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EVALUATION OF EMISSIONS FROM LATEX PAINT

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INTRODUCTION

Traditional methods of assessing latex paint emissions have been developed to determine cumulative mass emissions of volatile organic compounds (VOCs) for purposes of determining their impact on the ambient air, specifically for their contributions to photochemical smog. In indoor environments, the concern is directed to determining the time varying exposure of occupants to total VOCs, as well as individual organic compounds. The Indoor Air Branch of EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, has developed a three phase approach (i.e., small chamber source characterization - indoor air quality (IAQ) modeling - test house validation) for developing emissions data for indoor sources (see Figure 1)[1]. This approach provides information on the temporal distribution of indoor emissions and allows occupant exposures to these emissions to be determined[2]. Over the past year, this approach has been used to evaluate indoor emissions from latex paint.

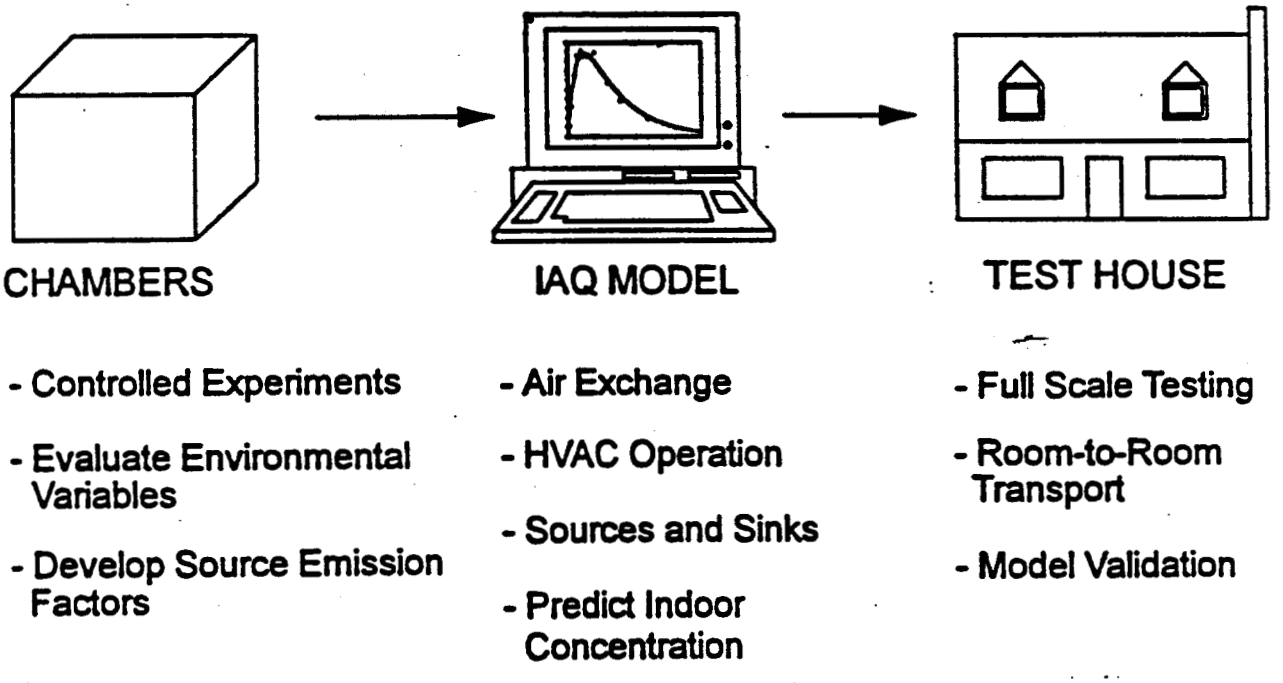

Figure 1. Three-phase IAQ research approach

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RESEARCH PLAN

A three-part latex paint emissions study is underway: 1) Initial Assessment; 2) Chamber Testing; 3) Test House Validation Studies. The *Initial Assessment* was designed to determine the most appropriate techniques for conducting the overall latex paint assessment program, including: a) selection and purchase of test paint; b) analysis of volatile organic compounds (VOC) and water content using American Society for Testing and Materials (ASTM) methods; c) determination of major organic compounds; d) development of optimal sampling and analysis methods for organic paint emissions; and e) evaluation of paint application methods. The purposes of the *Chamber Testing* are to: a) select the test substrate; b) develop data for determining VOC emission rates; and c) develop and evaluate source emission models, including mass transfer models. The *Test House Validation Studies* will develop data for evaluating and validating source emission models, including mass transfer models. In addition, the studies should provide data for assessing scale-up of small chamber source emissions data. The following information is expected to result from this assessment of latex paint: a) Emission rate data for VOCs from latex paint on gypsumboard for specific test parameters; b) Validated source emissions models for latex paint, including mass transfer models; and c) Test house data showing the concentrations of VOCs from latex paint. Ultimately, the effort should result in a test method proposal for ASTM.

The three part evaluation program was initiated in 1994. Part 1 (Initial Assessment) has been completed; Part 2 (Chamber Testing) is scheduled for completion early in 1995; and Part 3 (Test House Studies) will be completed by the end of 1995.

INITIAL ASSESSMENT

The purpose of the *initial assessment* was to determine the most appropriate techniques for conducting the overall latex paint assessment program, including: a) selection and purchase of test paint; b) compilation of information on paint composition based on product label and MSDS (Manufacturer's Safety Data Sheet); c) analysis of VOCs and water content using ASTM methods; d) determination of major organic compounds; e) development of optimal sampling and analysis methods for organic paint emissions; and f) evaluation of paint application methods.

Paint Composition

The paint selected for evaluation is a white interior flat latex wall paint (with vinyl acetate monomer) produced by a major US manufacturer. Based on ASTM methods[3] for paint analysis, the paint has the following composition by weight: non-volatiles = 57% and volatiles = 43% (water = 40% and VOC = 3%). Analysis of the paint by liquid injection to a gas chromatograph gave a total VOC (TVOC) content = 45 mg/g, with the following composition (in mg/g): ethylene glycol = 24; Texanol® = 13; butoxyethoxyethanol = 5; propylene glycol = 2; and diethylene glycol = 1.

Sampling and Analysis Methods

Evaluation of available methods resulted in the selection of the following sampling and analysis techniques for VOC emissions from latex paint: a) sampling on Tenax®TA sorbent; b) thermal desorption and concentration; and c) analysis by gas chromatograph (with a DB™-Wax column) using a flame ionization detector (FID).

Paint Application Methods

Three application methods were evaluated: slit applicator (a laboratory "standard" method), brush, and roller. The roller method was selected for use in the remainder of the study.

CHAMBER TESTING

Environmental test chamber methods have been developed for evaluating emissions from indoor materials and products[4]. Flow-through, dynamic chambers are used when emission rates are to be determined. The chambers used in this study have a volume of 53 liters and are constructed with electropolished stainless steel interior surfaces to minimize adsorption of VOCs. Small fans are used to enhance mixing and provide a velocity near the test surface of 5 - 10 cm/s, which is typical of indoor environments. Emissions testing is conducted by placing a freshly painted (2 - 3 min.) substrate (16.3 x 16.3 cm) in the chamber, painted side up. The chamber is then closed, and clean air (< 5 $\mu g/m^3$ TVOC) flow is started through the chamber. A flow rate of 0.44 l/min, equivalent to 0.5 air changes per hour, is used. Samples of the chamber outlet are taken using the techniques described above. Sufficient samples are collected to describe the change in emissions over time. Testing is conducted at 23°C with an inlet relative humidity of 50%.

The purpose of the *chamber testing* is to: a) Select the test substrate; b) Determine emission rates for total VOC as well as for individual compounds; c) Determine the effect of previous coats on emissions; d) Determine short- and long-term emission rates; and e) Evaluate and develop source emission models, including mass transfer models.

Selection of Test Substrate

VOC emissions from painted gypsumboard and stainless steel were evaluated using dynamic chamber tests. While stainless steel is routinely used as a test substrate in emissions testing due to its non-adsorbent properties, gypsumboard is a more realistic choice for latex paint. As shown in Figure 2, VOC emissions from painted gypsumboard are quite different than those from stainless steel. Significant amounts of VOCs are adsorbed by the gypsumboard, thus reducing the short term emissions to the indoor air. Thus, gypsumboard was selected at the test substrate.

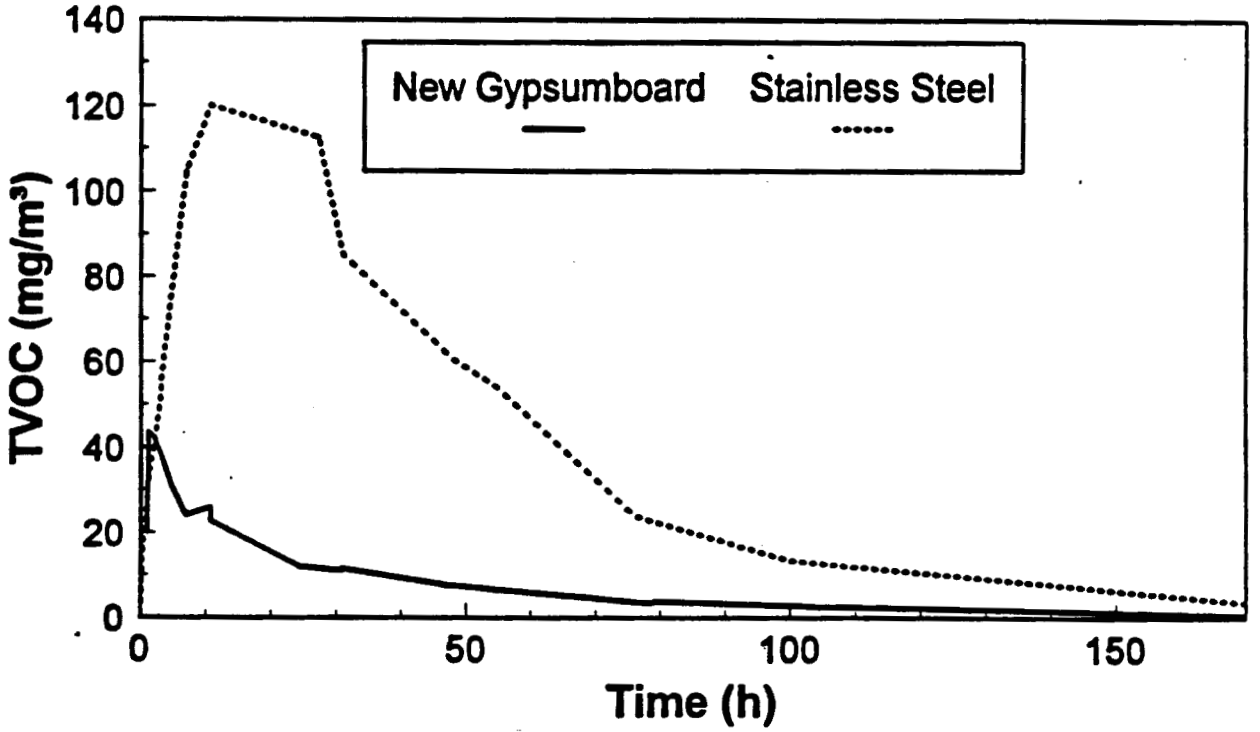


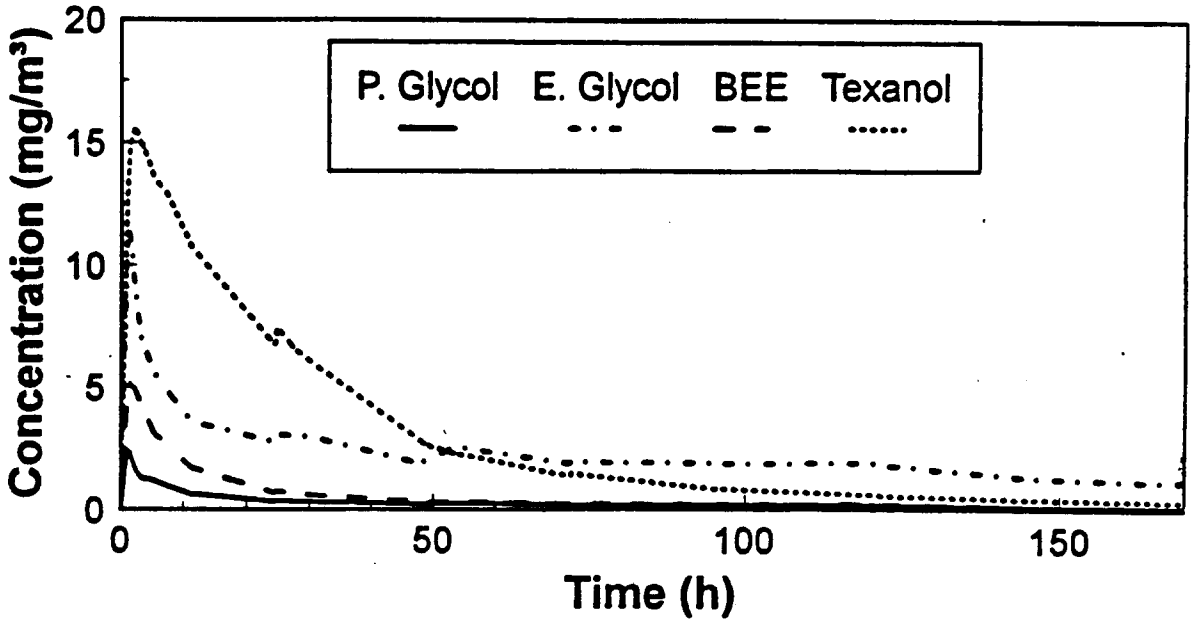
Figure 2. Emissions of TVOC from painted gypsumboard and stainless steel (Dynamic chamber tests)

Emissions of Individual Latex Paint VOCs

The chamber samples were also analyzed to determine the emissions of individual latex paint components, namely: ethylene glycol, propylene glycol, diethylene glycol, butoxyethoxyethanol, and Texanol® [2,2,4-Trimethyl-1,3-pentanediol Mono(2-methylpropanoate); mixture of two isomers]. As shown in Figure 3, emissions of Texanol® and ethylene glycol are the highest, with Texanol® emissions predominating for the first 50 hours and ethylene glycol emissions being the primary VOC emitted thereafter.

The Effect of Previous Coats on Emissions

Testing was conducted to determine if paint applied to previously painted gypsumboard affects the emission profile. Two previously coated boards were used: 1) a piece of gypsumboard cut from a wall of EPA's IAQ test house that had not been repainted for over 8 years and 2) a gypsumboard sample painted 5 weeks previously. As shown in Figure 4, the two previously painted gypsumboards had emission profiles essentially the same as for the first coat on new gypsumboard.



P. Glycol = Propylene Glycol
E. Glycol = Ethylene Glycol
BEE= Butoxyethoxyethanol

Figure 3. Emissions of latex paint VOCs from painted gypsumboard (Dynamic chamber test)

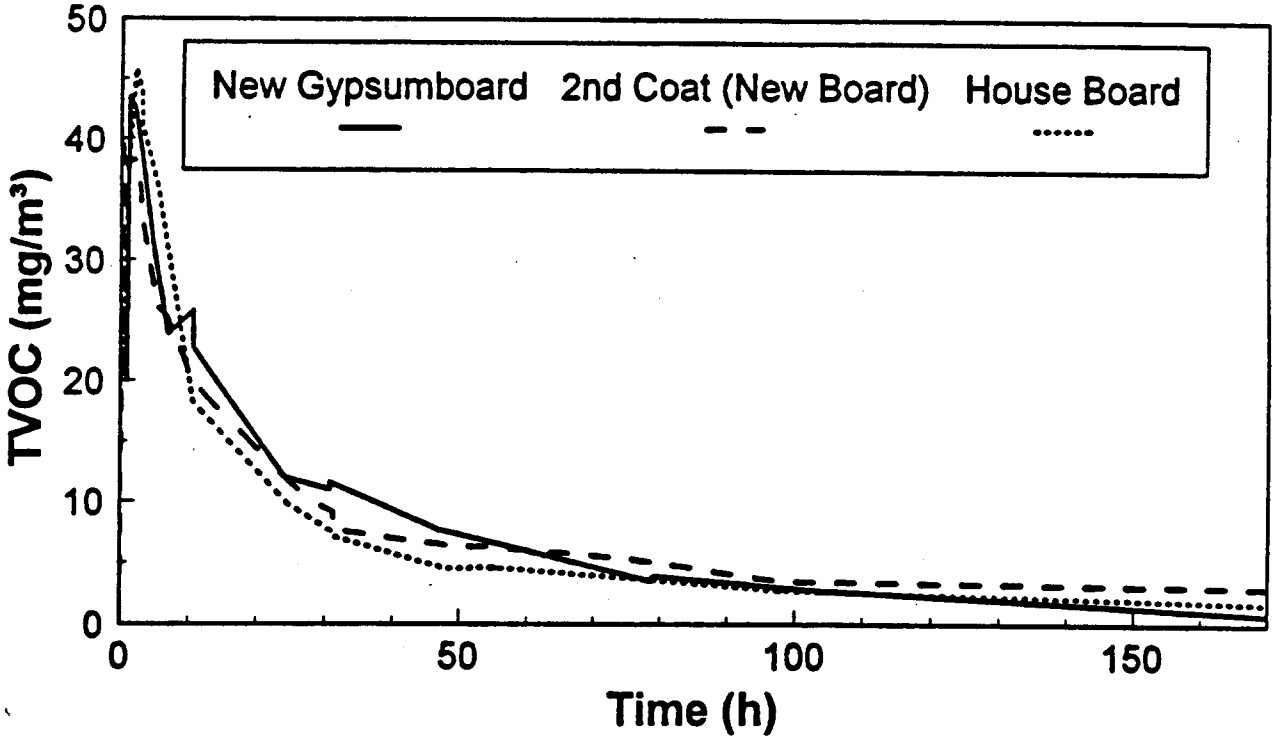


Figure 4. Emissions of TVOC from first and second coats of latex paint on gypsumboard (Dynamic chamber tests)

Long and Short Term Emissions

Many wet, evaporative sources of indoor air pollution emit for only a short time (e.g., several days). Most of the testing done in this evaluation program occurred over a 7 day (168 hour) period, as shown in Figures 2, 3, and 4. One test has been continued in order to observe the emissions from latex paint over the long term. Figure 5 shows the emissions of VOCs over a period of almost 6 months (4200 hours or 175 days). Note that the emissions of ethylene glycol are much higher than the other compounds. Also note that at the last sampling period, the concentrations of butoxyethoxyethanol and Texanol® were near the quantification limit of the sampling and analysis system.

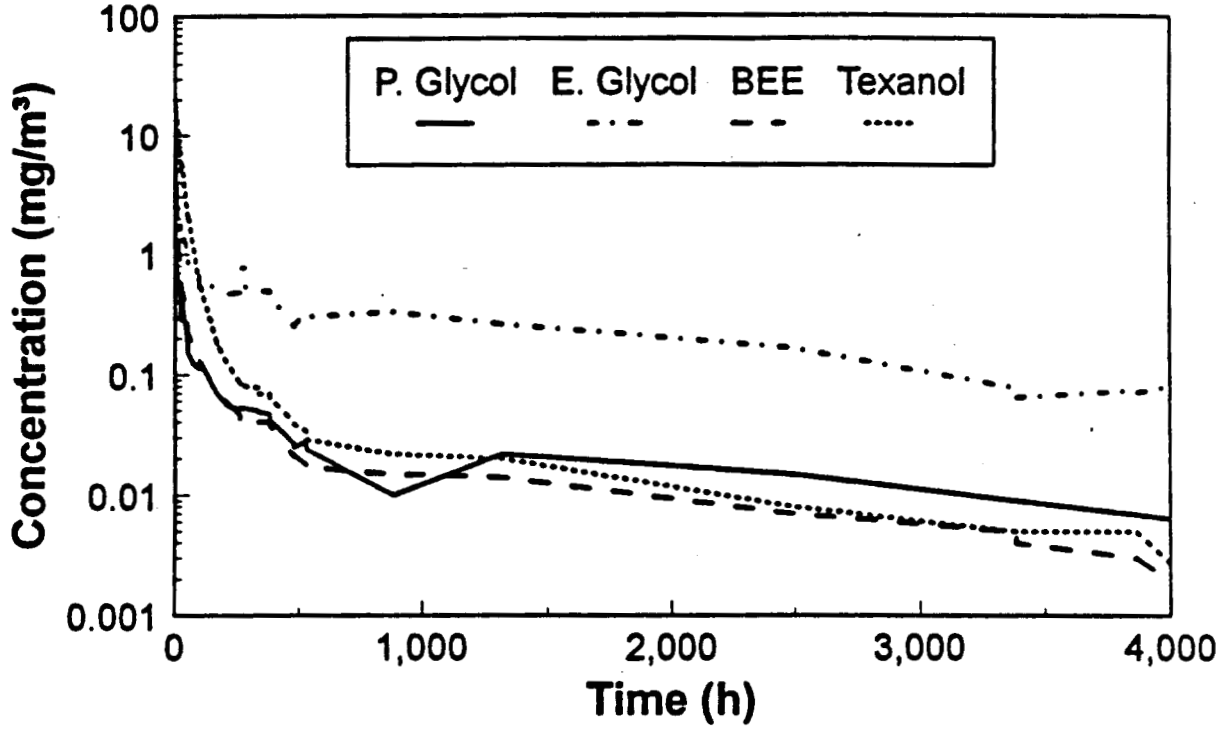


Figure 5. Long term emissions of latex paint VOCs from painted gypsumboard (Dynamic chamber test)

Source Emission Models

As discussed, dynamic chamber testing is the most common method being used to determine indoor source emission rates. Both empirical models and fundamental mass transfer models are being developed to predict the emission rates of sources.[5] Source emission factors are determined by fitting appropriate source models to chamber concentration vs. time data. The model selected is based on the source emissions profile over time.

For sources with decaying emissions, a common approach is to assume a first order decay:

$$EF = EF_o e^{-kt} \quad (1)$$

where EF_o = initial emission factor (mg/m^2h); k = first order rate constant (h^{-1}); and t = time (h). Some decaying sources, usually long lasting emitters, can be described by a second order decay equation:

$$EF = (EF_o)/(1 + k_2 EF_o t) \quad (2)$$

where k_2 = second order decay constant.

Source models have also been developed that are based on fundamental mass transfer processes. For sources with gas-phase limited mass transfer (e.g., evaporation from wet sources), the emission factor can be described as:

$$EF = k_g(C_s - C) \quad (3)$$

where, k_g = mass transfer coefficient (m/h); C_s = concentration of vapor in the air just above the emitting surface (mg/m^3); and C = concentration of vapor in the room air (mg/m^3). C_s is the vapor pressure, expressed as concentration, in equilibrium with the source. Previous work[5] has shown a linear relationship between C_s and the mass of VOC in the source (M):

$$C_s = C_v(M/M_0) \quad (4)$$

where C_v = concentration of VOC over fresh source (i.e., at time = 0); M = mass in source (mg/m^2) at time t; M_0 = initial mass in source (mg/m^2). The mass transfer coefficient (k_g) is determined by the vapor diffusivity of the emissions in air, the velocity above the source, and the geometry (size and shape) of the source.

Data from the dynamic chamber testing of painted gypsumboard have been fit with several source emissions models. As shown in Figure 6, the first order decay model (Equation 1) does not apply to latex paint TVOC emissions, while the gas-phase mass transfer model (Equations 3 & 4) does a good job of predicting short term emissions. Long term emissions are mainly controlled by diffusion within the gypsumboard, so a gas-phase limited model will not provide adequate predictions. Figure 7 illustrates the use of a second order decay model (Equation 2) for predicting long term emissions. A mass transfer model embodying both gas- and solid-phase mass transfer controls is under development.

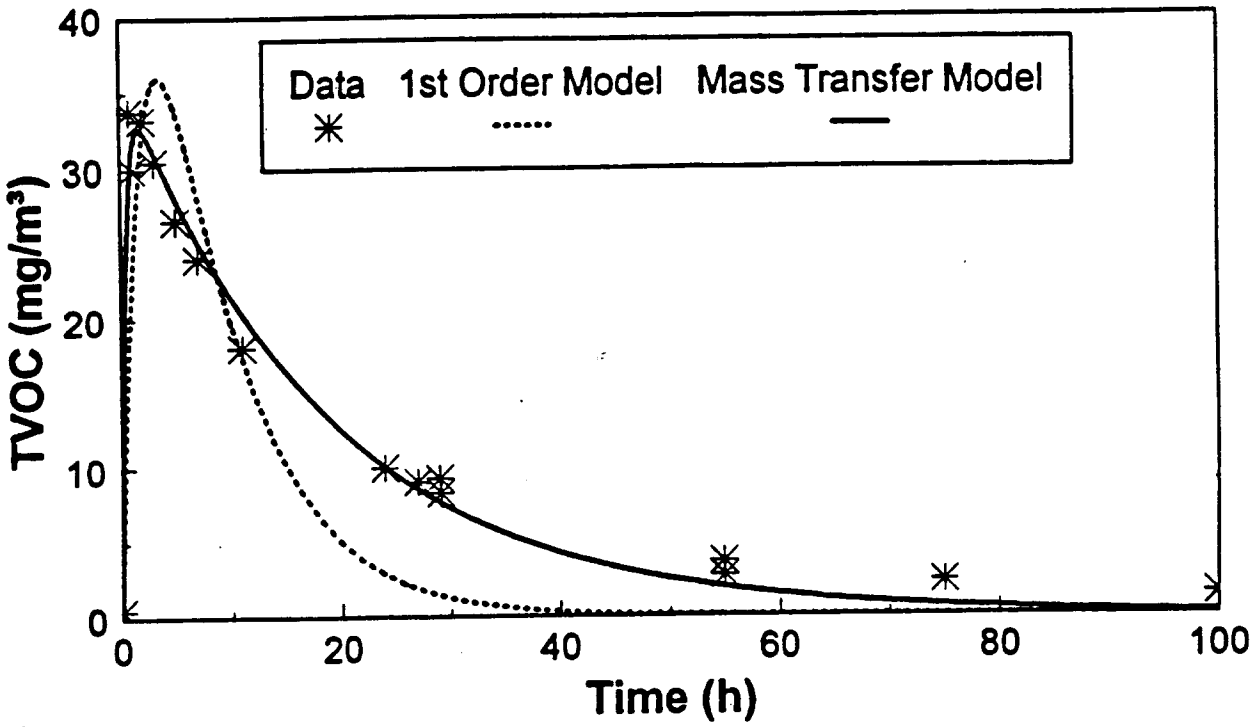


Figure 6. Short term emissions models - TVOC from painted gypsumboard (Dynamic chamber test)

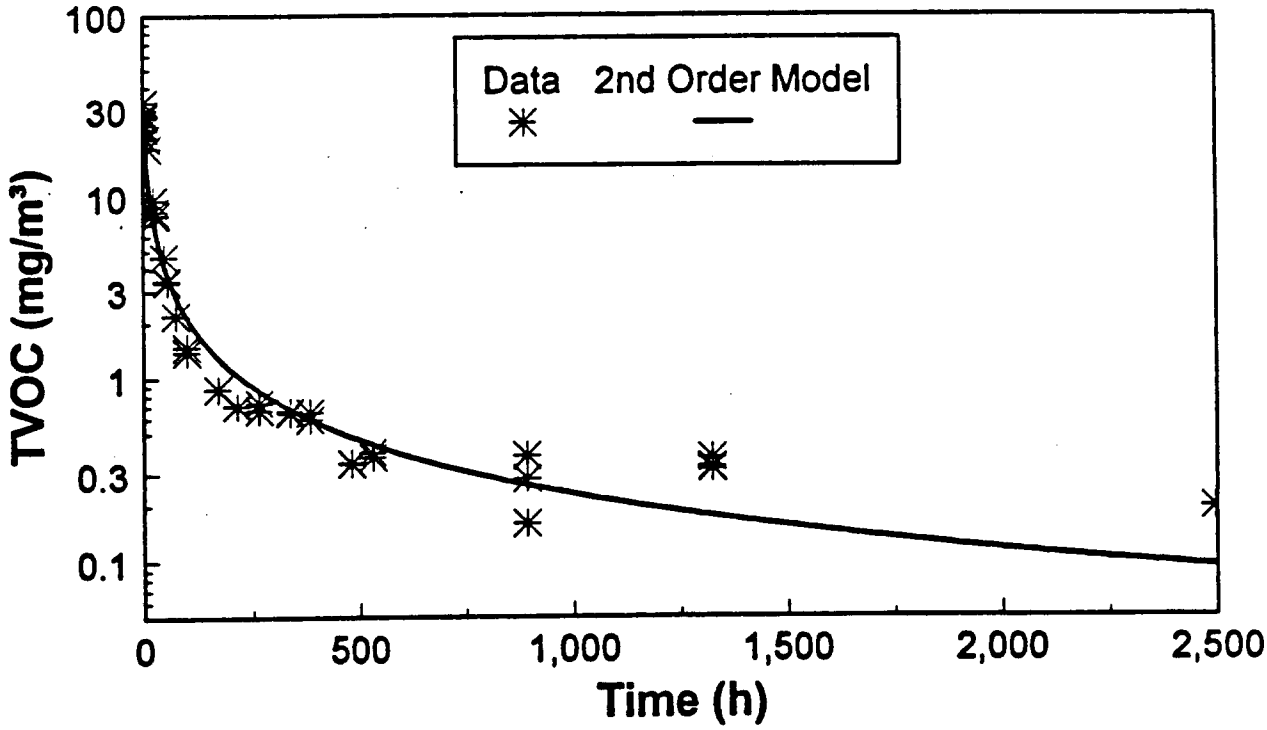


Figure 7. Long term emission model - TVOC from painted gypsumboard (Dynamic chamber test)

TEST HOUSE VALIDATION STUDIES

The purpose of the *test house validation studies* is to develop data for evaluating and validating source emission models, including mass transfer models. In addition, the studies should provide data for assessing scale-up of small chamber source emissions data. Test house studies will include: a) Anemometer traverses of test house walls to determine velocity distributions; b) Experiments to validate source emission mass transfer models; and c) Development of mass transfer coefficients for typical painting scenarios.

APPLICATION OF RESEARCH RESULTS

Emission rates developed from source testing are used in indoor air quality models[6] to predict indoor concentrations over space and time. The second order emission model (Equation 2 and Figure 7) was used to predict the concentrations of TVOCs in a hypothetical three-room apartment (see Figure 8) when latex paint is applied to interior walls.

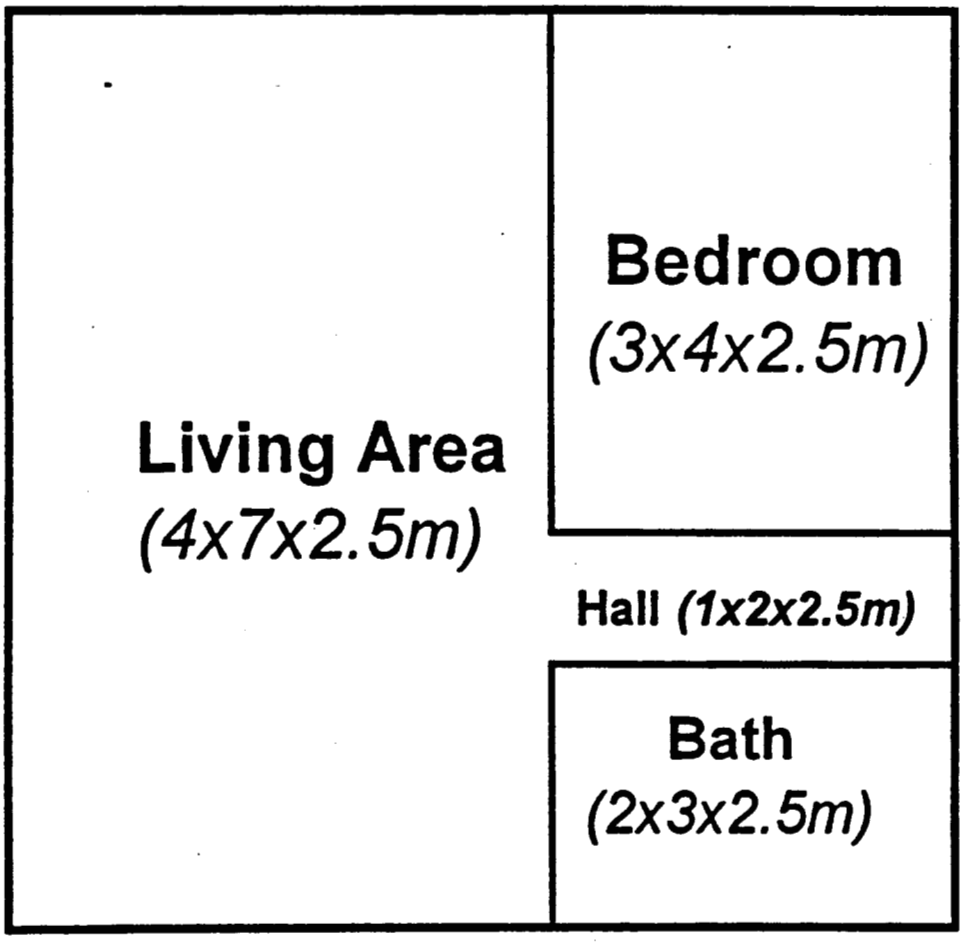


Figure 8. Floor plan for one-bedroom apartment

The model used an outdoor air exchange rate of 0.5 per hour and assumed a forced air heating/cooling system. The painting schedule was: Living area, 8AM - Noon; Hall, 1 - 2PM; Bedroom, 2 - 3PM; and Bath, 3 - 4PM. Figures 9 and 10 show the concentrations in each room for TVOC and Texanol®, respectively, for the first 100 hours. After that time, the concentration in all rooms was equal and the decay was much slower. Figure 11 shows the concentration of TVOC in the living area out to 700 hours.

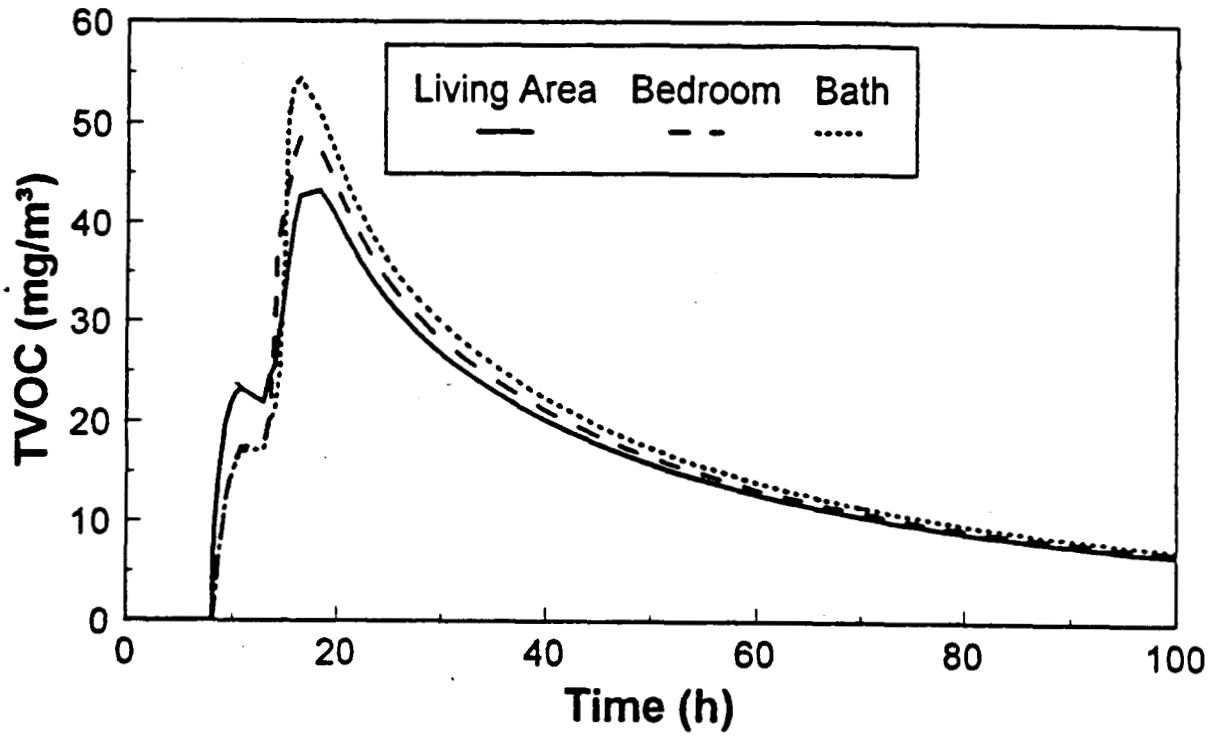


Figure 9. Predicted concentrations of TVOC from interior painting

FINAL PRODUCTS

The following information is expected to result from this assessment of a latex paint: a) Emission rate data for VOCs from latex paint on gypsumboard for specific test parameters; b) Validated source emissions models for latex paint, including mass transfer models; c) Test house data showing the concentrations of VOCs from latex paint; and d) A draft ASTM "Standard Practice for Determining Emissions from Interior Latex Paints." If a mass transfer model can be used to successfully predict emissions, a test method based on ASTM VOC content and equilibrium data from static headspace should be possible. Thus, the dynamic chamber test method would be replaced by a simpler and less expensive technique. Other latex paints need to be evaluated to provide data for generalizing these test methods.

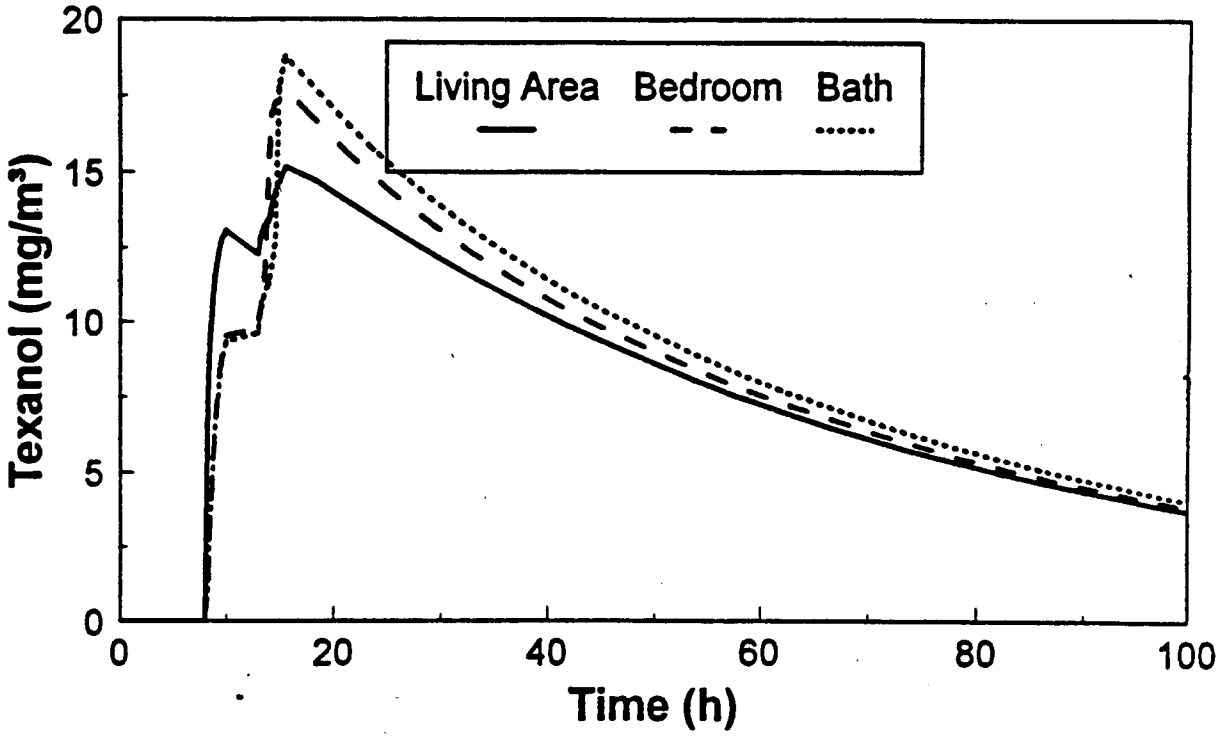


Figure 10. Predicted concentrations of Texanol® from interior painting

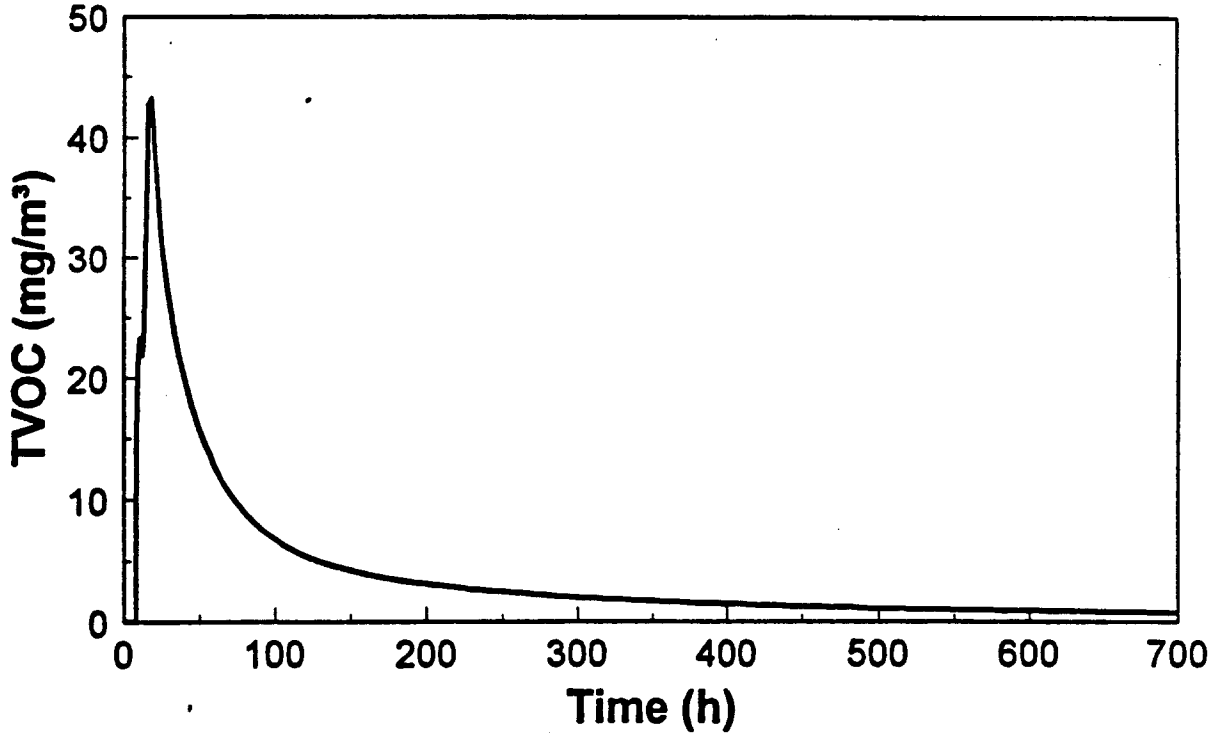


Figure 11. Predicted TVOC concentrations in living area from interior painting

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