Linoleum floors—properties, maintenance and effects on indoor air quality—maintenance with floor polish—powdering problems and VOC emissions

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ABSTRACT

Linoleum floors are widely used in the Scandinavian countries. Powdering is a degradation of the floor surface that can occur when linoleum floors are maintained with acrylic-based floor polishes. The degradation generates large amounts of dust, which may affect the indoor environment. The paper discusses the extent of the problem and possible causes. Measuring methods for documentation of a powdering-problem and results from measurements in problem buildings are presented. VOC measurements were performed in laboratory and in an office building before and after maintenance of floors with acrylic-based polish. The main component emitted from the floors after treatment with polish systems was 2-(2-ethoxy-ethoxy-ethanol). Measurements revealed moderately high concentrations of TVOC (1050 $\mu g/m^3$ measured as toluene equivalents) 12 h after stripping and re-coating. The TVOC-concentration had decreased below the old background-level 12 days after maintenance. Possible effects of powdering and use of floor polish on indoor air quality are discussed.

INDEX TERMS

Linoleum floors; Maintenance; Polish; Dust generation; VOC emission

INTRODUCTION

Linoleum floors are widely used in the Scandinavian countries, and cover approximately 10–20% of the floorings market. It can be used as flooring in all dry environments with low to moderate traffic. Linoleum consists of a binder made from oxidized linseed oil and resin (30–40%), fillers made from stone dust and wood dust (60–70%), and a carrier web made from jute. The surface is normally treated with an acrylic-based coating at the factory, which is later maintained during cleaning operations with either acrylic-based floor polish systems or wax-based systems. Incorrect cleaning and maintenance of floors may affect the indoor air quality (Bakke *et al.*, 2002; Bjørseth *et al.*, 2002). Powdering is a degradation of the floor surface that can occur when linoleum floors are maintained with acrylic-based floor polishes (Selin, 1995). The problem occurs mainly in the winter season, and can have many causes. The degradation generates large amounts of dust, which may affect the indoor environment (Malmberg and Flodin, 1995; Nyman, 1995) and bring about large increases in cleaning costs (Franzén, 1995). This study was initialized by the Norwegian Defence Estates Agency after having experienced problems with powdering of floor polish on linoleum floors in the northern part of Norway. The aim of the study was to elucidate the occurrence and causes of powdering, measure air quality during scrubbing and application of polish on linoleum floors, measure the degree of dust generation in buildings with powdering problems and develop new guidelines for maintenance and use of linoleum floors. Guidelines are given elsewhere (Dahl *et al.*, 2003). The results from the study have been supplemented with results from other buildings examined by the same group.

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METHODS

Literature studies were conducted in order to reveal the history and extent of powdering problems and their possible causes. In addition, different measurements were performed in problem buildings.

Dust on surfaces (floors, furniture) was measured before cleaning by using a laser extinction meter and gelatinous foils (Schneider *et al.*, 1996), as described in the inter-Nordic standard NS INSTA 800 (Norwegian Standards Association, 2000; Nilsen *et al.*, 2000).

Airborne particles (1.5 m above the floor) were measured with a particle counter (Met-One/Grimm) measuring total concentration of particles having a diameter $d > 0.5$ μm and the proportion of non-respirable particles with $d > 3.0$ μm.

Airborne particles (1.5 m above the floor) for examination of the composition of airborne dust were collected using a pump and a filter (Millipore RA 1.2 μm).

Dust from surfaces and air were examined under a light-microscope.

The hardness of floor polish was examined using a pencil-hardness test (Erichsen model 291). Temperature and relative humidity were measured using a psychrometer (Psychro-Dyne Model No 3312-40).

Laboratory tests for VOC emissions were carried out using a climatic chamber (Climpaq, 23°C/50% RH), sampling on adsorption test tubes (Tenax and Sep-Pak Cartridge/DNPH-silica), and analysis by ATD/GC-MS (Tenax) and HPLC (Sep-Pak). Two different polish systems consisting of primer/sealer, polish and restorer were applied on linoleum and tested. Samples were collected after 1 day conditioning (untreated linoleum), 1 day after application of two coats of primer on linoleum, 1 day after application of two coats of polish on primed linoleum, 1 day after application of one coat of restorer on primed and polished linoleum, and 1 week after application of one coat of restorer on primed and polished linoleum. Total test period was 10 days.

Field measurements of VOC before and after scrubbing and application of a polish system were carried out in an office building by sampling on adsorption tubes (Tenax) and analysis by ATD/GC-MS. Samples were collected before, 12 h after and 12 days after maintenance of the floor.

RESULTS

Literature studies revealed that powdering problems were registered for the first time in the early 1960s in connection with introduction of polymer-based floor polishes. Powdering occurs almost exclusively on linoleum floors (97–99%), most frequently in Norway and Sweden, more frequently in the northern than in the southern parts of the countries, and more frequently in the winter season than in the summer season, with a peak in January. Approximately 1–5% of all linoleum floors have powdering problems per year.

Powdering can have many causes and combinations of causes. The most frequently listed causes are:

- Use of too hard polish not adapted to the factory coating.
- Migration of polish plasticizer to linoleum and indoor air.
- Unfavourable climatic condition during application (draught, low RH, high/low T).
- Alkaline humidity from underlying floor.
- Too short drying time after scrubbing.
- Unfavourable cleaning and maintenance systems (dry buffing, too low cleaning frequencies).

Results from measurements of airborne particles, dust on surfaces and polish hardness can be seen in Table 1. Relative humidity varied from 24 to 41%, and temperature range was 20–

22.5°C in the buildings during the measurements. Particles from floor polish were found in samples of airborne dust and dust from furniture in one (building 6, large open landscape office) of the four buildings where dust was analysed.

Table 1 Results from measurements in eight buildings

Building	Pencil hardness	Airborne particles/ft^3		% Dust coverage	
		>0.5 µm	>3 µm	Furniture	Floor
1	B (–1)	30 000	900	6.2	3.1
2	3H (3)	26 000	750	2	29
3	H (1)	34 000	1135		4.6
4	2H (2)	20 500	1000		8.1
5	2H (2)	11 000	600	3.6	11
6	2B–3B (2.5)			2.4	7.1
7a	HB (0)				3.3
7b	HB (0)	28 400	750		4.3
7c	HB (0)				3.7
8	5B (–5) (flake off)				25

Table 2 Results from VOCs measured in climatic chamber. Linoleum without and with polish systems. TVOC and dominating components are given as toluene-equivalents in µg/m³

	TVOC	Aldehydes/ ketones	Formaldehyde	1-methyl-2-pyrrolidinone	Hexanoic acid	2-(2-ethoxyethoxy)-ethanol	2-(2-propoxyethoxy)-ethanol	1-(2-methoxypropoxy)-2-propanol
System 1								
Linoleum	96			10	8			
+ Primer	126	10.3	0	3		66		
+ Polish	425	5.4	0.5	9	12	306		
+ Restorer	145			5	7	45		
Restorer + 1 week	211			8	13	50		
System 2								
Linoleum	91			9	7			
+ Primer	537	10.8	0			142		48
+ Polish	919	3,3	0.7	40		545	53	21
+ Restorer	220			14	5	60		
Restorer + 1 week	457			24	16	142		

Table 2 shows results from laboratory tests for VOC emissions from polish systems. Figure 1 shows TVOC-concentrations before and after scrubbing and application of a polish system in an office building. Main components were 2-(2-ethoxyethoxy)-ethanol and 1-(2-methoxy-propoxy)-2-propanol.

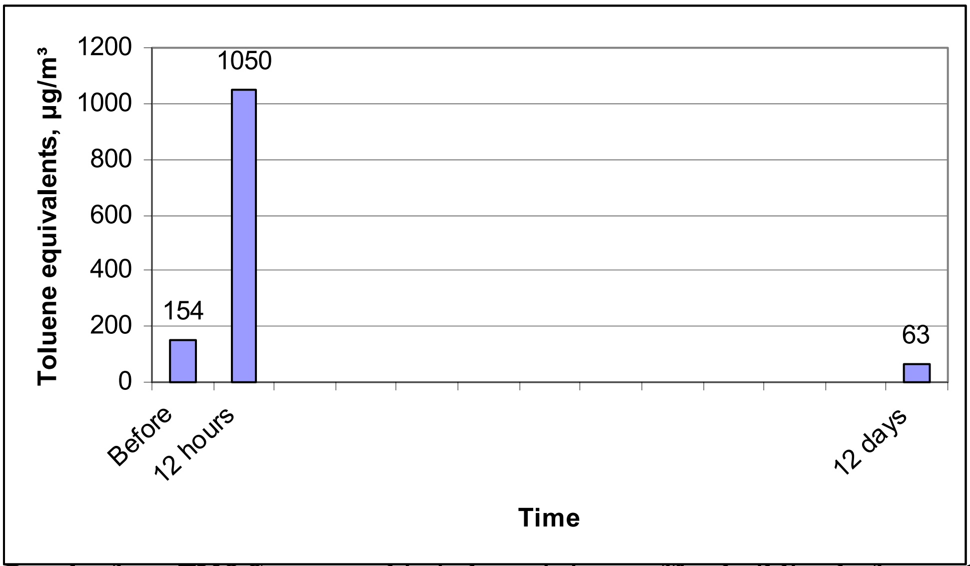

Figure 1 Results from TVOC measured in indoor air in an office building before and after scrubbing and application of a polish system. TVOC are given as toluene-equivalents in µg/m^3.

DISCUSSION

Dust coverage on floors before cleaning were well below the requirements for dust level 3 and close to dust level 4 according to NS INSTA 800 (Norwegian Standards Association, 2000) in three of the buildings (building 1, 3 and 7). Dust level 4 is the second best level in the standard, and is recommended in buildings where low levels of dust and good indoor air quality is desired (Schneider *et al.*, 1994; Nilsen *et al.*, 2000). The degree of powdering was very low or not existent in these buildings. On the other hand, two of the buildings showed higher dust levels for floors than those defined in NS INSTA 800, meaning that the degree of powdering was very high. In one of the buildings with high floor dust levels (building 8) the polish flaked off at very low pencil hardness, showing that the powdering was caused by lack of adhesion between the polish system and the linoleum surface (flake off). Other studies (Nyman, 1995) conclude that there is no correlation between occurrence of powdering and the adhesion of the polish system to the linoleum surface. The powdering seems in many cases to start with abrasion of the polish surface. Research carried out by a large producer of polish systems (SC Johnson Wax, 1996) concludes that the main reason for powdering is migration of the plasticizer into the linoleum, making the polish surface harder and less wear resistant. Other studies (Bjørseth *et al.*, 2002) have revealed that dry buffing of the polish surface increases the surface temperature up to 100° C in local spots. This is a widely used method for regular maintenance of polished floors, and the high temperatures involved may also contribute to loss of plasticizer, making the surface harder. Figure 2 shows results from measurements of pencil hardness of the polish surfaces and the amount of dust on the floor. There is a good correlation between the two factors ($r_{-} = 0.999$, $r_{+} = 0{,}729$). Degree of powdering increases with increasing hardness due to abrasion. In the low end of pencil hardness the powdering is mainly caused by flake off due to low adhesion of the polish system to the linoleum surface.

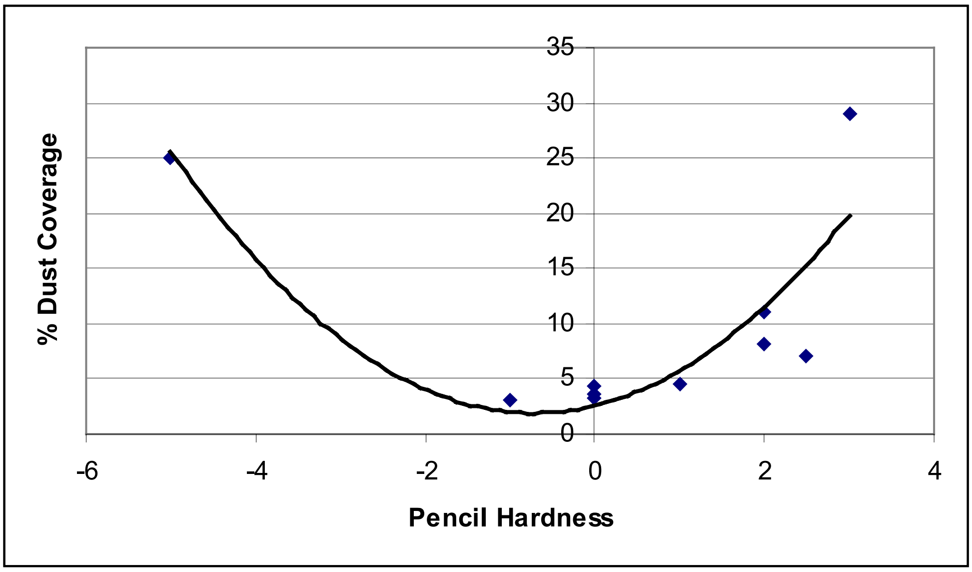

Figure 2 Dust coverage on floors and pencil hardness of the polish system. Polynom trend line is added (Excel).

Airborne particles were low to normal in all the six buildings measured, and no correlation between airborne particles and degree of powdering (dust coverage on floors) was found. Analysis of dust on furniture and air in air samples revealed low tendency for contamination with dust from floor polish, although polish dust were found on furniture and in air samples from one building with a long history of powdering problems. In another study (Nyman, 1995) polish dust were found in samples from exhaust filters in the ventilation system, showing that dust from floor polish powdering does contaminate the indoor air in some extent.

Climatic chamber tests for VOCs revealed TVOC levels below the limit of 400 μg/m^3 recommended by Norwegian health authorities (Folkehelsa, 1998) for one of the polish systems on linoleum. The polish (top coat) was the product giving the highest TVOC level in both systems. Measurements of VOCs after scrubbing and polish application showed TVOC levels approximately three times the recommended level 12 h after maintenance, decreasing to background level after 12 days. No sampling was carried out in the period between 12 h and 12 days. Other studies (Bakke *et al.*, 2002) have showed high levels of TVOC during the application process, decreasing to negligible levels soon afterwards. TVOC-levels decreased faster during field measurements than during laboratory measurements in a climatic chamber. The main component was 2-(2-ethoxyethoxy)-ethanol, with maximum level of 545 μg/m^3 in the climatic chamber test and 634 μg/m^3 in field measurements. This is well below 6000 μg/m^3, which is the level recommended for indoor air in order to avoid negative health effects (Nielsen *et al.*, 1998).

CONCLUSIONS

Powdering is a degradation of the floor surface that can occur when linoleum floors are maintained with acrylic based floor polishes. The problem occurs on 1–5% of all linoleum floors a year and is more abundant in the winter season. Powdering commences mainly as a result of abrasion of the surface of the polish systems. Lack of adhesion between the polish system and the linoleum surface may also cause powdering (flake off).

Powdering generates large amounts of dust on the floor, which may be transferred to the indoor air and furniture surfaces in some office environments. Measures should be taken in order to avoid such problems, see guidelines given elsewhere (Dahl *et al.*, 2003).

The degree of powdering is related to surface hardness of the polish, and high surface hardness increases the risk of having powdering problems. Measurements and analysis of dust on surfaces, and measurements of the hardness of the polish surface can be used in order to ascertain powdering problems.

Normal use of polish systems on linoleum floors has a low influence on the indoor air quality.

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