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Influence of Wooden Flooring on Indoor Air Quality – A Case Study

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Abstract: The main objective of this paper was to investigate how new parquet flooring affected the indoor air quality (IAQ). The main reason to undertake this study was that the residents, especially children, started having breathing and asthmatic problems when they changed their old flooring with a new parquet flooring.

VOC and aldehydes emissions were measured both for the parquet flooring material and for the indoor air and were found to be remarkably high exceeding all the internationally recommended threshold limits. These high values were assumed to be perhaps the main reasons for health problems.

Based on these measurements, all the new parquet material was removed and changes in both VOC and aldehyde concentrations in indoor air were followed as a function of time. The results show that decrease of VOC and aldehyde concentrations were exceptionally slow under normal conditions and the decrease was not linear as a function of time and it almost reached a plateau after some time. Therefore, accelerated weathering conditions were investigated and reported to obtain safe concentration levels quickly. The main implication of this study is that although wooden flooring materials belong to renewable and sustainable group of materials, it is important to assure that such materials do not have any negative influence on IAQ and thereby may cause health problems.

1. Introduction

We breathe about 12 times per minute, this suggests that we breathe more than 10 m^3 or 12 kg of air every day. Since people spend more than 90% of their time indoors, most of the air that we inhale is indoor air. It has been reported that people spend, on average, more than 20 hours per day inside their apartments, which means that they will be exposed to chemicals more at home than at their workplace. According to Meyer *et al.* (1985) people are exposed to chemicals at least three times more at home than at work.

So far air quality at industrial workplaces is concerned, exposure guidelines and standards are very well defined. However, these values are only applicable for exposure levels during one working day, *i.e.*, 8 hours. In workplaces, these values are commonly referred to as “Threshold Limit Values” (TLV), “Occupational Exposure Limit values” (OEL) in the US, and “Maximale Arbeitsplatzkonzentration” (TAK) in Germany. Salthammer (1999), presented recommendations to apply similar limiting values for indoor air in non-industrial buildings, such as private houses and apartments. An interesting review on formaldehyde in indoor air has earlier been presented by Salthammer *et al.* (2010). A recent publication succinctly summarizes the possible sources for different types of Indoor Air Pollutants (IAP), including volatile organic compounds (VOC) and aldehydes, from 167 office buildings in 8 European countries (Spinazze *et. al.* (2019)). Bradman *et al* (2017) reported air quality from 40 early childhood education (ECE) facilities serving children < 6 years old in California (ECE) during the period 2010-2011. Formaldehyde and acetaldehyde were detected in 100% of samples. The median (max) indoor formaldehyde and acetaldehyde levels (μg/m3) were 17.8 (48.8) and 7.5 (23.3), respectively. The study showed that formaldehyde levels exceeded California 8-hour and chronic

Reference Exposure Levels (REL) (both 9 μg/m3) for non-cancer effects in 87.5% of facilities. Acetaldehyde levels exceeded the U.S. EPA Reference Concentration in 30% of facilities. The buildings and furnishings investigated were generally, >5 years old.

In literature, several recommendations have been reported for safe exposures, *e.g.*, exposure values should be 1/10th of the TLV values (American Society of Heating (1990), Levin (1998)), or 1/20th of the TAK values (Kunde (1982), VDI 2310), or 5% of TLV values (US EPA (1996)), or 1/40th of the OEL values (Levin (1998)). These recommended values are based on observations obtained from areas where most of the population did not complain about any health problems during major part of their residence. However, these values are not applicable for persons who are overly sensitive to irritating compounds.

Although people are exposed to three times more chemicals in private homes than at their workplaces, as discussed above, it is remarkable that there exist no exposure limits or regulations for chemicals in indoor air in private apartments. Nielsen *et al.* (1997) suggested that, in cases where safe exposure values are missing, it may be suitable to use 1/40th of the OEL values as the limiting value for indoor air. These values, for private housing and apartments, are mainly aimed to obtain a healthy indoor air quality (IAQ).

One of the major causes for affecting the indoor air quality (IAQ) is primary emissions from building materials, such as from floors, walls, roofings and insulation materials, besides paints and adhesives. In addition to these primary emissions, indoor air quality is also affected by the secondary emissions, which occur when building materials undergo further degradation under use. IAQ can also be influenced by further reactions of the chemicals present in indoor air from primary emissions by environmental factors such as presence of ozone or radicals generated from the electrical equipment's.

This suggests that to assure good indoor air quality (IAQ), it is important to determine the total concentration of volatile and semi-volatile organic compounds (VOC and SVOC)) in indoor air and their compositions. Most often, measurements of VOCs and SVOCs are not enough to assess the indoor air quality but it is important to determine the concentration of other chemicals also, such as polyaromatics, amines and aldehydes, in indoor air. This is because they are much more hazardous to health, creates odor and have relatively low threshold values, compared to the commonly occurring VOC and SVOC compounds.

Meyer *et al.* (1985) reported several cases where the presence of exceptionally low concentrations of aldehydes in indoor air, specially, formaldehyde arising from the Urea Formaldehyde (UF) adhesives, caused serious health problems in schools in Germany (Deimel (1978), Formaldehyde (1984)).

In parquet flooring there is a big risk for high emission of aldehydes in indoor air because adhesives based on urea-formaldehyde are mostly used. It has been reported earlier (Paul (1996)) that formaldehyde emission from such adhesives occurs due to three main reasons: 1) incomplete reactions between Urea (U) and Formaldehyde (F), 2) different molar ratios of U and F used during manufacture of these adhesives and 3) the amount of the adhesive (as weight-%) that is being used to bond wood. UF adhesives are mainly manufactured by an addition reaction between formaldehyde (F) and urea (U) first, which result into formation of different methylol derivatives of urea. These methylol derivatives are then subsequently cured at high temperatures e.g., 150-190°C to obtain high molecular weight cured adhesives. Final properties of UF adhesives depends mainly on the extent of polymerization and the molar ratio of urea and formaldehyde. Hun et al (2010) and Kelly et al (1999) reported that UF resins are significant contributor to the formation of aldehydes in indoor air.

Among aldehydes, formaldehyde, acetaldehyde and acrolein are of main health concerns. U.S. Environmental Protection Agency (EPA) listed both formaldehyde and acetaldehyde as probable human carcinogens (U.S. EPA, 2012b; U.S. EPA, 2012c). Exposure to these compounds has been associated with increased risk of pediatric asthma and respiratory symptoms, including decreased lung function, inflammation, and airway obstruction (Norbäck et al (1995), Wieslander et al (1997), Roda et al (2011), Hulin et al (2010)).

In this paper, we present results from a case study where we investigated IAQ in a villa where the residents started complaining about health problems relating breathing and asthmatic symptoms after they changed the old flooring with a new parquet flooring. The health problems for the infants became so serious that they had to visit emergency hospital several times. Since parquet floor commonly uses UF adhesives, we suspected that the reason for health problems may be due to presence volatile organic compounds and especially aldehydes. In this study, we shall present our measured values of VOC and aldehydes initially and how they changed because of several measures of accelerated weathering. It was interesting for us to investigate and follow up the Indoor Air Quality (IAQ) in the villa under different conditions and to find if the health problems could be correlated to the IAQ factors such as VOC and aldehyde contents in the indoor air.

2. Materials and Methods

To measure primary emissions from the parquet samples, we analyzed parquet samples from originally delivered material from the supplier and the material that has been used in the flooring for three years in the villa. The villa we investigated was a two-story old building and did not has any active ventilation, but instead some passive ventilation through old-fashioned ventilation openings in the windows. This study was performed during the summer period between June to September 2019.

Before we started our measurements, it was interesting to investigate how such flooring materials are certified. According to the technical data sheets from the supplier such materials are certified according two methods*:* 1) ISO16000-3:2011, for sample preparation and 2) ISO16000-3:2011 or EN717-1, for analysis of aldehydes. According to ISO 16000-3:2011 standard, emission samples were collected from the flooring materials, placed in a chamber with controlled relative humidity and temperature, whereby both the back and the edges of the sample was covered with aluminum foil and tape. This suggests that during sample preparation, the emission path was only restricted to the surface. However, in practice, the total amounts of freely available volatiles in the flooring material is more interesting to assess the influencet of such materials on IAQ.

Since we were interested in determining the total amount of primary emissions from the parquet flooring both with respect to VOC and aldehydes, we used a different method for sample collection than described in the ISO 16000-3:2011 standard. According to our method, we placed a pre-weighed flooring sample into a tightly sealed desiccator and collected the volatiles and aldehydes by evacuating the desiccator through a Tenax TA adsorbent tube using a rotary vacuum pump to 1 mm vacuum for 90 minutes.

For determination of VOC in indoor air, 10 liters of air sample were collected on Tenax TA sampling tube using an Air-Check pump from SKC calibrated to 1 l/min. VOC analysis from the Tenax tubes were performed by using Thermal Desorption (TD) followed by GC/MS according to ISO 16000-6:2011 standard. TD was performed in a TD unity instrument from Markes, Unity 2. The significant peaks of the chromatogram were identified using the mass spectra of specific compounds and comparing the results with NIST and our own libraries. The amounts of identified compounds were determined as μ_g toluene equivalents/m^3 for air samples and as ng/ gram for material samples.

For aldehyde measurements, 80 liters of air sample was passed through the LpDNPH S10 adsorbent cartridge using SKC pump calibrated to 2 l/ min. Aldehyde analyses were performed according to ISO 16000-

3:2011/ EN 717-1 whereby the adsorbent cartridge was first eluted with acetonitrile followed by analysis of the eluant using HPLC/UV. Aldehyde compounds were identified and quantified in absolute values using aldehyde calibration standards. All amounts presented are expressed as ng/gram sample weight for the material samples and μ_g/m^3 for the air samples.

Sampling scheme

Flooring samples used for analysis were the original parquet samples from the supplier and used parquet material that was used in the villa for three years.

Air samples were collected for analysis of VOC and aldehydes according to following experimental scheme:

1. Air samples under normal living conditions in June.
2. Air samples after the villa was empty and closed for 3 weeks without any extra ventilation in July during vacation.
3. Air samples after the parquet was removed and the house was ventilated for one week by opening the doors and windows for long periods in mid-August. It is important to make a remark here that during sampling, it was quite warm, and the outdoor temperature was exceeding 30°C during the daytime. The air samples were taking on both floors where the parquet floor was removed. Since the infant had severe health problems, we specially performed measurements close to the infant´s room.
4. Air samples, one week after ambient temperature of both the floors of the villa was raised to about 40°C by using heated air blowers. During this period both the floors were ventilated at least a few times per day by opening all the windows and doors to obtain a cross ventilation. Many of the windows were left open in the night during this period.
5. Air samples after 3 weeks of accelerated weathering after the humidity was raised to 70-80 % keeping high ambient temperature.

3. Results and Discussions

VOC studies

TVOC results from the parquet floor samples from a new batch and floor that has been used for 3 years under regular conditions are summarized in table 1 below, where only three major peaks were identified and quantified.

Table 1: Primary VOC emissions from the parquet flooring material

Sample	**TVOC ng toluene equivalent/ g**	**Identification and quantification of the main components in ng toluene equivalent/ g**
From original packing	587.6	Toluene: **84.2**; 1,4-dioxane: **57.7**; 4,4,6-trimethyl-bicyclo [3,1,1] hept-3-en-2-one: **21.7**
After 3 years of use	55.3	2,2,4-trimethyl-1,3-pentanediol diisobutyrate: **5.2**; hexanal: **3.7**; β-pinene:2.5

The results show that the new batch contained exceedingly high amounts of TVOC per gram material. It was interesting to note here that TVOC value decreased substantially, by approximately 10 times, after 3 years of use. We also found a change in the chemical composition of the volatiles. These changes may be expected due to the reactions with other chemicals and ozone, as has been reported earlier (Spinazzè A et al (2019)).

We also measured free aldehyde contents for the new batch and for 3 years used materials. The results are summarized in table 2.

Table 2: Total aldehyde emissions from the parquet flooring

Aldehyde types	Original package (ng/g)	After 3 years of use (ng/g)
Formaldehyde	583.17	266.18
Acetaldehyde	-	5.50
Valeraldehyde	-	2.29
Benzaldehyde	-	-
Hexaldehyde	45.78	11.03
2-butanone	-	3.22

The results show that the formaldehyde concentration decreased to half after 3 years of use, and we could identify small amounts of new types of aldehydes that were not present initially in the original parquet sample. This suggests that aldehydes initially present in the material may have undergone further reactions during use and exposure, as has been proposed earlier (Spinazzè A et al (2019)).

To investigate the influence of parquet on the IAQ, we measured VOC and aldehyde concentrations in the indoor air. We analyzed air samples according to our experimental scheme from the living room on the ground floor and near the infant's room on the 2nd floor as described above. In our measurements we determined the Total Volatile Organic Contents (TVOC) and identified and quantified 7-8 major compounds present in the air samples as toluene equivalents. The main aim of these identifications and quantifications were to investigate changes in the chemical composition because of removing the parquet flooring, and changes in IAQ due to accelerated weathering measures. VOC results near the infant's room are summarized in table 3 below:

Table 3: VOC in the Indoor Air near the infant's room, 2nd floor under different conditions

Sample nomenclature	**TVOC (µg tol.ekv/m^3)**	**Concentration of main components (µg tol.ekv/m^3)**
Under normal living conditions	192	limonene: **14,02**; α –pinene: **12,02**; nonanal: **10,45**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **8,46**; hexanal: **7,70**; β-pinene: **10,13**; ethylacetate: **5,09**; 2-phenoxyethanol: **0,96**
House was closed for 3 weeks during holidays	267	2,2,3,4-tertramethyhex-5-en-3-ol: **21,54**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **15,16**; xylene: **14,12**; α –pinene: **13,00**; nonanal: **7,60**; limonene: **3,56**; 2-phenoxyethanol: **0,32**
After removal of parquet on the 2nd floor, and after 7 days of normal ventilation*	1195	toluene: **233,3**; heptane: **183,6**; hexanal: **64,0**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **45,05**; 1-ethyl-1-methyl cyclopentane: **42,08**; α –pinene: **41,43**; 3-methyl hexane: **38,76;** dioxane: **32,51;** nonanal**: 31,26**; 2-phenoxyethanol: **1,19**
Duplicate sample from the 2nd floor in nearby vicinity, as sample above after 8 days of normal ventilation	1009	toluene: **187,3**; heptane: **128,0**; hexanal: **53,0**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **47,07**; nonanal: **35,29**; 3-methyl hexane: **27,77**; 1-ethyl-1-methyl cyclopentane: **26,62**; dioxane: **23,15**; β-pinene: **22,52;** 2-phenoxyethanol: **0,90**
After 15 days of ventilation: 7 days normal ventilation and 8 days of blow heating**	446	hexanal: **29,45**; propanoic acid, 2-methyl,2-ethyl-1-propyl-1,3-propanediyl ester: **23,76**; α –pinene: **23,43**; β-pinene: **22,96**; nonanal: **22,07**; ethylacetate: **10,94**; toluene: **4,56**; 2-phenoxyethanol: **0,93**
After 30 days of ventilation: 7 days normal ventilation and 8 days of blow heating followed by 15 days of blow heating at high humidity***	145,13	propanoic acid, 2-methyl,2-ethyl-1-propyl-1,3-propanediyl ester **11,74**; nonanal: **8,36**; 2-pyrrolidinone,1-methyl: **8,00**; xylene: **5,55**; hexanal: **3,49**; benzaldehyde: **1,84**; 2-phenoxyethanol: **0,24**

***ventilation by opening doors and windows a few times per day**

****Blow heater at ambient temperature of 35-40°C**

*****Blow heater at ambient temperature of 35-40°C and RH at 60-70%**

Table 3 shows relatively high TVOC level on the 2nd floor under normal living conditions. When the villa was empty and closed for 3 weeks during the holidays, TVOC level increased substantially, with some changes in the chemical composition of the dominating compounds. This suggested that passive ventilation under living conditions may be the reason for lower TVOC values compared to when the villa was totally closed. It was amazing to observe that the TVOC values were so high when the villa was closed, and the parquet was used for 3 years.

Since we decided to remove the parquet due to remarkably high primary emissions from the parquet and high values of TVOC and aldehyde contents in the indoor air, it was of interest to investigate how the removal of parquet affected the IAQ. It was amazing to find that TVOC levels increased by 5 times when the parquet was removed and showed the presence of several new compounds. It was important to add here that the person who removed the flooring became dizzy and sick. This suggest that the emissions from the parquet might have accumulated under the flooring because they could not diffuse out through the barrier flooring material. The subsequent measurements show how TVOC values improved after removal of the flooring and after ventilating

2nd floor. The measured values showed that the rate of TVOC decrease was slow when only normal ventilation conditions was used, *i.e.*, only ventilation of 2nd floor by opening the doors and windows several times per day.

To confirm our findings, we repeated the measurements after one day, and we found that both the TVOC values and the composition were reproducible.

When forced ventilation was used, and the ambient temperature was raised to 35-45°C, the rate of TVOC decrease increased substantially. As shown in table 3 above the values reduced to half after 8 days of forced ventilation at elevated temperature.

Since formaldehyde is known to react with moisture forming glycols, which are not hazardous and could deposit as condensate on the surfaces, we used the accelerated weathering conditions by raising both the temperature and the relative humidity of the indoor climate. High temperature was used to accelerate the diffusion of volatiles and high humidity was used to convert aldehydes, especially formaldehyde to alcohols and glycols. Since alcohols and glycols are less reactive and have high boiling points, they are expected to deposit on the room surfaces thereby reducing the formaldehyde concentration in the indoor air. To confirm this hypothesis, we investigated how VOC and aldehydes changed because of such accelerated weathering conditions.

Therefore, in our next step, we raised the relative humidity to 60-70%, and kept the ambient temperature high for 15 days and measured the changes in TVOC and aldehyde concentrations. The results show that TVOC level decreased remarkably after this treatment, which was relatively slow under normal humidity. We found that TVOC values also started to reach the normal levels, although it was still on the higher end of the acceptable spectrum. We also found that the chemical composition changed particularly, contents of aromatic compounds decreased substantially.

Table 4 below summarizes results from the living-room on the ground floor *i.e.*, TVOC under normal living conditions, TVOC after removal of the parquet and finally TVOC after normal and forced ventilation conditions, as performed for the 2nd floor. The results show a similar behavior as for the 2nd floor. It was interesting to note that TVOC values in the living room were somewhat lower than the 2nd floor as shown in table 3. The chemical composition was also found to differ. This may be explained by the differences in the vapor pressures where the chemical compounds with lower density may move upward resulting into an increase in TVOC values on the 2nd floor.

Table 4: VOC in Indoor Air near the living room, ground floor, under different conditions

Sample nomenclature	TVOC (μg tol.ekv/m^3)	Concentration of main components (μg tol.ekv/m^3)
Under normal living conditions	208,3	limonene: **22,7**; 2-phenoxyethanol: **9,94**; xylene: **9,28**; nonanal: **9,06;** α –pinene: **8,10**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **7,98**; hexanal: **6,80**; β-pinene: **6,80;** ethylacetate: **2,70**
After removal of parquet from the ground floor and after 7 days of normal ventilation	668,1	toluene: **128,6**; heptane: **59,6**; propanoic acid, 2-methyl-2-ethyl-1-propyl-1,3-propanediyl ester: **24,4**; hexanal: **21.87**; β-pinene: **14,73;** 3-methyl hexane: **13,92**; 1-ethyl-1-methyl cyclopentane: **13,53**; α –pinene: **12,22;** 2-phenoxyethanol**: 1,35**
After 15 days of ventilation. 7 days normal ventilation and 8 days of blow heating	407	hexanal: **27,50**; α –pinene: **20,40;** β-pinene: **19,77**; propanoic acid, 2-methyl,2-ethyl-1-propyl-1,3-propanediyl ester: **17,30**; nonanal: **11,08**; ethylacetate: **7,44**; toluene: **4,73**; 2-phenoxyethanol: **0,99**
After 30 days of ventilation: 7 days normal ventilation and 8 days of blow heatingfollowed by 15 days of of blow heating at high humidity	121,99	nonanal: **8,43**; propanoic acid, 2-methyl,2-ethyl-1-propyl-1,3-propanediyl ester: **4,53**; hexanal **3,88**; benzaldehyde **1,59;** 2-phenoxyethanol: **0,21**

Aldehyde studies

We also measured aldehyde concentrations on the ground and 2nd floor under similar conditions as VOC. Table 5 summarizes the aldehyde values near the infant's room on the 2nd floor, and table 6 summarizes for the living-room on the ground floor.

Table 5: Aldehyde contents at the 2nd floor near infants' room

Aldehyde types	Aldehyde concentration, 2nd floor μg /m^3			
	Under normal living conditions	**After removal of parquet**	**After 7 days normal ventilation and 7 days forced ventilation**	**After 30 days of ventilation: 7 days normal ventilation and 8 days hot blowers followed by 15 days of hot blower at high humidity**
Formaldehyde	46,91	43,74	39,35	11,07
Acetaldehyde	20,10	32,44	19,99	2,20
Hexaldehyde	34,15	30,42	17,05	4,42
Benzaldehyde	7,56	5,48	4,48	-
Valeraldehyde	4,84	6,01	3,82	-
Metacrolein	3,49	2,94	1,09	-
2-butanone	-	-	-	-

Table 6: Aldehyde contents on the ground floor in the living-room

Aldehyde types	Aldehyde concentration in living room (µg /m^3)			
	Under normal living conditions	After removal of the parquet	After 7 days normal ventilation 7 days forced ventilation	After 30 days of ventilation: 7 days normal ventilation and 8 days hot blowers followed by 15 days of hot blower at high humidity
Formaldehyde	46,96	35,70	34,23	13,57
Acetaldehyde	17,88	16,07	16,98	2,18
Hexaldehyde	25,80	21,04	20,50	3,01
Benzaldehyde	5,74	3,08	2,23	-
Valeraldehyde	6,20	4,27	2,64	-
Metacrolein	6,49	2,68	1,91	-
2-butanone	2,10	0,69		-

It is remarkably interesting to note that the aldehyde levels are exceedingly high under normal living conditions. Formaldehyde concentrations were extremely high compared to the recommended levels described earlier, and the formaldehyde concentration were almost similar for both the floors. We could also identify other aldehydes, such as acetaldehyde and methacrolein, among others. Interestingly, the methacrolein level was almost double on the 2nd floor compared to the ground floor. The changes in the aldehyde concentrations and compositions are also summarized in the table because of forced weathering.

As shown in the table, we obtained exceedingly high decay rates of aldehydes after we raised the relative humidity at elevated ambient temperature. The results show that after 30 days of accelerated weathering conditions i.e., using weathering under elevated temperature and high humidity, the aldehyde concentrations started to decrease substantially and approached safe levels (REL) as described earlier.

Overview of all the measured values on TVOC and aldehydes are illustrated in figures 1-3 below:

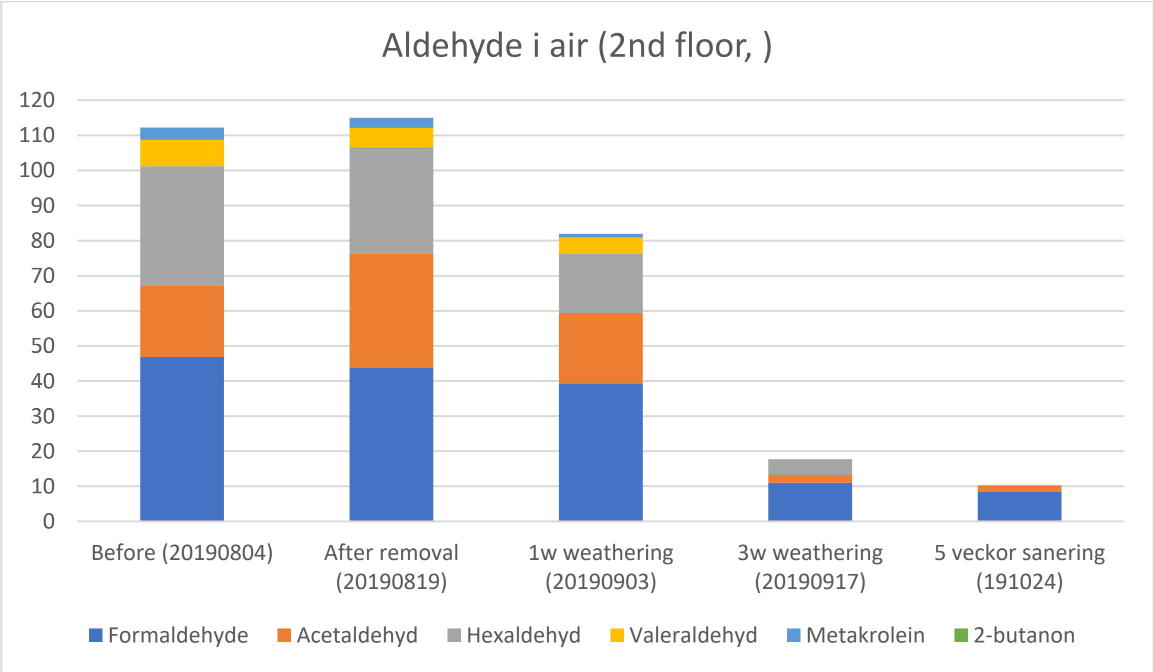

Figure 1: Aldehyde in air samples from 2nd floor near infant's room. Measured data are presented in table 5.

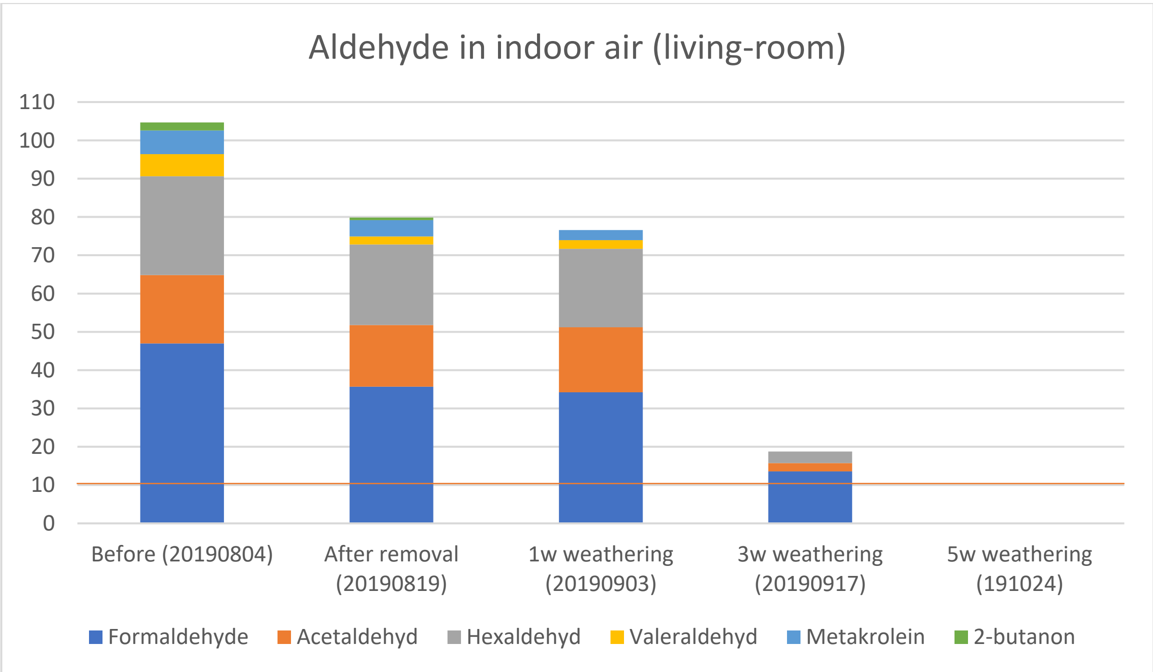

Figure 2: Aldehyde in air samples from living-room. Measured data are presented in table 6.

In figure 2 the orange line shows the recommended REL values for formaldehyde in indoor air.

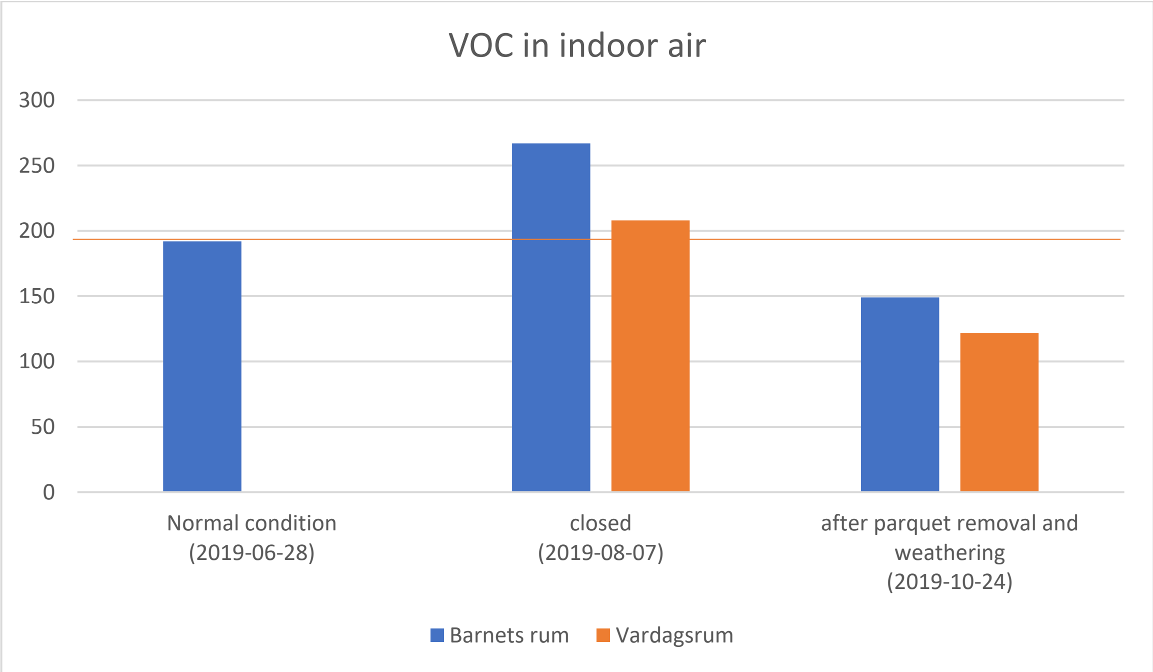

Figure 3: TVOC in air at the 2nd floor near infant´s room and living room according to data in tables 3 and 4.

In figure 3, the orange line shows the internationally recommended limiting values.

This study confirms our hypothesis that aldehyde concentration could be remarkably reduced of by reacting aldehydes with moisture at elevated temperature. The elevated temperature may also favor and accelerate such reactions resulting into relatively quick decay of hazardous aldehyde concentrations. The study presents a novel method that can be used to reduce aldehyde concentration in indoor air if it is required.

It is important to point out here that due to severe IAQ problems during this investigation, the family could not live in the villa. After we reached the safe levels, the family could move back, and we could follow up the health problems for the family. It became evident that family did not experience any health problems after removing the parquet and taking all these the elimination measures to reduce the formaldehyde concentration to safe levels.

The study shows that diffusion of aldehydes from the flooring material is not a simple diffusion process because of the interaction of aldehydes with the wooden materials. Therefore, it is extremely difficult to predict ventilation conditions to reduce or eliminate aldehydes using normal diffusion principles such as Fick´s or Henry´s laws. This study further reveals that accelerated weathering conditions were necessary to accelerate the reduction process of aldehydes to safe levels under a reasonable time.

4. Conclusions

The study shows that the main reason for the health problems in the residence was due to remarkably high concentrations of VOC and aldehyde and especially formaldehyde. Our measurements showed that parquet material may be the reason for such high emission levels. As soon as the flooring materials were removed the TVOC increased to a great extent initially. The study shows that normal weathering conditions did not help to reduce the concentrations but instead it was necessary to use special weathering conditions to reduce the concentrations to safe levels according to international recommendations in a practically reasonable time.

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