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Formaldehyde Release Characteristics from a Swedish Floor Finish

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A large number of consumer products have been identified as formaldehyde sources (Nizami; 1981, Spengler 1983). Many of these products are commonly used in the living environment and consequently are a source of air pollution. Of these sources it appears that urea formaldehyde foam insulation (UFFI) and particle board used in the construction of homes as well as furniture appear to be the most important sources of this gas (Pickrell et al. 1984; van Netten 1983). Exposure to formaldehyde gas has been linked to a variety of disorders and ailments (Spengler 1983). These include eye irritation (Spengler and Sexton 1983; Bender et al. 1983) tightness of the chest, lethargy, nasal congestion and headaches as well as possible neurological problems at levels of 1 ppm. Animal experiments indicate an increased incidence in nasal carcinoma in rats after long term exposure to high concentrations (15 ppm) (Swenberg et al. 1980). A 26 week inhalation study in monkeys, rats and hamsters indicate a distinct effect after nearly continuous exposure to 2.95 ppm (Swenberg et al. 1980). Exposure to lower concentrations did not show any effects. Because of the ill effects experienced by occupants of houses insulated with UFFI (Wiberg et al. 1981), many of these home owners have removed this material from the wall cavities in order to remedy the situation. One such family living in Vancouver, British Columbia, after experiencing the many influenza like symptoms when living in a UFFI insulated dwelling, decided to remove the material. Although the symptoms of the formaldehyde exposure disappeared after removal of the foam the family felt uncomfortable living in this dwelling where exposure to UFFI dust, generated by the removal activity, was still a potential hazard. The family decided to sell the house and move to one which was guaranteed not to be insulated with UFFI. No health problems were reported by the family during their stay in this new house until it was decided to refinish an upstairs wooden floor with a material which was apparently locally advertised as a natural Swedish oil floor finish known as "Glitsa". Co-incident with the finishing of the floor all the symptoms of the previous formaldehyde exposure returned to the family and it was decided that formaldehyde off-gassing measurements from the floor were warranted. In addition, the presence of other volatile organic compounds was also monitored using samples for GLC and GLC-mass spec analysis. In this article we would like to report on the off-gassing characteristics in three different dwellings with floors finished with this material at times varying from 3 month to 3.5 years ago.

MATERIALS AND METHODS

The formaldehyde release characteristics from the "Glitsa" finished floors were investigated by using the stainless steel dynamic testing chambers and procedures described before (van Netten 1983). The dimensions of the chamber were 63.5 x 63.65 x

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9.0 cm and corresponds to a total volume of 30.57 litres. A continuous flow of air from outside the building was maintained at a rate of 1 litre per minute through the chamber during all experiments. Control and test air samples were collected in the following order and under the following conditions. The chambers were either placed on top of a stainless steel plate (for the control samples) or on top of the "Glitsa" finished floor (for the experimental samples). After a fifteen minutes equilibration period at room temperature with the continuous air flow, as described above, a fifteen minutes air sample was collected using 20 mls. of a 0.1% aqueous sodium bisulfite solution in the impinger. After this period the chamber temperature was raised to 30° followed by another 15 minute equilibration period. Again a fifteen minute air sample was collected before the temperature was raised to 40°C. After an additional equilibration period, a final fifteen minute air sample was collected. The collection of air samples for the gas liquid chromatographic-mass spectral analysis was performed again using the chambers at the air flow rates described above. In this case the temperature of the chambers as maintained at 30°C throughout the period of time for sample collection which was two hours for the control and four hours for the experimental samples. Each sample was adsorbed onto a 30 centimeter Tenax column by placing the column between the exit port of the chamber and the vacuum pump. The Tenax columns were then purged and analyzed by a GLC mass spectrum arrangement. Formaldehyde determinations were made using the NIOSH chromotrophic acids method (NIOSH 1977). All analyses were performed within 24 hours after sample collection and atmospheric formaldehyde determinations were made by using the DuPont dosimeters. The dosimeters were placed in selected rooms within the building of interest for a period of one week after which the field blanks and its corresponding experimental samples were analyzed.

RESULTS AND DISCUSSION

The formaldehyde release from the floors finished with this material in the 3 dwellings under investigation is shown in Table 1. This information is also shown in graphical form in Figure 1. In addition the atmospheric formaldehyde levels, as measured by the DuPont dosimeters over the period of one week, are also shown in Table 1. Mass-Spec analyses of the air samples gathered from the chambers indicate the presence of the compounds identified in Table 2. Only the compounds which were found in the experimental samples but not in the controls are listed.

As indicated in Figure 1 the formaldehyde release over the temperature gradient shown is clearly dependent on the age of the floor finish. Although the youngest floor (Dwelling #1) was found to be the strongest source of formaldehyde, the oldest floor (Dwelling #3; hall) was still actively emitting formaldehyde at temperatures higher than 21°C. The formaldehyde measurements at room temperature (Figure 1) represent the formaldehyde release under near equilibrium or equilibrium conditions. If the room, where these measurements were taken, is completely closed up and left to equilibrate the formaldehyde concentration in that environment would be expected to climb up to the levels as measured with the chamber at room temperature. In a normal living situation, with the opening and closing of windows and doors and with an active circulating air heating and ventilation system, the atmospheric formaldehyde levels would not likely be close to, or identical to, the levels measured from the chambers at room temperature. This is clearly illustrated by the results obtained from the DuPont dosimeters which showed, in the bedroom of Dwelling #2, a formaldehyde level of .003 ppm in the environment whereas the floor was giving off .58 ppm at the same temperature. As only the 3rd story of this dwelling was finished with "Glitsa" and by

Table 1 Formaldehyde Measurements in ppm from chambers and atmosphere in 3 dwellings under the relative humidity and temperature conditions indicated.

	Chamber Measurements						Atmospheric Measurements	Presence and Age of Floor Finish
	ppm	%RH	ppm	%RH	ppm	%RH	ppm	month
Dwelling #1	**26°C**		**30°C**		**40°C**			
Control	.05	55	.04	50	.05	44	-	-
Bedroom	.58	76	.77	72	1.71	60	.033	2.5
Study	-	-	-	-	-	-	.008	-
Kitchen	-	-	-	-	-	-	.013	-
Dwelling #2	**25°C**		**30°C**		**40°C**			
Control	.03	68	.03	63	.03	50	-	-
Bedroom #1	.13	74	.23	68	.54	58	.046	4.5
Bedroom #2	-	-	-	-	-	-	.053	4.5
Living Room	-	-	-	-	-	-	.049	4.5
Dwelling #3	**21°C**		**30°C**		**40°C**			
Control	.05	56	.05	52	.05	44	-	-
Dining Room	.05	50	.08	52	.14	45	.035	25
Hall	.05	62	.06	52	.10	46	.022	49
Living Room	-	-	-	-	-	-	.029	49

Table 2 Volatile Hydrocarbons Detected by Mass-Spec Analysis of Air Samples Collected from above "Glitsa" Finished Floors of 4 Different Ages.

Dwelling #1, Bedroom (2.5 month)

freon
cyclohexane
Iso-butanol
benzene
5 carbon ketone
methyl cyclohexane
2,3,7-trimethy
tetrachloroethylene
2-Hexanone
toluene
xylenes

Dwelling #2 Bedroom (4., 5 month)

dichloromethane
1-fluoro,2-propane
2-methyl propane
4-methyl,3-pentene2-one
2,4-dimethyl pentanal
2-furancarboxaldehyde
methyl cyclopentanol
acetone
1-butanol
pentanal

Dwelling #3 Dining Room (25 months)

1-butanol
hexane
chloroform
benzene & trichloroethylene
1,2-dihydro-3-methyl-1,4-indene

Dwelling #3,Hall (49 months)

1-butanol
2-methyl butanol
2-methyl piperazine
1-ethyl-3-methyl benzene
3-(1,1-dimethylethyl) phenol
1-ethenyloxy decane.
1-methyl-4(1-methyl ethenyl cyclohexane)
octane
benzofuran
9-H fluorene
anthracene
phenanthrene

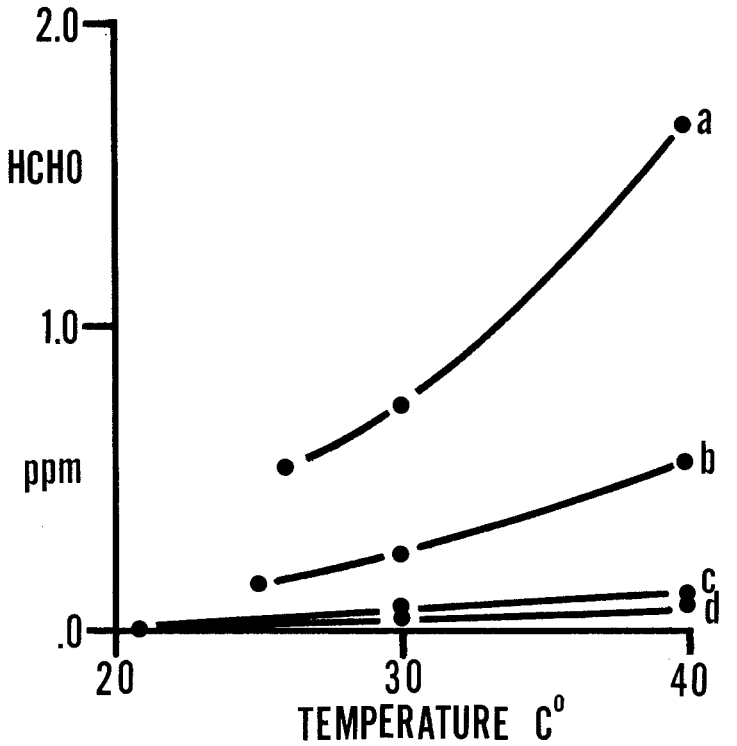

Figure 1. Formaldehyde release from 4 "Glitsa" finished floors of different ages: (a. 2.5 month; b. 4.5 month; c. 25 months; d. 49 months) and at the temperatures indicated.

including the basement, this means that only 1/4th of the house was finished with this material. As the cold air ventilation system was in use during the week of sample collection, a four fold dilution factor can be accounted for. If one further considers that these measurements were made in summer time, an additional dilution factor can be accounted for due to the uncontrolled high number of air exchanges that are part of summer indoor-outdoor living.

In dwelling #2, however, all the floors were "Glitsa" finished resulting in a dilution effect considerably less than what was observed in dwelling #1 (i.e. approximately 2 times compared to > 10 times). In dwelling #3 the room temperature formaldehyde levels, as measured by the chambers, were close to the atmospheric formaldehyde concentrations as can be expected from these, close to background, formaldehyde levels.

The 30°C and 40°C measurement of formaldehyde release, as shown in Figure 1, in contrast to the room temperature measurement, are not taken under equilibrium conditions. Unless the temperature in the whole dwelling is elevated to, and kept at these levels, equilibrium conditions cannot be expected. These measurements, however, are an indication of the formaldehyde release potential and tend to simulate a normal living environment where temperatures tend to fluctuate during the day when central heating is turned on or when solar radiation heats up certain sections of the floor. As noted in figure 1 the release potential decreases with the age of the floor varnish. It is interesting to note that even the older floors in dwelling #3 are still releasing formaldehyde at the maximum allowable level of .1 ppm, in the hall, or well above these levels in the dining room at a temperature of 40°C.

The presence of a large number of volatile organic components was confirmed in the air above the floors as collected by the chambers. The floors in dwelling #1 and 2 were relatively young and had not been washed since application. This is not true for the floors in Dwelling #3. Differences can, therefore, be expected. In addition the type of wear and tear associated with the traffic on the floor will have an effect and introduce a variety of external contaminants. This is best illustrated by the spectrum of volatiles that as measured above the oldest floor (hall, dwelling #3) where the high level of traffic from the outside would be expected to introduce a large array of volatile compounds. The much younger floor in the dining room of this dwelling, in contrast, indicated the presence of only a few volatiles.

Although prior to the measurements the floors are carefully wiped with high grade methanol followed by distilled water, the presence of local contaminants is minimized but is not excluded. An additional uncontrolled source of volatile components is the history of the floor and sub-floor. Although the newly finished "Glitsa" floor is sealed, a number of cracks and holes were always found to be present allowing free access of any volatile component within the floor to the space above it. The results shown in Table 1 should, therefore, be interpreted with caution and should be based on the consistent presence of certain volatile compounds rather than their occasional occurrence. As noted in Table 1, of all 4 floors investigated there is a consistent presence of butanol and, in addition, the two youngest floors confirmed the presence of of xylene. Consultation with the "Glitsa" manufacturer indicates that indeed butanol is the major solvent used in the process of application. Xylenes are used in minor amounts in the manufacturing process.

The results of this study indicate that the presence of "Glitsa" finished floors in a dwelling can be a very important and potent contributor to the atmospheric formaldehyde concentrations in the living environment. Even after close to 4 years of curing this floor finish still has not completely stabilized and still emits free formaldehyde at or above the recommended levels especially at elevated room temperatures. This incomplete stabilizations process is further substantiated by the consistent presence of butanol even in the oldest floor.

The manufacturer is presently reformulating this floor finish to improve on the off-gassing characteristics.

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