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CARPET, PAINT AND INDOOR AIR QUALITY

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Abstract

Indoor air quality was examined in a room following the application of latex paint, and again after the installation of carpeting (adhered with a solvent-based mastic). Tests for aromatic hydrocarbons were negative after the room was painted. Following carpet installation, substantial elevations in hydrocarbons were measured. These levels were readily reduced by ventilation. Without ventilation, concentration rapidly rose. A period of l-2 weeks was required for dissipation of the solvent to concentration levels equivalent to those attained with forced ventilation.

Introduction

Increasingly, health problems associated with indoor environments have been blamed on the quality of indoor air. It is well known that building materials and components, as well as products and practices introduced by building occupants, can contribute numerous potentially harmful compounds to the indoor environment. For many individuals, non-industrial exposures may be very important (Yocom, 1982; Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1987). This is because the duration of occupants' residential exposures is considerably longer than the eight-hour exposure assumed for workers. Furthermore, residential populations include the young, the elderly and others who might be especially susceptible to airborne pollutants. (Yocom, 1982; Federal-Provincial Advisory Committee on Environmental and Occupational Health, 1987).

It was the objective of this study to examine the impact on indoor air quality of two episodic activities that would temporarily degrade air quality: paint application and glued carpet installation. Furthermore, we wished to measure the time-decay behavior of these pollution spikes and the effect of ventilation changes on them. This information should be helpful in the management of such problems as householders develop and schedule ventilation strategies to reduce fumes and odors. Both of these products--paint and the adhesive--emit volatile organic compounds, which make up a very large category of low-boiling point chemicals. These have been implicated as a possible cause of sick building syndrome (SBS) (Girman, 1989; Levin, 1989; Molhave, 1985). Moreover, it is well known that volatile organic compounds are significant and widespread components of indoor air pollution (Wallace, Pellizzari, Sheldon, Hartwell, Sparacino and Zelon, 1986). Girman (1989) has suggested that low concentrations of volatile organics may act synergistically on human health. Floor covering adhesives, especially during and immediately after application, may be some of the most important sources of volatile organic compounds that can contribute to indoor air quality problems (Levin, 1990). Health effects attributed to volatile organic compounds range from sensory irritation (primarily affecting the eyes, nose and throat) to behavioral effects (leading to dizziness and loss of consciousness) and damage to the liver and nervous system (New Jersey Department of Health, 1987; U.S. Environmental Protection Agency, 1989).

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Methods

All measurements were taken in a second-floor room ("test room") of a wood-frame building. This structure, dating from the mid-nineteenth century, was originally a farm house and is currently used to house University offices. The building has not been subject to major structural modifications and retains most of its residential character. Significant improvements include aluminum siding, storm windows and an oil-fired water heating system. Principal dimensions of the test room are 14' 2" x 14' 3". The room has three windows with an air conditioner installed in one.

Air samples were tested for aromatic hydrocarbons (as a group, including benzene, toluene and xylene). These are likely to be components of mineral spirits, such as paint thinner which is a mixture of hydrocarbons distilled from petroleum and used as a solvent. The measurement technique was based on the use of colorimetric detector tubes using a hand operated, piston type sampling pump (Universal tester pump, Part No. 83499) and detector tubes manufactured by the Mine Safety Appliances Company. (In use, a measured volume of air is drawn through a capillary tube that is filled with an appropriate reagent. Development of a discoloration in the tube indicates the presence of one or more of the test substances; length of the stain is correlated with concentration of the test substance.) The upper end of the measurement range for benzene is 200 parts per million (ppm), and 800 ppm for toluene and xylene. According to the sampling device manufacturer's literature, expected errors are in the range of $\pm$ 25 percent, although other compounds in the environment can cause additional errors (negative or additive).

For the aromatic hydrocarbon test, interference may come from other aromatics, as well as aliphatic hydrocarbons. This methodology is commonly used to evaluate airborne levels of many hazardous substances in the workplace. While it lacks the specificity and the high level of precision of gas chromatography/spectrometry methods that are usually needed to evaluate low-level residential pollution, detector tube measurements have some distinct advantages. Measurements can be accomplished at once and do not require the use of laboratory facilities and equipment. Moreover, tests using the detector tube method are considerably less expensive than other tests.

Relative humidity was determined using a sling psychrometer or taken as reported by the campus-based weather station. Relative humidity was generally in the range of 80-90%. At this level, moisture causes a slight fading at the beginning of the stain in the tube but does not otherwise affect this measurement. Room temperature was always within a range of 70-85°F. Air samples were drawn and measured according to the manufacturer's instructions (as outlined above). Samples were tested prior to painting and carpet installation, and at intervals of one or more days afterwards until positive results were no longer obtained.

Because we did not have the capability of preparing air samples contaminated with known quantities of hydrocarbons, it was not possible to conduct quantitative verification of our measurement methodology. However, we did undertake a crude determination of this method's qualitative accuracy. This was accomplished by drawing an air sample with the detector tube inlet positioned at a known or expected source of the compounds of interest. Sampling at the mouth of a container of mineral spirits produced a response in the sampling tube for aromatic hydrocarbons that might be described as "off scale;" color change extended the entire length of the tube.

Samples of room air were drawn (with one exception) under closed-room conditions, i.e., door and windows closed. For the period immediately prior to sampling (usually 18 hours), the room was isolated from the rest of the building (door closed). The ventilation condition during this period was either "closed room" (door, windows closed) or "room ventilated" (door closed, windows open 3," air conditioner baffle in "vent" position, with the blower on). Air exchange rate for this room was not measured. Ordinarily, one would expect a relatively high rate of air exchange for such a structure during the heating season; however, due to the virtual absence of driving forces--indoor-outdoor temperature gradients and prolonged winds--(particularly in June, following carpet installation), we believe that, during "closed-room" conditions, ventilation of the room was quite low, and mixing with outdoor air was negligible.

The room was painted on April 11-12, 1989, using water-based paints. Walls and ceiling were painted with a vinyl acrylic latex flat paint; an acrylic latex semi-gloss enamel was applied to the trim. Windows were opened during painting. According to their labels, both these products have a volatile organic compound concentration below 2.08 lb/gal (or 250 gm/l.). A short nap, dense commercial carpet was installed on June 13, 1989. The main area of the carpet was laid with a mineral spirit-based mastic. Adhesion at the perimeter was accomplished with a solvent-based contact cement.

Results

Control Conditions. Tests for aromatic hydrocarbons conducted prior to painting or carpet installation were negative; none were present at the detection thresholds of this methodology.

Application of Paint. Testing on the morning following completion of the painting failed to reveal any aromatic hydrocarbons ("closed-room" condition). Doubling the volume of the air sample passed through the reactor tube also failed to reveal any aromatic hydrocarbons. A strong "paint aroma" was present, however.

Installation of Carpet. On the morning following carpet installation, closed-room conditions were associated with a strong odor and a discoloration in the reactor tube equivalent to 25 ppm of xylene (because the reaction in the detector tube is due to a mixture of compounds, concentrations will be expressed as equivalent xylene concentration. Reasons for this are presented in the discussion below). On the second morning following installation, with ventilation on overnight, no detectable levels of aromatic hydrocarbons were observed. On subsequent mornings when the room was closed overnight, the tests for aromatic hydrocarbons revealed levels of 25 ppm at three days, 3 ppm at eight days, and trace levels at 14 days.

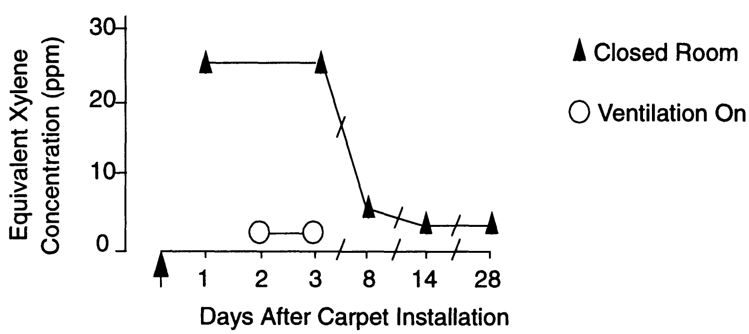

Figure 1. Time decay of organic vapors following carpet installation.

To examine the effects of short-term ventilation, an additional test was conducted on the afternoon of the third day following carpet installation. Closed-room conditions had been in effect the previous night; after six hours of ventilation that day, hydrocarbons were not detectable. Fourteen days following carpet installation, no aromatics were detected in the morning, following overnight, closed-room conditions. Doubling the volume of the air sample drawn through the detector tube revealed a trace amount of hydrocarbon. These results are summarized in Figure 1.

Discussion

This study, because of its narrow scope, has some obvious limitations. Testing was conducted in only one room, involving specific types of paint, carpet and adhesive. Measurement methodology was of limited specificity. This was of particular significance regarding the carpet adhesive. In a detailed analysis of such a product, 111 compounds were identified, including aromatic and aliphatic hydrocarbons (Wallace, Pellizzari, Leaderer, Zelon and Sheldon, 1987). Since the aromatic detector tubes were, according to the manufacturer, affected by some aliphatic hydrocarbons as well, measurements likely represent a mixture of these volatile organic compounds (VOCs).

Nevertheless, because Wallace et al. (1987) have identified xylenes as the most abundant aromatic components offgasing from a recently glued carpet sample, concentrations have been expressed in terms of this compound. Wallace et al. (1988) had earlier compared indoor and outdoor air quality in industrialized, urban and rural settings. They concluded that in all these locations, indoor sources were more important than outdoor sources of pollutants. Moreover, because its occurrence was so widespread, xylene was listed among a group of compounds designated as "ubiquitous chemicals" (Wallace et al., 1986). As indicated above, we have elected to report our measurements in terms of xylene, recognizing that the reaction in our detector tubes represents a spectrum of organic compounds. Installation of glued carpet would likely be an occasion for elevated concentration of this pollutant.

The findings in the present study represent a special situation, i.e., conditions immediately following the application of paint or the installation of carpeting. While it was not surprising that application of latex paint did not produce measurable levels of aromatic hydrocarbons (in spite of a strong "paint" smell), the consequences of ventilation after carpet installation provide potentially useful information. The next-day (closed room) xylene level of 25 ppm (equivalent to 108 milligrams per cubic meter, (mg/m^3)) represents a fairly high concentration. The permissible exposure limit for this compound in the workplace is 435 mg/m^3 (U.S. Department of Health, Education and Welfare, 1978.) Wallace et al. (1987) attempted to characterize the emission rates of various VOCs from building products placed in a test chamber ventilated at 0.6 air changes per hour. One week after installation, their glued carpet sample produced a total xylene concentration of 21.5 micrograms per cubic meter of air (mcg/m^3) in the ventilated chamber. For purposes of comparison, this is less than one percent of the xylene-equivalent concentration that we measured on day 8 (3 ppm, or 13 mg/m^3). Principal components identified in the chamber by Wallace's group (1987) were n-decane and n-undecane (aliphatic compounds) with a total concentration of 88 mcg/m^3 for these two. Measurements in a new office building (prior to occupancy) showed xylene concentrations of 250 mcg/m^3; this fell to 30 mcg/m^3 after occupancy (Wallace et al., 1987) attributed in part to reduced emissions as materials aged.

The findings in our study indicate maximum xylene-equivalent concentrations that are between one and two orders of magnitude greater than those reported by Wallace et al. (1987). This difference is probably explained by two factors. First, our measurement methodology detected a variety of VOCs, reflecting an aggregate concentration. Secondly, our highest measurements represented closed-room conditions shortly after product installation, in contrast to continuous ventilation in Wallace's chamber (1987).

While the sensitivity of our measurement methodology is somewhat crude and more suited to the higher concentrations likely to be found in industrial settings, two clear patterns emerge with respect to glued carpet. First, the VOCs that were emitted from the adhesive were substantially cleared from the room by fan-assisted ventilation. Second, it was only after one to two weeks that the "closed-room, overnight" condition failed to produce peak VOC levels consistently seen in the room during the first week. It should be remembered that these studies represent observations in a single room. Nevertheless, they can probably provide a reasonable approximation of the interaction of VOCs and ventilation when carpeting is glued to the floor in a home. Closed-room conditions will, during the first week or so following installation, produce high levels of VOCs, perhaps approaching industrial exposure limits. Fan-assisted ventilation can substantially lower these concentrations, even on the day following installation, and after only a few hours of operation.

While adhesives are not normally associated with residential carpet installation, these findings should be useful in many residential situations involving large releases of indoor pollutants. Pollution reductions following overnight ventilation show the effectiveness of forced ventilation, even with a relatively small blower. Such strategy should be useful in reducing odor problems from non-glued new carpet installations, and also when other floor coverings (involving adhesive) are installed. More difficult is the prediction of how long ventilation needs to be maintained before pollution levels are reduced to levels that are at least sensorially acceptable. VOC emissions from floor covering adhesives are influenced by numerous factors, including VOC content and emission rate when applied, permeability of the floor covering, temperature and absorption and reemission of VOCs by floor coverings and other materials in the room (Levin, 1990).

Conclusions and Implications

The most significant finding of this study is that while VOC emissions progressed at a relatively high rate during the week following carpet installation, concentrations could be lowered substantially and quickly during relatively modestly-forced ventilation. (Most studies that we have seen of indoor VOCs focus on commercial or public buildings or day-to-day levels in homes.) Information from our study should be of value in managing large, episodic releases of VOCs in homes. While this is an obvious strategy, there seems to be little quantitative information on this subject in the literature. A homeowner contemplating carpet installation, for example, and wishing to minimize the impact of odors will want to know the sort of duration needed for ventilation, particularly during the heating or cooling season. For rooms that are used only briefly or occasionally, forced ventilation on an as-needed basis might be an acceptable strategy, even during the heating/cooling season.

Although adhesives are not normally associated with residential carpet installation, these findings should provide a useful reference point in many residential situations involving large releases of indoor pollutants. Ventilation can be a useful strategy, but the needed duration has not been well defined for other common emission sources.

While the present study did not provide any clear endpoint for the need for ventilation, one week seems to be a likely minimum for the conditions described here. Levin (1989) states that emissions from carpet fall fairly rapidly and may be reduced by a factor of 10-50 in three to six weeks. He further estimates that emissions from adhesives would be released more quickly than from the carpet itself, backing and pads.

Additional work in this area is needed to examine the decay characteristics of other products responsible for large, abrupt releases of pollutants into residential environments. Other types of carpeting and other varieties of floor coverings (sheet goods, for example) would seem prime candidates for such studies because of the relatively large areas involved. More sensitive measurement techniques would provide better definition of the later phases of pollutant clearance. Analysis for other categories of pollutants (i.e., other groups of organic compounds) might reveal interesting correlations with product type and could be coupled with sensory acceptability to occupants. Ventilation has shown a high potential effectiveness in controlling episodes of indoor pollution from known sources. For this reason, installation of carpeting or other types of floor coverings (or other materials likely to release large amounts of pollutants) should be scheduled for times when ventilation can be conveniently accomplished.

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Author's Note:

VOC emissions from coatings such as paint are coming under increased legislative scrutiny. In several states and municipalities, VOC emission from such products is regulated by law. Many new formulations have appeared on the market, and there is speculation that, as a result of the Clean Air Act, national standards may eventually be established.