Material Testing

INTRODUCTION

New building materials, products and furnishings are known to emit a large number of chemicals into indoor air (Berglund et al, 1984; Levin, 1985; Molhave, 1984; NRC, 1981; Stolwijk, 1983; Wallace, 1984). Building occupants' sickness, irritation and discomfort are often blamed on the presence of such chemicals in indoor air (Finnegan, 1984; Stolwijk, 1984; Turiel, 198?). The health effects of these chemical emissions are not well understood, but substantial numbers of known or suspected human irritants and carcinogens are among the chemicals emitted by building products, materials and furnishings into indoor air (Molhave, 1984).

Building designers, owners, operators and occupants are increasingly concerned about problems related to indoor air pollution. The results of building products and materials emissions testing are beginning to be used in the design process as well as in the establishment of ventilation system operational protocols to maintain acceptable indoor air quality. Special procedures are utilized to prevent or remedy indoor air quality problems resulting from materials' emissions. Many office buildings are now operated under special ventilation protocols prior to or shortly after initial occupancy to "bake off" chemicals from materials, products and furnishing (Levin, 1984). Product manufacturers and building designers (architects, engineers, interior designers) are increasingly concerned about the products specified for use in buildings. This paper reports the first utilization of emissions testing for building design, construction planning, and building operation.

Background. A broad program of materials and indoor air quality testing is in progress for a large new office building in California. The purpose of the project is to minimize problems associated with indoor air pollution. A major element of the work is to identify products which might release significant quantities of known toxins or irritants and to recommend methods to reduce their airborne concentrations. The recommended methods have included product selection by architects; modifications of selected products by manufacturers; packing, shipping and handling procedures for building materials and furnishings; and "bake-off" procedures prior to occupancy.

In addition to the recommendations related to the materials testing program, a number of other recommendations have been made. Protocols for operating ventilation during the initial occupancy period have been recommended. Procedures for determining minimum acceptable ventilation rates have been designed and recommended. Maintenance and pest control procedures have also been reviewed. Air sampling and environmental monitoring have been conducted in some of the initially-occupied spaces.

A variety of emissions testing methods were utilized. Where there was agreement between experimental results and those reported in the literature for similar products, results were considered valid. Due to cost constraints, uses of replication methods for validation of test results were minimal.

The objective of the materials testing portion of the project is to assist in controlling airborne concentrations of toxins and irritants in order to minimize the problems associated with their presence indoors. Literature reviews and products testing were utilized to screen candidate materials and products for potentially strong emitters of toxic or irritating materials or for weaker emitters of potent toxins. In some instances, candidate products were tested prior to selection to assist designers in choosing more stable, less toxic or less irritating products. Other materials have been screened by reviewing Manufacturer's Safety Data Sheets (MSDSs) to identify potentially problematic substances. Substances listed in the MSDSs (or otherwise determined to be present in the products under consideration) were reviewed using published data on toxicity such as Sax's Dangerous Properties of Inudstrial Materials, Patty's Toxicology and NIOSH Registry of Toxic Toxic Effects of Chemical Substances (Refs). The quantity and distribution of the product or material to be used in the building was also considered in evaluating potential sources of indoor air pollution.

The results of this screening process led to the determination that the products most likely to emit significant quantities of irritating or toxic substances were the carpet, the work stations (office furnishings), and the ceiling tiles. These materials were evaluated during the emissions testing phase reported below.

EXPERIMENTAL WORK

Methods. Tests have been conducted using an environmental chamber, bulk testing, and headspace sampling. Temperature variation was used in both chamber and headspace tests. Temperatures of 20 ^{o}C. and 37 ^{o}C were used. The lower limit was chosen to represent ambient temperatures indoors. The upper limit represents about twice the elevation above the lower limit which would be expected during normal building operations.

Chamber tests were conducted in a 1.7 m^3 sheet metal box with controlled air flow and temperature, and with excellent mixing within the chamber. Chamber temperatures were monitored within the chamber and at the sampling location. The chamber size was established to allow the placement of full-sized (uncut) samples of furnishings and large samples of sheet materials with a maximal surface-to-edge ratio, thus reducing or eliminating problems associated with edges of cut samples. Material samples were generally placed in the chamber to condition them for $\geq$16 hours prior to testing.

Materials were generally not pre-conditioned as has been done in many other materials emissions investigations (cf, Matthews, 1984). Rather, the purpose of the testing required that materials be handled in a manner similar to that employed in their actual installation in buildings. Thus, they were often left in factory packaging or cartons, or they were wrapped to simulate their normal "conditioning" where they are left in closed packages until they are inside the building in which they will be installed.

Sample collection

Bulk samples were dissolved in appropriate solvents; these included carbon disulfide for hydrocarbons and a 0.5% solution of KOH for formaldehyde.

Air samples were collected using personal monitoring pumps. Formaldehyde samples were collected in midget impingers filled with a 0.5 ???? solution in distilled water. Sampling times ranged from ?? to ?? hours at flow rates of ?? L/min. Organic compounds were collected on charcoal tubes. Sampling times ranged from ?? minutes to ??/ minutes at flow rates of ?? L/min. to ?? L/min.

Headspace samples were collected in stainless steel laboratory containers. Material specimens were weighed and placed inside the containers. Personal monitoring pumps were used with charcoal tubes to collect organic compounds. Sampling times were from 30 to 60- minutes at flow rates of 1 L/min. Formaldehdye samples were collected in midget impingers with a 0.5% KOH solution in distilled water. Air was supplied to headspace cannisters by personal monitoring pumps through charcoal tubes or KOH solution in distilled water at rates equal to the sample collection rate.

Relative humidity was computed from wet and dry bulb temperatures. Carbon dioxide measurements were made by drawing air through Draeger tubes with a ??? pump. Formaldehyde and Total hydrocarbon measurements were made using equipment and methods similar to those used in the chamber tests. Collection locations were distributed throughout the approximately 10,000 square feet of occupied area. Additionally, background samples were collected on the rooftop and at the return air plenum in the basement.

Analysis

Analysis for formaldehyde was by NIOSH P & CAM #???. Analysis for Total Identifiable Hydrocarbons was by NIOSH P &CAMm #???. Draeger tubes were read directly for carbon dioxide concentrations.

Results. The results are given in Tables 1 and 2 and Figures 1 - ? which follow.

Discussion. Results from various test methods are consistent with each other and comparable to tests conducted elsewhere for certain products. The age of materials being tested was generally known. Testing results suggest significant impacts of material aging on emission rates and material chemical content. (Aging is defined as exposure to environmental elements over time.) Among the elements apparently important to aging is the presence of ventilation or air movement around the material. That is, the materials are removed from wrapping or containers and at least one major surface is free from obstruction of air movement at and immediately above the surface. Of particular interest is the observed decline in formaldehyde content and emission rates for carpet specimens.

The use of an environmental chamber large enough to accommodate full-size test specimens reduces errors associated with edge conditions of specimens. It also allows for extrapolation of results from the chamber to actual buildings with cautious interpretation of surface conditions and material specimen surface-area-to-chamber-volume ratios.

Rapid decline of formaldehdye bulk content of carpet during the first six weeks of exposure to the environment. This accounts for low emissions rates test results reports for samples which are not relatively new. It also suggests that the currently prevailing view that carpet is not a source of formaldehyde in new buildings may be misleading (Refs????).

Discuss Figure 1. (Graph of vertical panel and carpet formaldehyde results against age of sample).

APPLICATION OF RESULTS

Discussions with manufacturers and suppliers of some products have resulted in modifications intended to reduce unstable chemical content or emissions inside the completed structure.

Test results have been used to predict indoor pollutant concentrations in the completed building. Ventilation protocols have been recommended to limit certain air pollutants to acceptable levels. The recommendations included operating the building at minimum acceptable temperatures and maximum acceptable ventilation rates during the initial occupancy period for each portion of the phased building project. It was also suggested that panels of occupants subjectively evaluate indoor air quality to assist building operating engineers in determining acceptable reductions in the hours of operation, the amount of outside air to be introduced, and the acceptable temperature range.

CONCLUSIONS

The work supports the assumption that significant contributions are made by material testing for use during building design, material selection, and mechanical system operations. Screening materials based on manufacturer's information on content reduces the number of materials requiring actual emissions testing. Using existing data on chemcial and toxicological properties of materials further assists in screening materials for testing as well as in interpretation of results. Extrapolations to the actual building environment are assisted in this fashion.

Further work is needed to identify organic compounds and validate temperature effect testing. Effects of different chamber surface materials on concentrations of diverse compounds (especially those of low volatility) need to be determined. And tests using multiple products containing compounds known or expected to interact or impact air concentrations need to be conducted to determine source-sink dynamics.

This type of testing is of great potential use to building designers, owners, and operators.

Inclusion of consumer products and appliances should be considered in f;uther testing projects. The results from such testing will broaden the scope of the useful contributions ;emissions testing can make in the efforts to predict or model indoor air quality prior to building construction.

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