance of a holistic approach to interior material selection—one that considers emission data from standardized tests and integrates knowledge of material interactions, environmental context, and human sensory response. For architects, designers, and building engineers, the findings provide actionable guidance: selecting low-emission or sorptive materials, optimizing material pairings, and evaluating them in realistic scenarios can significantly enhance indoor air quality and occupant well-being. This comprehensive perspective is particularly relevant for sustainable building design and for the future development of healthy indoor environments in residential, educational, and commercial buildings.

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