



Inside IAQ

EPA's Indoor Air Quality Research Update

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A Small Chamber Test Method for the Measurement of Volatile Organic Compounds and Hazardous Air Pollutants from Alkyd and Latex Paints

Americans spend about 90% of their time indoors, where concentrations of pollutants are often much higher than they are outdoors. It is not surprising, therefore, that risk assessment and risk management studies have shown that indoor environmental pollution poses significant risks to human health.

The U.S. Environmental Protection Agency (EPA) has evaluated a number of indoor materials and products as potential sources of indoor air pollution under the Indoor Air Source Characterization Project (IASCP). Interior architectural coatings, especially alkyd and latex paints, were identified as potentially high-risk indoor sources by the Source Ranking Database developed under the IASCP. EPA conducted a literature survey and found that there was a lack of reliable and consistent paint emission data for developing and evaluating risk management options. Further investigation showed that a standardized test method needed to be developed so that testing laboratories, researchers, and paint manufacturers could generate and

report emission data that were complete, consistent, and comparable.

Between 1995 and 1999, EPA's National Risk Management Research Laboratory (NRMRL) conducted a paint emission characterization research program. The program was devoted to developing, verifying, and demonstrating a small chamber test method for the measurement of volatile organic compound (VOC) and hazardous air pollutant (HAP) emissions from alkyd and latex paints. The test method has been documented and submitted to the American Society for Testing and Materials (ASTM) for adoption as a standard practice.

This report briefly summarizes the resulting test method, presents new findings, and describes the key results generated by NRMRL as it assessed emissions from alkyd and latex paints. The report is divided into four parts. After introducing the study and providing background

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Fine Particle Emissions from Burning Incense

Recent studies have shown that human exposure to fine particulate matter (PM) constitutes a potential health hazard and that some indoor PM is from unknown sources. Principal adverse health effects associated with PM exposure are increased respiratory symptoms, increased respiratory illnesses, increased respiratory morbidity in asthmatics, and increased mortality in persons with COPD (chronic obstructive pulmonary disease). EPA initiated research in 1999 to identify and characterize potentially important indoor PM sources. As part of this effort, incense burning was investigated, because, according to the literature, it is a significant source of PM and has been linked to various illnesses. Studies in the literature have found harmful health effects associated with incense smoke including cancers, asthma, dermatitis, mutagenesis, and genotoxic effects.

Incense is burned to produce fragrances or mask odors, and burning incense is incorporated in the rituals of several different religions. Incense is burned inside homes and places of worship on a daily basis by some large minority populations in the U.S. and by large populations in other countries. In the U.S., incense is burned in public places including stores, shopping malls, and places of worship. EPA has no regulations for incense smoke in indoor air.

A study was recently conducted to (1) determine the PM emissions from different types of incense, and (2) estimate the significance of human exposure to incense smoke. The study did not directly examine the health effects of burning incense. Results from the study were included in a paper entitled "Characterization of Emissions from Burning Incense" that was published in the international journal, *The Science of the Total Environment*, Volume 295, pp. 51-67, August 5, 2002. The study was conducted by the Indoor Environment Management Branch in Research Triangle Park, NC, and the authors were James Jetter, Zhishi Guo, Jenia McBrian, and Michael Flynn.

In the study, scientists purchased 23 types of incense locally and tested for PM emissions in a specially designed test chamber. PM was collected on filters, from which the emission rates were calculated. Using an indoor air quality model, the emission rates were used to calculate the indoor PM concentrations due to incense burning in homes. The results were compared with ambient air quality standards.

Results from the study showed that emission rates for PM_{2.5} (particulate matter less than 2.5 micrometers in aerodynamic diameter) ranged from 7 to 202 milligrams per hour, and PM_{2.5} emission factors ranged from 5 to 56 milligrams per gram of incense burned. These results suggest that burning incense emits fine PM in large quantities. An indoor air quality model showed that, under certain conditions, burning incense at home can result in indoor concentrations of PM_{2.5} that far exceed the outdoor concentrations specified by the NAAQS (National Ambient Air Quality Standards), so incense smoke can pose a health risk to incense users due to inhalation exposure of PM. Risk is increased when exposure duration is long, room ventilation is low, room size is small, burning time of the incense is long, and emissions are high.

Providing information to consumers of incense products could reduce health risks. Incense users may eliminate risk by choosing not to burn incense. Users may reduce risk by burning incense outdoors instead of indoors or by burning incense in a well-ventilated area, such as under an operating ventilation hood for a stove. Users may reduce risk by burning incense for shorter periods of time, by increasing room ventilation, by burning incense in a larger room, and by burning incense with lower emissions.

For further information, contact Jim Jetter, (919) 541-4830, jetter.jim@epa.gov.

Parameter Estimation for Indoor Source Models in the Absence of Experimental Data

Estimating human exposure in the indoor environment requires knowledge of pollutant penetration from outdoors and emissions from indoor sources. In general, the latter are more difficult to estimate because of the vast variety of

indoor sources. To account for the contribution of indoor sources, one needs indoor emission source models. Over 50 such models have been developed over the years. While they represent a great achievement made by indoor air

quality (IAQ) modelers, there is certainly room for improvement. A recent review by the author reveals that many of these models have not been used in exposure assessment programs, and that genuine predictive models are still few. A major obstacle is the lack of methods to estimate the model parameters in the absence of experimental data. Only a fraction of the model parameters (molecular weight, vapor pressure, Henry's constant, etc.) can be found from the literature. Estimation of the rest parameters (diffusivity, mass transfer coefficient, etc.) relies on quantitative structure-activity relationships (QSARs) and other types of correlations. The author recently compiled 48 published methods for estimating parameters in the indoor source models and is developing a Microsoft Windows-based computer program to implement commonly used QSARs and other correlations, among which are:

- first-order decay rate constants for organic solvent- and water-based coating materials,
- diffusivity in air, water, and solids;
- solid/air partition coefficient;
- gas-phase, liquid-phase, and overall mass transfer coefficient;

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information about existing literature on the subject paint emissions testing, the report describes the developed standard test method for characterizing organic compounds emitted from paint. It also describes the results of NRMRL's tests on alkyd and latex paints.

Standardized Test Method

The standardized test method addresses the following key issues:

- Storing and handling paint samples prior to analysis
- Analyzing paint in bulk (as a liquid)
- Selecting and preparing a paint substrate for testing
- Applying paint to a substrate to create a test specimen
- Establishing and controlling test conditions
- Sampling the VOC emissions from the painted specimen
- Analyzing the samples with chemical instruments
- Calculating emission rates/factors using experimental data
- Conducting quality assurance/quality control

The core experimental apparatus employed by the standardized test method is a device called a Small Environmental Test Chamber ("small chamber" for short). A test chamber is a hollow box that may range in size from a few liters to 5 m³. The chamber used at NRMRL is 53 L

- vapor pressure by compound class and carbon number;
- total pressure and partial pressure for petroleum-based solvent;
- properties of air (density, viscosity, moisture contents, etc.); and
- properties of water (vapor pressure and viscosity).

A beta version of this program will be available for user testing in the Spring of 2003. It should be pointed out that the existing methods cannot solve all the problems associated with parameter estimation. Many parameters in indoor source models can only be determined by experiment. Thus, parameter estimation is a research area that IAQ modelers should pay more attention to in the future. In particular, research is needed to (1) develop new methods, (2) refine the existing methods, (3) evaluate existing methods for accuracy and uncertainty, (4) recommend the best available methods.

For further information, contact Jim Jetter, (919) 541-0185, guo.zhishi@epa.gov.

(0.053 m³) in volume. Chambers with volumes greater than 5 m³ are defined as "large"—they may reach the scale of an entire room. The small chamber, on the other hand, is an apparatus suited to the spatial and financial constraints of a typical laboratory environment. It is also more convenient to operate than a large chamber. An environmental chamber test facility designed and operated to determine organic emission rates from paints should contain the following: test chambers, clean air generation system, monitoring and control systems, sample collection and analysis equipment, and standards generation and calibration systems. The purpose of these components is to provide a controlled environment for conducting emissions testing that can reflect common indoor air conditions.

The standardized test method includes a series of procedures and guidelines for preparing a painted test specimen. Procedures for handling and storing the paint to be tested were established to guard against the possibility of evaporative losses, stratification, and property changes. A modified version of EPA Method 311 (40 CFR, 1996) was adopted for the bulk analysis of paints, to facilitate the experimental design of the emissions test and the selection of sampling and analytical techniques. Instead of traditional test substrates such as glass, stainless steel, and aluminum, common indoor materials such as gypsum board and wood are recommended in the method for creating realistic and

representative testing samples. Either a roller or a brush should be used to apply the paint to the substrate. A protocol was developed to quantify the amount of the paint applied so that the emission data can be consistent and comparable.

The “time zero” for the start of an emission test is established when the chamber door is closed (immediately after placing the test specimen inside the chamber). The small chamber should be operated to match the actual environmental conditions at which people paint the interiors of houses. The standardized method guides investigators in setting up their sampling protocols. The instructions help to ensure that investigators collect an adequate quantity of chamber air samples on the appropriate sampling media. The method describes several kinds of analytical instruments that can be used to determine the amounts and kinds of VOCs in the collected sample. Data reduction techniques and an example of an emission model are included in the method—it describes the mathematical procedures used to convert the analytical results into emission rates and emission factors. In addition, the method provides guidelines for reporting and quality assurance. These guidelines should help investigators compile their results in a consistent and complete fashion that allows for comparison or repeat emissions testing of similar or new architectural coatings.

Alkyd Paints

Alkyd paint continues to be used indoors because it has desirable properties such as durability, gloss, gloss retention, and fast drying. NRMRL has employed the newly developed standardized test method to conduct research that characterizes VOC emissions from alkyd paint. NRMRL used the results of its paint emissions tests to develop source emission models. These models, in turn, were used for the assessment of indoor exposure levels and risk management options.

The first test series that NRMRL performed on alkyd paints was integrated into the process of developing and validating its new standard practices for paint testing. The tests involved one primer and three alkyd paints. Bulk analysis indicated that the alkyd primer and two of the three paints tested contained more than 100 different VOCs, primarily straight-chain alkanes, with decane and undecane being the predominant compounds. The third paint had more branched alkanes. All four coatings contained low levels of aromatic compounds. The total VOC content of the liquid paints ranged from 32% to 42%. Measurements of the total VOC levels in the liquid coatings by gas chromatography/mass spectrometry (GC/MS) agreed well

with manufacturers' data.

Mass balance calculations were conducted to compare the bulk analysis results and chamber emission data to evaluate the recovery. It was found that for total VOC, the majority (greater than 80%) of the mass in the applied paint could be accounted for in the subsequent air emissions. The data for the more abundant compounds (e.g., nonane, decane, and undecane) in the paint suggest that there was a margin of error of $\pm 20\%$ in measuring these recoveries.

Due to the relatively high VOC content and fast emission pattern, peak concentrations of total VOC as high as 10,000 mg/m³ were measured during small chamber emissions tests with a loading factor of 0.5 m²/m³ and an air exchange rate of 0.5 h⁻¹. Over 90% of the VOCs were emitted from the primer and paints during the first 10 hours following application.

A series of tests were performed to evaluate those factors that may affect emissions following application of the coatings. It was found that the type of substrate (glass, wallboard, or pine board) did not have a substantial effect on the emissions with respect to peak concentrations, the emissions profile, or the mass of VOC emitted from the paint. The emissions from paint applied to bare pine board, a primed board, and a board previously painted with the same paint were quite similar. There were differences among the emissions from the three different paints, but the general patterns of these emissions were similar. The effect of other variables, including film thickness, air velocity at the surface, and air exchange rate, were consistent with theoretical predictions for gas-phase, mass-transfer-controlled emissions.

Results from the testing performed in this study are being used to develop computational methods for estimating the emission rate of total VOCs from solvent-based coating products used indoors. The database on total VOC emission from alkyd paint should also be useful for others involved in model development and validation.

In addition to studying the effects of substrates and other environmental variables on total VOC emissions, small environmental chamber tests were conducted to characterize the emissions of a toxic chemical compound—methyl ethyl ketoxime (MEKO)—from three different alkyd paints. The data resulting from these tests facilitated the development of a set of risk management options for MEKO.

Methyl ethyl ketoxime, another name for 2-butanone oxime or ethyl methyl ketoxime [CH₃C(NO₂)C₂H₅, CAS Registry No. 96-29-7], is often used by paint manufacturers as an

additive to interior alkyd paints (Weismantel, 1981; Turner, 1988). MEKO has been found to be a moderate eye irritant (Krivanek, 1982). It was also the subject of a Section 4 test rule under the Toxic Substances Control Act (Fed. Regist., 1986). A number of toxicological endpoints have been evaluated by testing conducted under the test rule (Fed. Regist., 1989). MEKO demonstrated carcinogenic activity in long-term inhalation studies, causing liver tumors in both rats and mice.

MEKO acts as an anti-skinning agent (or anti-oxidant) that prevents oxidative drying or skinning of the alkyd paint to improve stability in the can. Usually, the MEKO content in a paint is less than 0.5% (Krivanek, 1982). Due to its relatively high volatility (its boiling point is only 152°C), the majority of the MEKO in the paint is expected to be released into the surrounding indoor air after painting to allow the paint to dry properly on the painted surfaces. The effects of MEKO emissions on indoor air quality (IAQ) and associated exposure risk depend on characteristics such as emission rates and patterns.

Bulk analysis showed that the MEKO content in alkyd paints can be as high as several mg/g. Material balance from the chamber tests indicated that the majority (greater than 68%) of the MEKO in the paint applied was emitted into the air. MEKO emissions occurred almost immediately after each alkyd paint was applied to a pine board. Due to the fast emission pattern, more than 90% of the MEKO emitted was released within 10 hours after painting. The peak concentrations of MEKO in chamber air correlated well with the MEKO content in the paint.

The chamber data were simulated by a first-order decay emission model that assumed that the MEKO emissions were mostly gas-phase mass-transfer-controlled. The first-order decay model was used as an input to the continuous-application source term of an IAQ model to predict indoor MEKO concentrations during and after the application of an alkyd paint in a test house. The predicted test house MEKO concentrations during and after the painting exceeded a suggested indoor exposure limit of 0.1 mg/m³ for all three paints. The predicted MEKO concentrations also exceeded the lower limit of a suggested sensory irritation range of 4 to 18 mg/m³ with two of the three paints tested. The elevated MEKO concentrations can last for more than 10 h after the painting is finished. The model was also used to evaluate and demonstrate the effectiveness of risk reduction options. These options involved selecting lower MEKO paints and establishing higher ventilation levels during painting. The higher ventilation should be maintained about 2 h after the painting is finished to avoid exposure to residual MEKO emissions.

In addition to total VOC and MEKO emissions, the unpleasant “after-odor” which can persist for weeks after application of alkyd paint has been a cause of IAQ concerns. Three different alkyd paints were tested in small environmental chambers to characterize the aldehyde emissions. Emission data indicated that significant amounts of odorous aldehydes (mainly hexanal) were emitted from alkyd paints during the air-drying period. Bulk analyses showed that the alkyd paint itself contained no aldehydes. Mass balance calculations indicated that any aldehydes emitted should have been produced after the paint was applied to a substrate. The aldehydes emission patterns were consistent with the theory that the aldehydes were formed as byproducts from spontaneous autoxidation of unsaturated fatty acids in the applied paint. Chamber data showed that the major volatile byproducts generated by the drying of the alkyd paints were hexanal, propanal, and pentanal. These results facilitated the development of an exposure assessment model for hexanal emissions from drying alkyd paint.

The hexanal emission rate was simulated by a model that assumed that the autoxidation process was controlled by a consecutive first-order reaction mechanism with an initial time lag. The time lag reflects an induction period after painting during which little oxygen is taken up by the alkyd coating. As the final byproduct of a series of consecutive first-order reactions, the hexanal emission rate increases from zero to reach a peak and is followed by a slow decay. This model was confirmed by chamber concentration data. The modeling results also showed that the hexanal emissions were controlled mostly by the chemical reactions that formed intermediates (i.e., the precursors to hexanal production).

An IAQ simulation that used the emission rate model indicated that the hexanal emissions can result in prolonged (several days long) exposure risk to occupants. IAQ simulation indicated that the hexanal concentration due to emissions from an alkyd paint in an indoor application could exceed the reported odor threshold for about 120 hours. The occupant exposure to aldehydes emitted from alkyd paint also could cause sensory irritation and other health concerns.

Latex Paints

The majority (over 85%) of the interior architectural coatings used in the United States are latex paints. Previous testing of latex paint emissions has focused on determining cumulative mass emissions of VOCs. The purpose of previous testing was to assess the effect of these paints on the ambient air and to determine how they contributed to

photochemical smog (Brezinski, 1989). NRMRL's concern has been to estimate people's time-varying exposure to overall VOC levels and to specific VOCs from indoor latex paints.

The first test series that NRMRL performed on latex paints was integrated into the process of developing and validating its new standard practice for paint testing. NRMRL's small chamber tests indicated that the organic emission patterns of latex paints are very different from those of alkyd paints. Bulk analysis showed that the total VOC content of a commonly used latex paint is usually in the range of 2% to 5%, which is considerably lower than that of alkyd paints (32% to 42%). Instead of alkanes, alkenes, and aromatics, only several polar compounds such as glycols, alcohols, and aldehydes were found in the latex paints.

The chamber test results showed significant differences between the emissions of the same latex paint applied to two different substrates (a stainless steel plate and a gypsum board). The amount of VOCs emitted from the painted stainless steel was 2 to 10 times greater than the amount emitted from the painted gypsum board during the 2-week test period. After the first 2 weeks, over 90% of the VOCs was emitted from the paint on the stainless steel plate but less than 20% had left the gypsum board. The dominant species in the VOCs emitted also changed from ethylene glycol to 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate when stainless steel was replaced with gypsum board. Data analysis by a double-exponential model indicated that the majority of the VOC emissions from the painted stainless steel could be simulated by an evaporation-like phenomenon with fast VOC emissions controlled by gas-phase mass transfer. On the other hand, only a small fraction of the VOCs emitted from the painted gypsum board appeared to be controlled by the evaporation-like drying process. The majority of the VOCs were emitted after the painted gypsum board surface was relatively dry. They were probably dominated by a slow, solid-phase-diffusion-controlled mass transfer process. Long-term experimental data indicated that it may take as long as 3.5 years for all the VOCs to be released from the paint applied to the gypsum board.

The small chamber test results demonstrate that, when the objective of a test is to provide emissions data that are relevant to understanding a paint's emissions behavior in typical indoor environments, one should use "real" substrates such as wood and gypsum board instead of "ideal" substrates such as glass, aluminum, or stainless steel. Proper choice of substrate is therefore crucial for exposure and/or risk assessment studies involving indoor latex paints.

NRMRL also used the small chamber test method to evaluate a relatively new type of interior architectural coating, the so called "low-VOC" latex paint. Low-VOC paint has been used as a substitute for conventional latex paints to avoid indoor air pollution. Low-VOC latex paints are promoted for use in occupied hospitals, extended care facilities, nursing homes, medical facilities, schools, hotels, offices, and homes where extended evacuation of an entire building section for painting would be particularly difficult or undesirable.

Four commercially available low-VOC latex paints were evaluated as substitutes for conventional latex paints. They were evaluated by assessing both their emission characteristics and their performance as interior wall coatings. Bulk analysis indicated that the VOC contents of the four paints (which ranged from 0.01% to 0.3%) were considerably lower than those of conventional latex paints (3% to 5%). EPA Method 24 (40 CFR, 1996) for determining VOC content (commonly used by paint manufacturers) is not accurate enough to quantify the VOC contents of low-VOC latex paints for quality control and product ranking purposes. Other methods such as EPA Method 311 are more suitable, especially when individual VOC content data are needed.

The fact that "low-VOC" paint had relatively low VOC emissions was confirmed by small chamber emission tests. However, the experimental data also indicated that three of the four low-VOC latex paints tested either had some inferior coating properties or emitted hazardous air pollutants. Significant emissions of several aldehydes (especially formaldehyde, which is a HAP) were detected in emissions from two of the four paints. ASTM methods were used to evaluate the paints' coating performance including hiding power, scrub resistance, washability, drying time, and yellowing. The results indicated that one of the four low-VOC paints tested showed performance equivalent or superior to that of a conventional latex paint used as control. It was concluded that low-VOC latex paint can be a viable option to replace conventional latex paints for prevention of indoor air pollution. However, certain paints marketed as "low-VOC" may still emit significant quantities of air pollutants, including HAPs. In addition, some of these paints may not have performance characteristics matching those of conventional latex paints.

Due to the use pattern of low-VOC paints proposed by their manufacturers (i.e., partial occupancy during painting and immediate re-occupation after painting), the intimate exposure of sensitive occupants to the low-VOC latex paint emissions (especially to HAPs such as formaldehyde) is of special concern. Long-term environmental chamber tests

were performed to characterize the formaldehyde emission profiles of a low-VOC latex paint. The formaldehyde emissions resulted in a sharp increase of formaldehyde concentrations within the chamber, rising to a peak followed by transition to a long-term slow decay. Environmental chamber data indicated that formaldehyde emissions from a low-VOC latex paint can cause very high (several ppm) peak concentrations in the chamber air. When the paint was applied to gypsum board, the formaldehyde emissions decayed very slowly after the initial peak, and the emission lasted for more than a month. The results of these tests allowed for the development of exposure assessment emissions models to facilitate pollution prevention efforts to reduce the amount of formaldehyde released by low-VOC paints.

A semi-empirical first-order decay in-series model was developed to interpret the chamber data. The model characterized the formaldehyde emissions from the paint in three stages: an initial “puff” of instant release, a fast decay, and a final stage of slow decay controlled by a solid-phase diffusion process that can last for more than a month. The semi-empirical model was used to estimate the amount of formaldehyde emitted or remaining in the paint. It also predicted the initial peak concentration of formaldehyde and the time necessary for the formaldehyde to become depleted

from paint. Once the activity patterns of building occupants were defined, the model was used for exposure risk assessment.

Additional small chamber tests were performed to investigate the major sources of formaldehyde in the paint. Through comparing emission patterns and modeling outcomes of different paint formulations, a biocide used to preserve one of the paints was identified as a major source of the formaldehyde emissions. Chamber test results also demonstrated that paint reformulation by replacing the preservative with a different biocide for the particular paint tested resulted in an approximately 55% reduction of formaldehyde emissions. However, since other sources (e.g., additives and binders) of formaldehyde are present in the paint, biocide replacement can reduce only the long-term emissions. Short-term generation of high concentrations of formaldehyde remains a problem. Additional research is needed to identify other potential sources of formaldehyde to completely eliminate formaldehyde emissions from low-VOC paints.

For further information, contact John Chang, (919) 541-3747, chang.john@epa.gov.

SUMMARIES OF RECENT PUBLICATIONS

Characterization of Emissions from Burning Incense - The primary objective of this study was to improve the characterization of particulate matter emissions from burning incense. Emissions of particulate matter were measured for 23 different types of incense using a cyclone/filter method. Emission rates for PM_{2.5} (particulate matter less than 2.5 [μ]m in aerodynamic diameter) ranged from 7 to 202 mg/h, and PM_{2.5} emission factors ranged from 5 to 56 mg/g of incense burned. Emission rates were also determined using an electrical low pressure impactor (ELPI) and a small electrostatic precipitator (ESP), and emission rates were compared to those determined using the cyclone/filter method. Emission rates determined by the ELPI method were consistently lower than those determined by the cyclone/filter method, and a linear regression correlation was found between emission rates determined by the two methods. Emission rates determined by the ESP method were consistently higher than those determined by the cyclone/filter method, indicating that the ESP may be a more effective method for measuring semivolatile particle emissions. A linear regression correlation was also found between emission rates determined by the ESP and cyclone/filter methods. Particle size distributions were measured with the ELPI, and distributions were found to be similar for most types of incense that were tested. Size distributions by mass typically ranged from approximately 0.06 to 2.5 [μ]m in

aerodynamic diameter, with peak values between 0.26 and 0.65 [μ]m. Results indicated that burning incense emits fine particulate matter in large quantities compared to other indoor sources. An indoor air quality model showed that indoor concentrations of PM_{2.5} can far exceed the outdoor concentrations specified by the US EPA's National Ambient Air Quality Standards (NAAQS), so incense smoke can pose a health risk to people due to inhalation exposure of particulate matter. Emissions of carbon monoxide (CO), nitric oxide (NO), and sulfur dioxide (SO₂) were also measured for seven types of incense. Emission rates of the gaseous pollutants were sufficient to cause indoor concentrations, estimated using the indoor air quality model, to exceed the outdoor concentrations specified by the NAAQS under certain conditions. However, the incense samples that were tested would fill a room with thick smoke under these conditions. Source: *The Science of The Total Environment*, Vol. 295, Issue 1-3, 51-67, 2002. (EPA Contact: Jim Jetter, 919-541-4830, jetter.jim@epa.gov)

Development of a Windows-based indoor air quality simulation software package A Microsoft Windows-based indoor air quality (IAQ) simulation software package has been developed and has completed a small-scale beta test and quality assurance review. Tentatively named Simulation Tool Kit for Indoor Air Quality and Inhalation Exposure, or STKi for

short, this package complements and supplements existing IAQ simulation packages and is designed mainly for advanced users. STKi Version 1 consists of a general-purpose simulation program and four stand-alone, special-purpose programs. The general-purpose program performs multi-zone, multi-pollutant simulations and allows gas-phase chemical reactions. With a large collection of models for sources, sinks, and air filters/cleaners, it can perform simulations for a wide range of indoor air pollution scenarios. The special-purpose programs implement fundamentally based models, which are often excluded from existing IAQ simulation programs despite their improved performance over statistical models. In addition to performing conventional IAQ simulation, which generates time-concentration profiles, STKi can estimate the adequate ventilation rate when certain air quality criteria are given, a unique feature useful for product stewardship and risk management. STKi will be developed in a cumulative manner. More special-purpose simulation programs will be added to the package. Key numerical methods used in STKi are discussed. Ways to convert the STKi programs into language-independent simulation modules that can be used by multi-pathway exposure models are also being explored. Source: *Environmental Modeling and Software*, Vol. 15, 403-410, 2000. (EPA Contact: Zhishi Guo, 919-541 0185 guo.zhishi@epa.gov)

Comparison of Methods for Measuring Concentrations of Semivolatile Particulate Matter

The purpose of this study was to compare methods for measuring concentrations of semivolatile particulate matter (PM) from indoor-environment, small, combustion sources. Particle concentration measurements were compared for methods using filters and a small electrostatic precipitator (ESP). Particle size distributions were measured using an electrical low-pressure impactor (ELPI). Semivolatile PM was produced from cigarette and incense smoke, and, for comparison, a relatively nonvolatile aerosol was produced from polyalphaolefin oil. Results showed that semivolatile PM concentrations measured using the ESP method were significantly higher than those measured using the filter method. The ESP method was shown to be a more effective means of measuring semivolatile PM under the test conditions Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Jim Jetter, 919-541-4830, jetter.jim@epa.gov)

Air Toxic Emissions from a Vinyl Shower Curtain

Three static chamber tests were performed to measure the headspace concentrations of the curtain when stored in a sealed container. Four air toxics--toluene, methyl isobutyl ketone (MIBK), ethylbenzene, and phenol-- were detected. Although the chamber loadings varied by a factor of 3.1, the average headspace equilibrium concentrations differed by less than 32% among the three chambers. The emission patterns of the four air toxics were measured by a dynamic chamber test. An emission model was

developed to interpret both the static and dynamic chamber data. The model verified that the measured static chamber headspace equilibrium concentration should represent the maximum air toxics level achievable by the shower curtain in an enclosed environment. Analysis of the dynamic chamber data indicated that the air toxics emissions were controlled by a solid-phase diffusion process and could result in elevated indoor air toxics concentrations for more than a month. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: John Chang, 919-541-3747, chang.john@epa.gov)

Potential for Reducing Styrene Exposures from Copied Paper Through Use of Low-Emitting Toners

Tests were conducted using 53-L chambers to determine styrene emission rates from freshly copied paper produced on a single photocopier, using two toners manufactured for the copier but having different styrene contents. Copied-paper styrene emissions with both toners could be represented by a power law or a 3rd-order decay model ($R^2 = 0.94$ to 0.99). The two toners resulted in copied paper having significantly different styrene emissions ($p < 0.01$). Unit mass emissions of styrene ($\mu\text{g}/\text{m}^2$) over 1,000 h are predicted to be 9 times greater from paper with the higher-emitting toner. But even copied paper produced using a still-higher-emitting toner reported in the literature, is predicted to produce peak indoor styrene concentrations in a typical office only 0.3% of the estimated minimum concentration of concern to susceptible sub-populations. Thus, for the toners studied here, indoor styrene

exposures from copied paper appear too limited to provide incentive for switching to the lower-emitting toner. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Bruce Henschel, 919-541-4112, henschel.bruce@epa.gov)

The Distribution of Chlorpyrifos Following a Crack and Crevice Type Application in the U.S. EPA Indoor Air Quality Test House.

A study was conducted in the U.S. EPA Indoor Air Quality Research House to determine the spatial and temporal distribution of chlorpyrifos following a professional crack and crevice application in the kitchen. Following the application, measurements were made in the kitchen, den and master bedroom over 21-days. Airborne concentrations were collected using both polyurethane foam (PUF) and a XAD/PUF (OVS) media. Measured airborne concentrations were similar for the two samplers, were higher in the three rooms following the application, reached maximal levels 24-h post-application, and declined steadily over the 21-day study period. Spatial and temporal distributions were measured using 10-cm² cotton deposition coupons. Sections were cut from existing carpet to determine the total extractable residues. Chlorpyrifos was measured from all matrixes in the kitchen, den and bedroom and shows the transport of airborne residues from the point of application to remote locations in the house. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Mark Mason, 919-541-4835, mason.mark@epa.gov)

Impact of an Ozone Generator Air Cleaner on Styrene Concentrations in an Indoor Air Quality Research Chamber

We investigated the impact of an ozone generator air cleaner on vapor-phase styrene concentrations in a full-scale indoor air quality test chamber. The time history of the concentrations of styrene and ozone is well predicted by a simulation model using the reaction rate constant for styrene/ozone that has been determined at atmospheric pressure and room temperature. In three tests, the reaction products, formaldehyde and benzaldehyde, were produced in ratios of 0.64 ± 0.22 and 0.82 ± 0.19 mole (average \pm standard deviation), respectively, for each mole of styrene consumed. Two tests were conducted in near-static-chamber conditions, and one test was conducted at 1 air exchange per hour (ACH). The test results demonstrate that, where styrene is present, ozone generator air cleaners increase indoor exposure to formaldehyde and other oxygenated organic compounds as well as to ozone and nitrogen dioxide. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Mark Mason, 919-541-4835, mason.mark@epa.gov)

Improved Test Methods for Electronic Air Cleaners The objective of this project was to develop a fractional filtration efficiency test protocol for residential ESPs that avoids the limitations of the ASHRAE 52.2 method. Specifically, the objectives were to a) determine the change in efficiency that residential ESPs undergo in real life and b) develop accelerated laboratory methods that reasonably reproduce the real life changes. This work was

conducted as part of the Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) program for Indoor Air Products. Results from the real life study revealed that the observed decrease in ESP filtration efficiency was due to reduced corona discharge from the ionizing wires, as opposed to dust collection on the precipitator plates. Analysis of the wires showed that they had become coated with a silicon compound, presumably silicon dioxide formed by a corona-enhanced vapor deposition process. A laboratory method to reproduce and accelerate the vapor deposition process was developed. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Les Sparks, 919-541-2458, sparks.les@epa.gov)

Testing Indoor Air Products: One Approach to Developing Widely Accepted Protocols RTI is a partner in the US EPA's Environmental Technology Verification (ETV) Program, with responsibility for evaluation of products intended to improve indoor air quality. The program objective is to further the development of self-supporting private environmental testing/certification programs for indoor air products by convening stakeholder groups and developing and verifying test protocols. The protocols have also been specified in public and private procurements. Two areas of emphasis have been low emitting (i.e., low off gassing) commercial furniture and general ventilation filters for removal of aerosol contaminants. These areas have been reported earlier. A third area of emphasis currently being pursued is the evaluation of in-duct electronic air cleaners. While the

ASHRAE 52.2 is a starting point for the test protocol, RTI has investigated conditioning and dust loading issues specific to electronic air cleaners. A companion paper at the conference discusses the laboratory results. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Les Sparks, 919-541-2458, sparks.les@epa.gov)

A Multipollutant Model for Estimating the Impact of Pollutants on Indoor Air Quality Most existing indoor air quality (IAQ) models are not well suited for analysis of the impacts of sources that emit several pollutants into the indoor environment. These models are also not well suited for the analysis of the impacts of particulate matter (PM) on the indoor environment because of the need to include particle size distribution in the analysis. The IAQ model RISK was rewritten to allow analysis of multiple pollutants and PM. The IAQ model includes several new source emission models developed from EPA's ongoing indoor source research program. For PM, the model allows analysis of the effects of: the building shell on the penetration of outdoor particles into the indoors, the deposition of particles to indoor surfaces, particle removal by air cleaners, and indoor particle sources. Model predictions are in good agreement with the experimental data from EPA's IAQ research house. Source: "Proceedings: 9th International Conference on Indoor Air Quality and Climate" Monterey, California June 30 – July 5, 2002 (EPA Contact: Les Sparks, 919-541-2458, sparks.les@epa.gov)

GLOSSARY OF ACRONYMS

ACH-Air Exchanges per Hour	Agency	NRMRL-National Risk Management Research Laboratory
APPCD-Air Pollution Prevention & Control Division	ESP-Electrostatic Precipitator	NTIS-National Technical Information Service
ASHRAE-American Society of Heating, Refrigerating, and Air-Conditioning Engineers	ETV-Environmental Technology Verification	PM-Particulate Matter
ASTM-American Society for Testing and Materials	HAP-Hazardous Air Pollutant	PM _{2.5} -Particulate Matter < 2.5 um in aerodynamic diameter
CFM-Cubic Feet per Minute	HVAC-Heating, Ventilating, and Air-Conditioning	PUF-Polyurethane Foam
COPD-Chronic Obstructive Pulmonary Disease	IAQ-Indoor Air Quality	QSARs-Quantitative Structure-Activity Relationship
ELPI-Electrical Low Pressure Impactor	IEMB-Indoor Emissions Management Branch	RH-Relative Humidity
EPA-Environmental Protection	MEKO-Methyl Ethyl Ketoxime	RTI-Research Triangle Institute
	MIBK-Methyl Isobutyl Ketone	STKi-Simulation Tool Kit
	NAAQS-National Ambient Air Quality Standards	VOC-Volatile Organic Compound

SYMPOSIUM ANNOUNCEMENT

Indoor Air Quality Problems and Engineering Solutions

The *Indoor Air Quality Problems and Engineering Solutions* Symposium, an international symposium cosponsored by EPA's National Risk Management Research Laboratory and the Air & Waste Management Association, will be held **July 21-23, 2003**, at the Sheraton Imperial Hotel and Conference Center in Research Triangle Park, NC. Papers are invited on the following topics:

Managing the Risk of Indoor Air Pollution
Indoor Air Source Characterization Methods
Protecting the Indoor Environment from Terrorism
Indoor Air Source Management
Low Emitting/Low Impact Materials Development
(Pollution Prevention)
Biocontaminant Prevention and Control
Indoor Air Cleaning Methods
Asthma and Children's Health in the Indoor
Environment

Ventilation for Indoor Air Quality
HVAC Systems as Sources of Indoor Air Pollution
Air Duct Cleaning
Particles and Particle Entry into the Indoor
Environment
Indoor Air Quality Modeling
Costs of Managing Indoor Air Quality
Evaluation and Verification of IAQ Alternatives
Exposure in the Indoor Environment

The symposium will consist of one general session so that participants will be able to attend all sessions. A poster session, continuing education courses, and an exhibition of related products and services are planned. A tour of the U.S. EPA's new research facilities will be offered. The conference site has convenient access to nearby restaurants, shopping, and entertainment. A reception is also planned for the first evening.

Send abstracts of 200-300 words by January 10, 2003, to: Jim Jetter, U.S. EPA, Mail Drop E305-03, Research Triangle Park, NC 27711; telephone (919) 541-4830; fax (919) 541-2157; email jetter.jim@epa.gov. Abstracts should include paper title, author name(s), address(es), phone number(s), fax number(s), and email address(es). For further information on the symposium and exhibition, see AWMA's web site at <http://www.awma.org/events/>, or contact Denise Stotler at (412) 232-3444, ext. 3111, dstotler@awma.org.

United States
Environmental Protection Agency
National Risk Management Research Laboratory
Indoor Environment Management Branch
Mail Code E305-03
Research Triangle Park, NC 27711

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