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Research Paper

Determination of the Effect of Laminate Flooring on Indoor Air Quality During the Installation Phase of the Building#

Caner Yetiş[1], Merve Tuna Kayili[2, *]

[1]*Karabuk University, Institute of Graduate Education, Karabük, Turkey;* [2,*] *Karabuk University, Faculty of Architecture, Karabük, Turkey,*

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Abstract: In today's world, where most of the time is spent indoors, determining the indoor air quality and making suggestions is essential in protecting the user's health. Pollutants that reduce indoor air quality can be listed as carbon dioxide, bioaerosols, particulate matter and volatile organic compounds (VOCs). These pollutants can be released from many sources, such as building materials, adhesives, paints or cleaning agents. In particular, building materials reduce the air quality of the space by releasing VOCs with the highest and then decreasing acceleration from the installation and can harm human health in case of prolonged exposure. The study aims to determine the volatile organic compounds released into the interior space after installing laminate flooring, which is frequently used as a floor covering in houses, and to control them according to threshold values. As a result, it has been determined that the VOCs emitted by the laminate flooring, which decreases and continues from the installation and the VOCs values measured in the initial phase were reached 28 days after the installation of the laminate flooring.

Keywords: *Laminate Parquet Flooring, VOCs, installation process*

Introduction

Emissions caused by building materials that people use while building construct, cause an increase in indoor and outdoor air pollution and increase ventilation and heating costs accordingly (Lombard Perez *et al.,* 2016). When the sealing levels of the building materials are lowered in order to provide the thermal comfort (EPA 2001) of the space, the amount of pollution in the indoor air increases even more (Kraakman *et al*., 2021). The high concentration of pollutants in the indoor environment compared to the outdoor environment has increased the importance of the indoor air quality (IAQ) concept (Hansen, 1999; Suryawanshi *et al.,* 2016; Du *et al*., 2019; Cao *et al.,* 2020). People spend more time indoors than in the past and are therefore exposed to 2-5 times more pollutants. However, the adverse effects of the pollution exposed will occur in the long term, and the necessary attention is not paid to indoor air quality (Fanger, 2005).

Indoor air pollutants are CO_2, volatile organic compounds (VOCs), particulate matter (PM) and bioaerosols. These pollutants are classified according to their particle size, gas or granular structure, and phase state (Abt *et al.,* 2000; Chao ve Cheng, 2002; Cattaneo *et al.,* 2011; Coşgun, 2012; Salma *et al*., 2013; Luengas *et al*., 2015; Lei *et al*., 2019; Shrubsole *et al*., 2019; Sun *et al*., 2019; Kozielska *et al*., 2020; Abdel-Salam, 2021; Gonzalez-Martin *et al.,* 2021). It is possible to evaluate these environmental pollutants under two main headings as outdoor and indoor air pollutants. Pollutants originating from the external environment are generally known as combustion gases, hydrocarbons, and radon gas. Pollutants originating from the indoor environment can be emissions and biological pollutants from building materials and human activities (Yurtseven, 2007; Kurutaş, 2009). Considering the developing construction technology, it is possible to say that building materials come to the fore among the sources of pollutants. The vinyl coating, plastic-based coating materials, polyurethane-added thermal insulation materials, and formaldehyde-added building materials can cause carcinogenic effects by emitting high amounts of volatile organic compounds in their environment. Studies have shown that indoor pollutants above the threshold values cause many ailments such as headache, nausea, fatigue, respiratory tract infections (Myhrvold *et al*., 1996; ECJRC,

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* *Corresponding: E-Mail: mervetunakayili@karabuk.edu.tr, Tel: +903704188582; Fax: +903704188330;*
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1997; Mendell *et al.,* 2005; Satish *et al*., 2012; Annesi-Maesano *et al*., 2013; Zhou *et al*., 2017; Fernandez-Agüera *et al.,* 2019).

The use of plastic-based building materials that produce volatile organic compounds in the building endangers human health by causing high VOCs pollution in the space (Yu *et al*., 2010; Liu, 2019). VOCs released into the environment from materials such as formaldehyde-added solvents, adhesives, paints and varnishes used in the production process of building products occur at a high rate after the installation of the material, and then these emissions decrease over time due to ventilation (Jimenez *et al*., 2017; Adebayo *et al*., 2018). However, as a result of the reaction of the VOCs in the environment with other chemicals in the space, their life in the ambient air may be longer (Kim *et al*., 2005; Farmer *et al.,* 2019; Haines *et al.,* 2020; Pytel *et al*., 2020; Liu *et al.,* 2021). For this reason, the building must be ventilated at a high rate in the period after the installation of building materials.

VOCs that cause indoor pollution are caused by the finishing elements on the wall, floor and ceiling surfaces that make up the space, and the amount of emission may vary depending on the content of these elements (Kim *et al*., 2005; Alawode *et al*., 2019; He *et al.,* 2019; Naldzhiev *et al*., 2020; Wi *et al*., 2020). With the increase in temperature in the interior, the dissolution of volatile organic compounds in the environment (Kim *et al.,* 2005), the movement of heated gases from the bottom up in the space highlight the finishing elements used on the floor surface (Wiglusz *et al.,* 2002; Wilke *et al.,* 2004; An *et al*., 2010; An *et al.,* 2011). The fact that flooring materials in buildings are mostly made of wood-based materials brings up the determination of the amount of VOCs that may occur with laminate flooring and, accordingly, the determination of ventilation strategies after its installation. Because the concentration of VOCs, especially from wood flooring materials, can remain in the space for a long time compared to adhesives, carpets and paints (GETI, 2012). For this reason, in the study, it was aimed to determine the amount of VOCs released by the laminate parquet flooring material during and after the installation and the room of a house under construction in Safranbolu was chosen as the field study. After the installation of the laminate flooring in the building, the amount of TVOCs emitted into the environment was measured depending on time and the access time to the threshold limit value recommended by EPA was determined. Although there are studies in which the amount of TVOCs emitted by laminate flooring to the environment (Kim, 2010; Kim *et al*., 2012), there is no study to determine the TVOCs value of laminate flooring produced in Turkey. The study is expected to guide architects, material producers, decision-makers, and users in the selection of materials and the time of use after the material installation is completed.

Floor Covering Materials and Laminate Parquet

Floor covering materials are the finishing material of the carrier ground layer in the structure. Floor covering materials play an important role in providing the visual, physiological, acoustic, physical and mechanical qualities required in the space (Toydemir *et al*., 2000). VOCs originating from the chemical processes applied during the production and installation of floor covering materials, especially from rotting fungi in wood-based floor covering materials and the chemical adhesives it contains, are the main sources of VOCs emissions in the building (Kim *et al.,* 2005) (Table 1). In addition, the longevity of these emissions in the environment (Table 2) makes it important to detect VOCs caused by floor covering materials and to take necessary precautions accordingly. In addition to nylon carpet and vinyl coverings (Kraus and Juhásová Šenitková, 2020), which cause high VOCs emissions from installation, wood and laminate flooring, in particular, is known to produce more VOCs compared to PVC, marley, carpet, mosaic flooring and ceramic flooring materials (Lakestani, 2015).

Table 1. Emission amounts of various building materials (GETI, 2012)

Product	Maximum Emission Rate(μg/hour/m^2)
Oil paints	200 000
Ceiling tile	12 000
Wood veneer	**12 000**
Dry cleaning	10 000
Water-based paint	9 000
Photocopier	7 000
Carpet	6 000
Floor wax	1 000

Table 2. Time-dependent variation of emissions from various building materials (GETI, 2012)

Product	1 Hour (µg/hour/m²)	1 Day (µug/hour/m²)	1 Week (µg/hour/m²)	1 Month (µg/hour/m²)	1 Year (µg/hour/m²)
Adhesives	400	100	<1	0	0
Carpet	600	80	20	10	5
Wood floor	**1 000**	**1 000**	**900**	**600**	**3**
Oil-based paints	3 000 000	200 000	0	0	0
Water-based paints	50 000	40 000	20 000	200	20

Laminate flooring is one of the most preferred flooring materials for interiors due to its impermeability, easy cleaning, aesthetics and resistance to impacts, especially with the developing technological processes. Laminate flooring is a decorative flooring material consisting of 4 layers, with carrier elements such as chipboard or MDF in the middle, and balance paper, HDF board, decorative paper overlay, with the bottom and top surfaces impregnated with the help of resins (Figure 1) (Kim & Kim, 2005; Kim 2009a,b). In addition to these positive features, the wrong selection of the methods and chemicals used in the production process of laminate flooring causes various emissions during the installation and use phase of the material. Although these emissions vary according to the raw material used in laminate flooring, the type of adhesive and the production method, it has been determined that the laminate flooring emits TVOCs between 400 µg/m²h-1300 µg/m²h during the installation (Kim *et al.*, 2012). It is also known that laminate flooring with HDF (High Density Fiberboard) in its structure emits more VOCs (Kim, 2010).

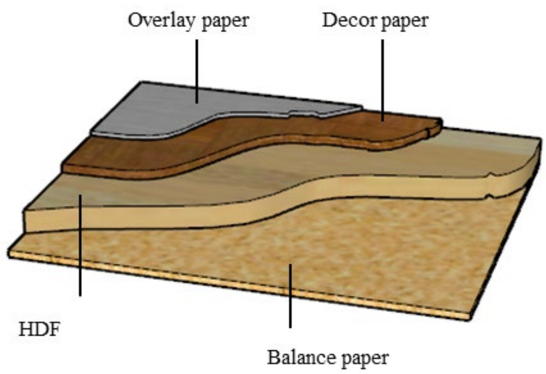

Figure 1 Laminate flooring layers

Basically, laminate flooring production consists of 6 main processes. These; Raw material preparation and fiberization, Glue and drying, Pressing, -Sanding, -Impregnation Application -Sizing (Alkan, 2019).

Formaldehyde added resins used for fast drying of the parquet during these processes, chemicals used during the impregnation process and polishing processes cause high VOCs release. (Filiz *et al.,* 2011). Effective ventilation for a month (Yrieix, 2010) is considered important in terms of protecting human health, especially in places where such laminate flooring is used, which emits high levels of VOCs during installation.

Material and Method

Laminate parquet

Platinum Rustic Oak 32 AC / 4 coating material, the technical specifications of which are given in Table 3, has been preferred in order to detect volatile organic compound emissions originating from laminate flooring and to follow the change of these emissions over time. According to the TS EN 13329+A1:2017 standard, this material is in the class of "exposed to normal impact in commercial areas". Considering TVOCs emission, HDF density in the parquet and the fact that the parquet contains joints from all four edges are among the parameters taken into consideration when choosing the material. Due to the wide variety of materials emitting volatile organic compounds in the interior, other structural elements in the environment have been determined and given in Table 4.

Within the scope of the study, a room in the housing block under construction in Safranbolu was chosen as the study area. The selected room is a room with a north facade and is located on the 3rd floor in the building with an area of 12 m^2. There is a 100*140 cm window on the north façade and a 90*210 cm door on the inner wall. The apartment, measuring room, and measuring points are given in Figure 2.

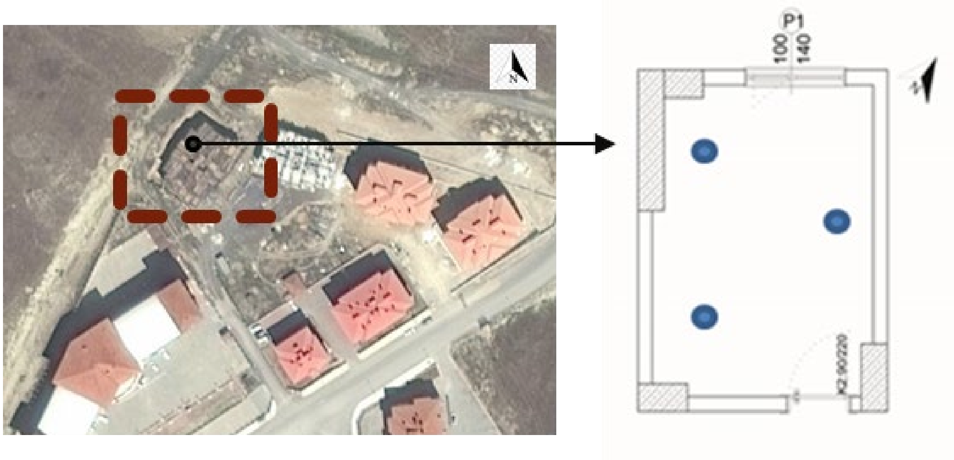

Figure 2 The apartment, schematic plan of the room, and measurement points

Table 3. Properties of the laminate flooring

Platinium Rustique Oak 32 AC/4	
Dimensions	1.380-190-10mm
Surface Wear Class	AC4-32
HDF Density	900kg/m^3 +-20kg/m^3
Taber EN 438	>2000 Cycle
Press Sheet Depth	50-75 micron
Suture	Suture with 4 sides

Table 4. Properties of the room compounds

Building Element	**Material**
Wall	Plastic-based interior paint
Ceiling	Water-based ceiling paint
Door	Wood MDF
Window	PVC

Method

In order to determine the amount of volatile organic compounds originating from laminate flooring, the paint works on the walls and ceilings were completed and the door windows were placed. After the application and assembly of these materials, the space was ventilated periodically and the possible VOCs concentration caused by other materials in the space was reduced. During the measurement phase, three different measurement points were determined in the space and measurements were made from these three different points for 90 minutes in 15-minute periods on each measurement day. Each measurement in the same period was repeated 3 times and the arithmetic average was taken. Thus, one value was determined for each period by taking the arithmetic average of a total of nine values measured in the space.

Also, the amount of TVOCs before the laminate flooring installation was measured to form a control group. Temperature, humidity, and TVOCs measurements, which started right after the installation of the parquet, were determined with the help of the equipment given in Table 5. These measurements were repeated every day for the first week and once a week in the following stages. The data obtained were evaluated in the SPSS Statistics 28 program.

Table 5. Measurement information

Schedule	0., 24., 48., 72., 96., 120. hours and 7.,14.,21. and 28. days
Measuring time	13.00-14.15
Measured Parameters	Temperature, Humidity, VOCs
Measurement Frequency	3 times in 15 minutes
Measurement Site	3 point
Measuring Device 1	Extech CO250 (CO_2,Temperature and Humidity meter)
Measuring Device 2	Extech VFM 200 (TVOCs meter)

Results

As can be seen in Table 6, when the measurements made in the field are evaluated, the control measurement TVOCs value was determined as 1.61 ppm. Immediately after the laminate flooring installation, the TVOCs value was measured at 2.54 ppm. In this context, it is seen that the installation of laminate parquet flooring increases the concentration of TVOCs in the space by approximately 1 ppm. This increase amount is equivalent to the minimum threshold limit value recommended by EPA indoors. The amount of emission, which showed a decreasing acceleration with each subsequent measurement, showed a sharp decline in the first 2 days, and decreased stably in following measurements (Figure 3). Studies have also indicated that laminate parquet flooring has a decreasing VOCs emission after its installation (Kim *et al.,* 2012; An Yoon *et al.,* 2011). Emission value in the space remained above 2 ppm for 5 days. This value range is stated by the EPA / 600 / P-97001F standards as the stage where discomfort such as irritation and burning in the eyes, respiratory tract, difficulty in breathing, sleep, sneezing, skin allergic reactions, fatigue and headache may be observed (EPA, 1998). The concentration of TVOCs in the space decreased to an equal value only with the control measurement four weeks after the installation.

Table 6. Result of the measurements

Date	TVOCs (ppm)		Temperature (°C)		R. Humidity (%)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Control Measurement	1.61	0.014	10.2	0.353	78.1	0.777
0. hour	2.54	0.056	10.6	0.494	71.1	0.353
24. hour	2.23	0.028	9.8	0.141	77.5	0.212
48. hour	2.15	0.049	10.6	0.898	70.1	0.070
72. hour	2.07	0.021	11.6	0.494	70.0	0.494
96. hour	2.02	0.014	11.8	0.424	65.8	0.707
120. hour	1.91	0.070	12.3	0.494	64.1	0.353
7. day	1.83	0.035	11.7	0.636	67.2	0.353
14. day	1.76	0.014	3.5	0.070	71.4	0.070
21. day	1.71	0.007	5.7	0.212	66.3	0.353
28. day	1.50	0.007	7.7	0.353	73.9	0.212

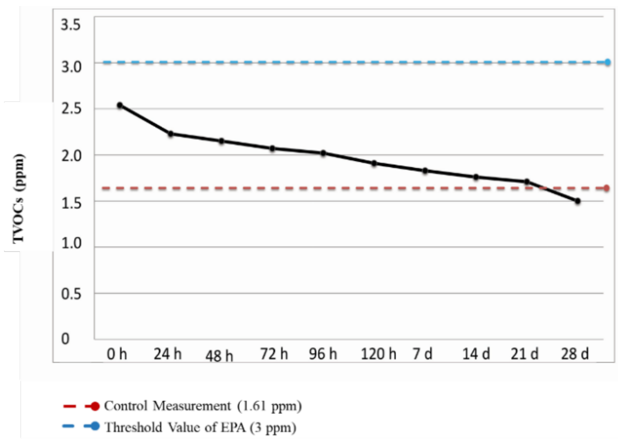

Figure 3. TVOCs values for laminate flooring during 28 days

Conclusion and Suggestions

Building materials, which are pollutant sources that affect indoor air quality, release a high amount of VOCs during their installation and these emissions continue to decrease over time.

The TVOCs values emitted by the laminate flooring material, which is preferred due to its intense use among floor covering materials and the chemical processes it undergoes, were determined in a 28-days from its installation. Accordingly, after the installation of the laminate flooring, it was determined that the concentration of TVOCs in the space increased by 0.93 ppm and reached 2.54 ppm. This concentration decreased below the control measurements at the end of 4 weeks. While increased concentrations of TVOCs in internal volumes cause symptoms such as headache, nausea and throat irritation at the initial level, higher amounts can cause respiratory tract infections and asthma attacks in humans (Fernandez-Agüera *et al.,* 2019; Mother-Maesano *et al*., 2013). Therefore, effective and long-term natural ventilation is considered important for the installation of laminate flooring, which releases a large amount of VOCs and to protect it from the effects that threaten human health. In this context, it can be recommended to reduce the amount of VOCs contained in laminate flooring by keeping it in open areas during storage or immediately after production. In addition, keeping the completed parquets in the facility storages may endanger the health of the warehouse employees. Therefore, the design of effective natural and mechanical ventilation methods in storage areas is also important. In addition, with measures such as the selection of building materials with low VOCs emission and furniture, the use of products that reduce the formaldehyde concentration in the environment with correct and sufficient ventilation (ISO 16000-23: Indoor Air - Dampening building materials) and performance tests to evaluate the reduction of formaldehyde concentrations, the indoor air quality can be increased. The choice of materials with the Environmental Product Declaration (EPD), which are documents verified by independent organizations, where the environmental impact data of the products and other related information, which are revealed as a result of LCA studies, are reported according to the ISO 14025 international standard, is also important in terms of low VOCs emissions.

At the other stage of the study, it is thought that making laminate flooring of different types in different climatic regions can reshape the laminate flooring production process and guide the producers, decision makers and users in material selection

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