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EPA

Inside IAQ

EPA's Indoor Air Quality Research Update

Inside IAQ is distributed twice a year and highlights indoor air quality (IAQ) research conducted by EPA. If you would like to be added to or removed from the mailing list, please mail, fax, or e-mail your name, address, and phone number to:

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Engineering Solutions to Indoor Air Quality Problems

July 24-26, 1995
Sheraton Imperial Hotel and Conference Center
Research Triangle Park, NC

Register now to attend this international symposium cosponsored by the Air & Waste Management Association (A&WMA) and the U.S. Environmental Protection Agency's (EPA) Air Pollution Prevention and Control Division. The symposium will include oral presentations, a poster session, continuing education courses, and an exhibition.

For registration information and a copy of the program, contact the A&WMA Registrar at 412-232-3444, ext. 3142; fax 412-232-3450. For information on the exhibition, contact Roy Neulicht at 919-677-0249, ext. 5126; fax 919-677-0065.

Symposium Program

Monday, July 24 - Source Characterization
Source Management & Pollution Prevention
Reception and Poster Viewing in Exhibition Area

Tuesday, July 25 - Ventilation & Modeling - Air Cleaning

Wednesday, July 26 - Biocontaminant Control

Who's Who in EPA's Office of Research and Development (ORD)?

ORD is reorganizing into four national laboratories. The organizational changes that affect IAQ research are:

New Organization	*Former Organization*
National Risk Management Research Laboratory (NRMRL)/Air Pollution Prevention and Control Division (APPCD)	Air and Energy Engineering Research Laboratory (AEERL)
National Exposure Research Laboratory (NERL)/ & Human Exposure Research Division (HERD)	Environmental Monitoring Sampling Laboratory (EMSL)
National Health and Environmental Effects Research Laboratory (NHEERL)	Health Effects Research Laboratory (HERL)
NERL/Human Exposure and Field Research Division (HEFRD)	Atmospheric Research and Exposure Assessment Laboratory (AREAL)
National Center for Environmental Assessment (NCEA)	Environmental Criteria and Assessment Office (ECAO)

Source Characterization Research

Evaluation of Emissions From Latex Paint

This three-part study was initiated in 1994. Part 1 (Initial Assessment) has been completed and was summarized in the Fall/Winter 1994 issue of *Inside IAQ*. Results from Part 2 (Chamber Testing) are covered in this article. Part 3 (Test House Studies) will be completed by the end of 1995 and will be presented in a future issue.

The *Initial Assessment* was designed to determine the most appropriate techniques for conducting the study, including: a) selection of a test paint; b) analysis of volatile organic compounds (VOCs) 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 purpose of the *Chamber Testing* is to: a) select the test substrate; b) determine emission rates for Total Volatile Organic Compounds (TVOCs) 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. (Modeling results will be discussed in a future issue of *Inside IAQ*.)

Environmental test chamber methods used for this study have been developed for evaluating emissions from indoor materials and products. The flow-through, dynamic chambers 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 minutes) substrate (16.3 x 16.3 cm) in the chamber, painted side up. The chamber is then closed, and clean air, < 5µg/m^3 TVOCs, flow is started through the chamber. A flow rate of 0.44 l/min, equivalent to 0.5 air change per hour, is used. Sufficient samples of the chamber outlet are collected to describe the change in emissions over time. Testing is conducted at 23°C with an inlet relative humidity (RH) of 50%.

VOC emissions from painted gypsumboard and painted stainless steel were evaluated in the dynamic chamber. As shown in Figure 1, TVOC emissions from painted gypsumboard are quite different than those from painted stainless steel. Significant amounts of VOCs are adsorbed by the gypsumboard, thus reducing the short-term emissions. Gypsumboard was subsequently selected as the test substrate for this study.

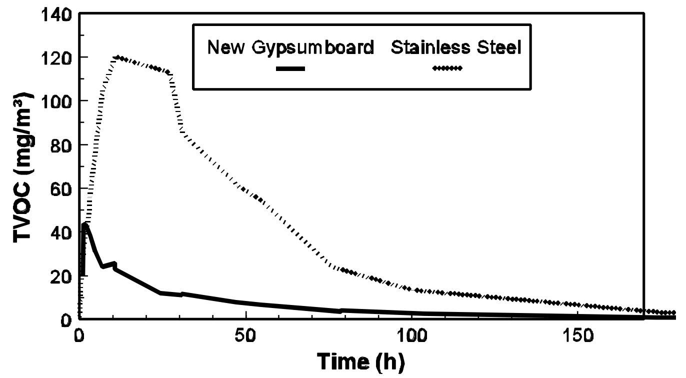

Figure 1 Emissions of TVOCs from Painted Gypsumboard and Painted Stainless Steel

The chamber samples were also analyzed to determine the emissions of individual latex paint components, namely: ethylene glycol, propylene glycol, diethylene glycol, butoxyethoxyethanol (BEE), and Texanol® (2,2,4-trimethyl-1, 3-pentanediol mono 2-methylpropanoate). As shown in Figure 2, 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.

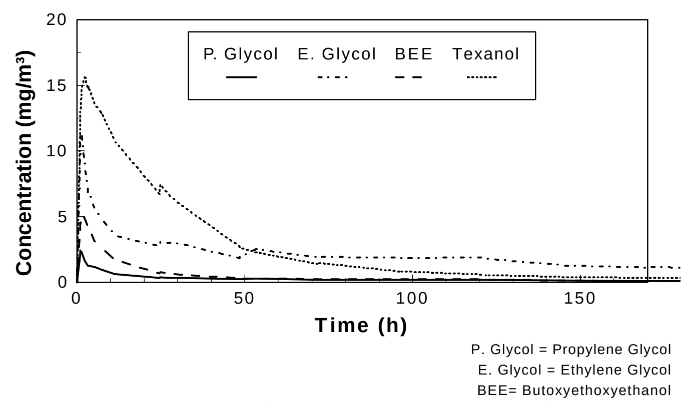

Figure 2 Emissions of Latex Paint VOCs from Painted Gypsumboard

Testing was then 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. These two samples had emission profiles essentially the same as for the first coat on new gypsumboard.

Many wet, evaporative sources 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. One test has been continued in order to observe the emissions from latex paint over the long term. Figure 3 shows the emissions of VOCs over a period of almost 6 months. 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.

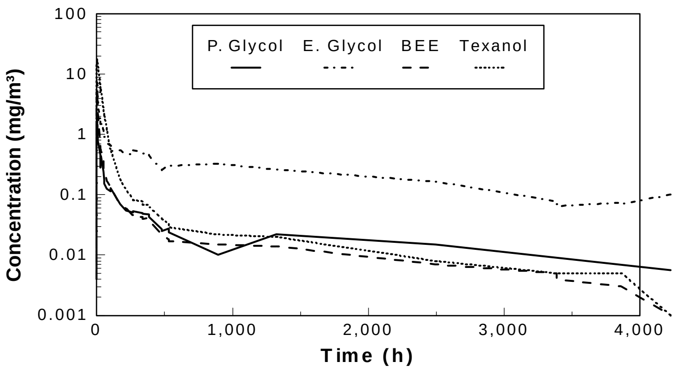

Figure 3 Long Term Emissions of Latex Paint VOCs from Painted Gypsumboard

This study should result in the following information: 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. (EPA Contact: Bruce A. Tichenor, APPCD, 919-541-2991)

Source Characterization Research

Carpet Freshener Study

Carpet fresheners are typically intended to be used as a cover for household odors. They consist of a fine powder with a fragrance added. The powder is applied broadcast to a carpet and then the carpet is vacuumed to remove the excess and volatilize the fragrance. Given the concerns about the impact of breathable fine particulates on lungs, EPA conducted a series of tests on carpet fresheners.

The study was done in APPCD's test house, and two carpet fresheners were examined. Each product uses a different substrate as the powder. The immediate impact after application and long-term buildup due to periodic reapplication were evaluated. The effect of vacuuming was also examined since the average vacuum cleaner redistributes a third or more of all the fine particulates collected.

Figure 4 shows a typical result from this study where the breathable fines (defined as 0.35 µm and smaller) increased from 16.9% of the total to 29.1% following application of the carpet freshner. While vacuuming reduces this increase in breathable fines, background concentrations continue to remain high for an additional 8 to 24 hours. However, to put this in perspective, similar if not greater increases can be caused by random activities in any busy household.

The long-term buildup of airborne particulates due to repeated applications of carpet freshener (60 days and 3 applications) was masked by normal day-to-day fluctuations in background particulate concentration. Therefore, it would appear that in most cases the impact of applying carpet freshener is limited to the application phase and immediately afterwards. (EPA Contact: Ray Steiber, APPCD, 919-541-2288)

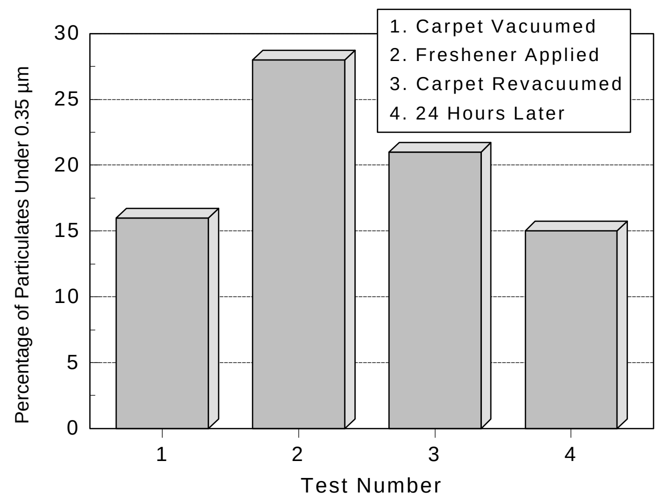

Figure 4 Increase in Breathable Fine Particulates Following Application of Carpet Freshener

Source Characterization Research

EPA Compares Large Chamber Design With International Chambers

Large (room-sized) environmental test chambers are being constructed by three different governments for use in characterizing sources of indoor air pollution. Participating government organizations include: EPA's APPCD, the National Research Council Canada, and Australia's Institute of Minerals, Energy and Construction. These "large" chambers are intended to supplement existing indoor air emission source characterization facilities by providing adequate size facilities to contain and characterize emissions from large assemblages, such as furniture; equipment operation, such as photocopying; and activities, such as painting or cleaning. These large chambers will also be helpful in studying the usefulness of computer modeling for scaling up emissions data from small environmental chambers to a controlled room-like environment. This study should improve the ability of each of the laboratories to develop test methods which give reliable results when run on chambers of different construction.

The three large chambers, while intended for similar purposes, have been designed and constructed to different specifications. The organizations involved will conduct a study to compare the design and performance of these chambers in order to develop a better understanding of how they can be best used. The first phase of this interlaboratory comparison study will consist of a comparison of the design specifications and construction. Later phases will address such topics as air flow patterns, ability of the systems to hold temperature and humidity setpoints, airtightness and cleanliness of the chamber systems, analytical measurements, and measured emission rates from a standard source. (EPA Contact: Betsy Howard, APPCD, 919-541-7915)

Exposure Assessment Research

Development of a Medium for Recovering Aerosolized Bacteria

Researchers at NERL/HERD and at the Maryland Biotechnology Institute are conducting cooperative research to develop the best medium or set of media for recovery of the diverse types of bacteria found in indoor air. Recoveries on various media are being compared with those on Trypticase Soy Agar (TSA), a nutritionally complex medium known to recover injured bacteria and frequently used in indoor air investigations. Media selected for the study are those employed by other investigators in aerobiology and, in addition, media designed for growth of a wide range of bacterial species.

Twelve species of bacteria are being tested. An important finding was that aerosolization of bacteria resulted in decreased colony forming ability. From the data gathered in this study, it is concluded that, for the media tested, there are large differences in recovery, with recovery success a function of the time bacteria remained in the air, as well as the type of medium employed for recovery.

A total of 120 media or media combinations have been evaluated. Results of recovery experiments performed with Staphylococcus aureus and Serratia marcescens are shown in Tables 1 and 2, respectively. The data illustrate that (i) recoveries on the reference medium, TSA, are low compared with those on several media formulations not typically used in indoor air investigations; (ii) the best recovery medium varies with the microorganism that is being recovered; and (iii) only a small proportion of the total bacteria observed in microscopic counts, Acridine Orange Direct Counts, are being resuscitated and recovered as viable colony forming units (CFUs). Thus far, Brain Heart Infusion Agar (with or without serum), TSA combined with Trehalose or serum, and Mueller Hinton Agar have yielded the best recoveries of aerosolized cultures.

Table 1
Recovery of Staphylococcus Aureus on Selected Media

MEDIA	CFU/Total	Standard Error
TSA	0.189	0.0117
TSA+10%FBS	0.4207	0.07152
MUELLER HINTON+5% FBS	0.4055	0.07948
BRAIN HEART+5% FBS	0.3694	0.046
GC+1%BSA	0.3194	0.076
BEEF EXTRACT AGAR	0.2991	0.026
BHI AGAR	0.2926	0.051
CAMPYLOBACTER+5%FBS	0.288	0.046
BEEF EXTRACT +5% FBS	0.2829	0.027
LAB-LEMCO+5% Blood	0.2827	0.067
GC+0.5% TSOVITALEX	0.282	0.067
TSA+5%FBS	0.2802	0.037
SCHAEDLER+5% BLOOD	0.2782	0.052
GC+1%BSA+5% BLOOD	0.278	0.06
CTA	0.2734	0.011
EUGON AGAR	0.2687	0.071
EUGON+5% BLOOD	0.2687	0.051
GC+5% BLOOD	0.2668	0.053
CHAPMAN STONE AGAR	0.2643	0.064
SHAEDLER AGAR	0.2635	0.067

Table 2
Recovery of Serratia Marcescens on Selected Media

MEDIA	CFU/Total	Standard Error
TSA	0.01405	0.0028
½TSA+6% TREHALOSE	0.07167	0.01112
YEAST+0.04% CYSTEINE	0.07117	0.05621
TSA+0.04% CYSTEINE	0.06789	0.01766
TSA+2mM BETAINE	0.06789	0.02295
½TSA	0.04036	0.01835
YEAST+2mM Betaine+0.04% CS	0.03875	0.01612
TSA+50mM INOSITOL	0.026	0.00271
½TSA+2mM BETAINE	0.02944	0.01066
½TSA+0.04% CYSTEINE	0.01761	0.00874
½TSA+8% TREHALOSE	0.01761	0.01116
YEAST EXTRACT AGAR	0.01639	0.00557
YEAST+2mM BETAINE	0.01577	0.00665
MSA+0.04% CYSTEINE	0.01503	0.00171
MSA+50mM INOSITOL	0.01445	0.00377
½TSA+4% TREHALOSE	0.01417	0.00566
MSA+2mM BETAINE	0.01411	0.00162
c TSA	0.01358	0.0471
½TSA+2% TREHALSOE	0.01307	0.051

Additional media which can recover a broader spectrum of airborne bacteria are being developed and tested. (EPA Contact: Gerard Stelma, HERD, 513-569-7384)

Irritation of the Nasal Septum

Many indoor air pollutants affect the body by entering the blood stream and impairing the normal function of organs (a systemic mechanism). Many indoor air pollutants are also irritating to the nose and eyes. A person's ability to perform tasks can be affected by both a systemic mechanism and by sensory irritation (a peripheral mechanism). Usually, a study of a pollutant's effects on task performance involves both systemic and peripheral mechanisms.

To understand the observed effects of an indoor air pollutant, it would be desirable to know the relative contribution of each mechanism. It is possible, for instance, that the peripheral mechanism would produce effects on one class of tasks and the systemic mechanism would affect another class. Similarly, low exposure could involve mainly one, while high exposure could involve mainly the other, or both, mechanisms. It is also possible that a peripheral and systemic mechanism could produce opposing effects. An EPA research project is studying the effects of purely sensory irritation, without concomitant systemic effects.

The study is addressing nasal irritation, as opposed to eye only or both. To produce a nasal irritation usually involves injection of an irritant chemical into the nose, a process that is difficult to control and quantify as well as mechanically cumbersome. A new method of electrical stimulation of the nerve endings which are responsible for sensory irritation is being developed to avoid the problems with chemical stimulation. Small (0.5 cm) metal disks are placed on each side of the nasal septum and held in place by a weak spring clip. Small alternating electrical currents are delivered via the disks with the goal of producing a burning or irritating sensation, but at an intensity so low that tissue damage does not result. One of the other effects of electrical stimulation of body tissues is to produce involuntary muscle twitch or tremor. Muscle tremor would be undesirable because it would not well simulate chemical stimulation.

Human subjects were required to press a button when they first noticed either irritation or muscle tremor while electrical stimulation was presented. Figure 5 gives the observed relative electrical current strengths needed for each in the nasal septum.

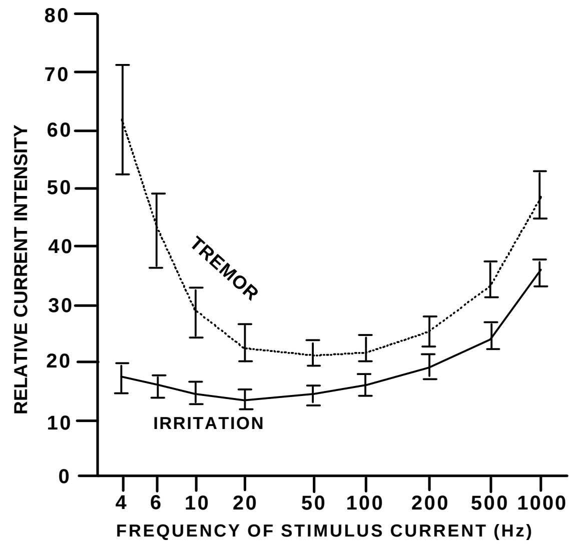

Figure 5 Relative Electrical Current Strength Required to Produce Irritation or Tremor in the Nasal Septum as a Function of Frequency or Electrical Current

Note that stimulation below 6 - 10 Hz produces irritation at relatively low intensities whereas production of muscle tremor requires much more current. At higher frequencies the thresholds for each phenomenon were not found to be so widely separated. Electrical currents of 4 Hz are to be used for future work. Magnitude and similarity estimates are also planned comparing electrical stimulation with more traditional chemical stimulation.

One of the major effects of irritation is expected to be distraction from task performance Such distraction could interfere with attention, memory, and cognition. Experiments are being conducted in which distractions (noises) are being presented to people in a effort to produce disruption. Such parameters as probability of signal presentation and various task instructions are being tested to find ways of making tasks more sensitive to disruption. When task standardization is complete, the tasks will be used to test the effect of various intensities of irritation as produced by electrical stimulation of the nasal septum. (EPA Contact: Vernon A. Benignus, NHEERL, 919-966-6242)

Solutions Research

EPA Researches Office Equipment

EPA, Research Triangle Institute, and Underwriters Laboratories are working together with industry to identify and evaluate pollution prevention opportunities to reduce indoor air emissions from office equipment. The project includes:

- conducting a literature review on indoor air emissions from office equipment,
- developing standard test guidance to characterize indoor air emissions from office equipment,
- measuring indoor air emissions from selected types of office equipment, and
- identifying and evaluating pollution prevention approaches for reducing indoor air emissions from office equipment.

The literature review has been completed, and a standard test method is being developed. Currently, indoor air emissions from dry-process photocopy machines are being evaluated. The remainder of this article discusses project progress to date.

Literature Review-The literature review, *Office Equipment: Design, Indoor Air Emissions, and Pollution Prevention Opportunities* (EPA-600/R-95-045, NTIS PB95-191375, March 1995), summarizes information on office equipment design; indoor air emissions of organics, ozone, and particulates from office equipment; and potential pollution prevention approaches for reducing these emissions.

The report covers 1) dry and wet process photoimaging machines (copiers, printers, and faxes); 2) spirit duplicators; 3) mimeograph machines; 4) digital duplicators; 5) diazo (blueprint) machines; 6) computers; 7) impact matrix printers; and 8) other equipment types. Photoimaging machines are emphasized in the report because of their prevalence and potential opportunities for pollution prevention.

Emissions from office equipment result from operation, offgassing from components, or episodic releases related to catastrophic failure of a unit. For equipment that does not use supplies (e.g., video display terminals, VDTs), emissions are primarily from offgassing of residual organics. The source can be either construction materials (e.g., plastic casings) or components (e.g., circuit boards). Emissions from offgassing decrease with time. For VDTs, over 300 hours of "on time" is normally required before emissions reach a negligible level.

Equipment that uses supplies (e.g., toner, ink, and paper) has emissions from both offgassing and operation. Emissions from offgassing will decrease with time; however, emissions from operation will either remain fairly constant or may even increase between routine maintenance and as the equipment ages. For example, ozone emissions from five tested photocopiers ranged from 16 to 131 µg/copy before routine maintenance and were reduced to less than 1 to 4 µg/copy after maintenance.

Published data on emissions from office equipment are limited. However, increased levels of ozone, TVOCs, and particulates have been observed in the presence of operating office equipment. One researcher measured increased levels of ozone, formaldehyde, TVOC, and particulates in a chamber evaluation (three personal computers, one photocopier, and one laser printer). Thirty human subjects participating in the experiment had a significantly increased perception of headache, mucous membrane irritation, and dryness in the eyes, nose, and throat as well as dry and tight facial skin when exposed to the operating equipment in the chamber. Other researchers have also reported that emissions associated with normal operation of office equipment can contribute to increased indoor air pollutant concentrations and complaints by exposed workers.

Table 3 summarizes published emission rates, IAQ impacts, and potential pollution prevention solutions associated with some of the equipment types discussed in the literature review.

Development of Standard Test Guidance-In cooperation with industry, a guidance document for measuring indoor air emissions from office equipment is being developed. The test method is designed to be analytically sensitive and generally applicable to all types of office equipment. It is intended to characterize emissions, to support identification of potential pollution prevention strategies, and to promote uniform testing.

Flow-through dynamic test chambers have been selected because they are generally applicable to all types of equipment and provide the most versatile data. A technical paper detailing the test guidance will be presented at, and included in the proceedings of, the upcoming symposium, *Engineering Solutions to Indoor Air Quality Problems*.

Measurement of Emissions-Research Triangle Institute, in cooperation with several equipment manufacturers and private testing companies, will be conducting a round-robin validation of the test method this summer. Emissions from three different dry-process photocopy machines will be measured with two primary objectives: 1) to evaluate the test method so that it can be readily adapted for use by industry, and 2) to identify the root causes of indoor air emissions from dry-process photocopy machines and to develop pollution prevention solutions to reduce these emissions. Dry-process photocopy machines were selected for this initial evaluation because they are prevalent in most office environments and are a known source of ozone (up to 158 µg/sheet or 1350 µg/min), particulate, and VOCs (up to 16 µg/sheet) emissions. (EPA Contact: Kelly Leovic, APPCD, 919-541-7717)

Table 3 Summary of Office Equipment Emissions From Literature Review *

Type of Equipment	Emissions	Emission Rates (from various studies)	Potential Pollution Prevention Solutions
Dry-process photocopying machines	Hydrocarbons, respirable suspended particulates (toner powder), and ozone	O_3: Average 40 μg/copy; peak production 131 μg/copy; 0-1350 μg/copy, average - 259 μg/min; 48-158 μg/copy; <4-54 μg/copy Particulate: 0.001 $\mu g/m^3$ room concentration of black carbon; 90-460 $\mu g/m^3$ in exhaust air TVOC: 0.5-16.4 μg/sheet from paper	Lower voltage to reduce ozone, toner reformulation, improved transfer efficiency, low maintenance machines, lower fuser temperature, changes in toner particle size, low-emitting components.
Laser printers	Hydrocarbons, respirable particulates, and ozone	O_3: 100-4,000 $\mu g/m^3$ room concentration; average 438 μg/min 100 μg/min (w/filter) Particulate: 60 $\mu g/m^3$ TVOC: 2.0-6.5 μg/sheet from paper	Same as for dry-process photocopying machines
Computer terminals	Ozone and off-gassing VOCs	Limited published data, TVOC: Maximum of 175 μg/hour from VDT drops quickly within 300 hours of on time	Low-emitting materials and/or lower voltage, low-emitting materials for cards used in integrated circuit boards
Wet-process photocopying machines	Aliphatic hydrocarbons and ozone	TVOC: 25 g/h, 0.241 g/copy observed, high room concentration of 64 mg/m^3, 4,150 mg/m^3 in exhaust air	Solvent reformulation, pressure fusing, decrease voltage, low-emitting components
Ink/bubble jet printers	Hydrocarbons and ozone	No published emission rate or IAQ data	Solvent reformulation, low-emitting components
Spirit duplicators	Methanol	Breathing zone concentrations of 40-635 ppm; 195-3,000 ppm with no ventilation, 80-1,300 ppm with ventilation, and 9-135 ppm with enclosure and ventilation	Mineral spirits or replacement with photocopiers
Mimeograph machines	Hydrotreated heavy and light naphthenic distillates	Heavy naphthenic distillate, 30 mg/page, 10 mg/page light naphthenic distillate	Ink reformulation, replacement with photocopiers or other technologies
Fax machines	Ozone and VOCs	No published emissions rate or IAQ data	Same as for dry-process photocopying machines
Digital duplicators	VOCs–petroleum solvent and ethylene glycol	Combined VOCs: 20 mg/page	Lower VOC inks, replacement with photocopiers
Blueprint machines (dyeline)	Ammonia, carbon monoxide, methanol, ethanol, trinitrofluorene, and trichloroethane	1-40 ppm ammonia in breathing zone of operator, average – 8.2 ppm	Computer Aided Design/alternative technologies, improved maintenance

* (Source: *Office Equipment: Design, Indoor Air Emissions, and Pollution Prevention Opportunities*, EPA-600/R-95-045, NTIS PB95-191375, March 1995)

Solutions Research

Evaluation of Fungal Growth on Ceiling Tiles

Fungal growth on ceiling tiles is one of the major causes of IAQ problems. Suspended ceiling tiles have been extensively used in offices, schools, hospitals, and commercial buildings, and after installation, there is often no cleaning or maintenance. The ceiling tiles are subject to dust accumulation and water intrusion from plumbing leaks and from condensation. This frequently leads to microbial (fungi and bacteria) growth on the tiles. The fungal growth can result in destruction of the tiles and in indoor air contamination by emitting spores and VOCs.

APPCD evaluated the potential for fungal growth on four different types of ceiling tiles using static chambers. Two of the predominant genera of allergenic fungi found in indoor problem environments are *Penicillium* and *Aspergillus*. Three species, *P. glabrum*, *P. chrysogenum*, and *A. niger*, representative of these two genera, were selected as test microorganisms. All ceiling tiles were purchased as 30.5 x 61 cm boards and cut into 3.8 cm squares. The pieces of tiles were sterilized by autoclaving before inoculation. After being inoculated with the test microorganisms, the ceiling tile samples were placed in the chamber at the desired RH and temperature.

Figure 6 shows the static chamber test results for new Class A tiles inoculated with *P. glabrum*. No growth of *P. glabrum* was obtained in chambers with an equilibrium RH of 85% or less. Significant growth of *P. glabrum* was obtained in chambers with equilibrium RH at 90% or greater. Therefore, the minimum equilibrium RH at which growth of *P. glabrum* was initiated was between 85 and 90%. Other ceiling tiles and test microorganisms were also evaluated by the same procedures.

It was found that even new ceiling tiles could support fungal growth under favorable conditions. Used ceiling tiles appeared to be more susceptible to fungal growth than the new ones. It was suspected that better nutrient supply from the dust accumulated on the used tiles facilitated the fungal growth. The minimum equilibrium RH at which growth occurred for these materials and organisms was always above the currently recommended 60% from the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 55-92 for indoor environments. Therefore, maintaining a building at below 60% RH can help prevent the growth of the molds tested provided no other sources of water (i.e., from condensation or leaks) are available. However, when there is a water source to wet the ceiling tiles, even if the RH is below 85%, fungi could still proliferate as long as the moisture content in the ceiling tiles was adequate. Episodes of fungal growth could be avoided if the wetted ceiling tiles were dried quickly and thoroughly. (EPA Contact: John Chang, APPCD, 919-541-3747)

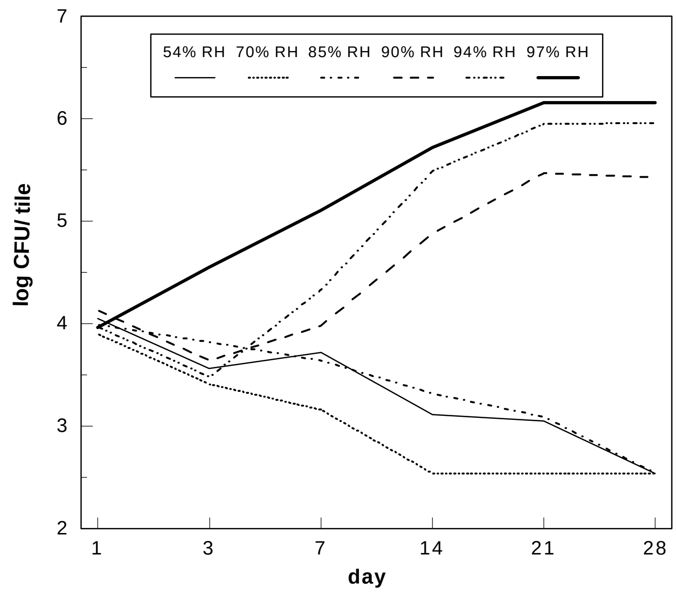

Figure 6 *Penicillium Glabrum* Growth on Chamber-Conditioned New Class A Ceiling Tiles

Solutions Research

Influence of Climatic Factors on House Dust Mites

House dust mites cause perennial allergies in dust-sensitive individuals. In the U.S., the dust mites most commonly found in homes are *Dermatophagoides farinae* (DF), *D. pteronyssinus* (DP), and *Euroglyphus maynei* (EM). DF and DP are cosmopolitan, while EM is limited to the southern U.S. Most homes are co-inhabited by both DF and DP or by DF, DP, and EM, but some homes in a geographical area may contain only DF or DP. In co-inhabited homes, one species is predominant and usually makes up greater than 75% of the total dust mite population. The dominant or only species present varies between homes within a geographical area. In a given geographical area, some homes contain large mite densities, while others contain low or no mite densities.

It is not clear what factors contribute to the development of large mite populations in a home or what factors favor one species over the others. As a result, a research project has been initiated to: 1) identify climatic factors that favor development of a large population of each species or one mite species over another, 2) determine the role temperature and RH play on the fecundity, development, and population dynamics of dust mites, and 3) identify key factors that can be manipulated to control mite and allergen levels in homes and thus manage these allergies. (EPA Contact: John Chang, APPCD, 919-541-3747)

Ventilation Research Program

Heating, ventilating, and air-conditioning (HVAC) systems play a major role in determining the quality of the indoor environment. The lack of proper thermal comfort can often result in the perception of poor IAQ by the occupants. A typical complaint is that the air is too "stuffy." Sore and irritated throats and eyes are often a result of insufficient RH control. Inadequate levels of outdoor air are most often blamed for poor IAQ. The literature is filled with studies that document the many problems associated with HVAC systems that result in unacceptable IAQ: poor design and construction practices, insufficient ventilation rates, lack of proper operational and maintenance procedures, and others. Many of these problems can be avoided by combining good engineering practice with appropriate indoor source management. EPA is currently conducting research into ventilation systems. Its focus is to increase our understanding of how HVAC system design and application can be combined with source management strategies to reduce exposure.

Currently the research activities are devoted to the following areas: large buildings studies, air duct cleaning, HVAC pollution sources, gas-phase filtration, and energy and IAQ studies. A brief description of each follows.

! Field studies in large buildings are an important aspect of the research program. In order for designers to fully understand the implications of providing acceptable indoor environments, a good understanding of HVAC performance characteristics and the impact on IAQ is essential. Field studies are currently being performed in various large buildings located in different geographical areas of the U.S. to fully understand and demonstrate accepted ventilation standards, such as ASHRAE Standard 62-1989, Ventilation for Acceptable Indoor Air Quality.

! Air duct cleaning is a new area of research for EPA. Working with industry representatives, the APPCD is investigating the effect that cleaning has on IAQ and energy consumption. Additional concerns are cleaning technologies and techniques. A test facility is being designed and constructed to provide information to the public and the industry. A field study of residential cleaning procedures and techniques will also be carried out. (See related article on page 10.)

! Traditionally, HVAC systems have always been considered to be a part of the solution to poor IAQ since one of its primary functions is to introduce outdoor air for dilution and odor control. Recent studies have indicated that in many cases the HVAC system can be a part of the problem. Table 4 shows emissions sources and typical problems associated with HVAC systems. Many HVAC system components can act as direct or indirect sources of particles and/or VOCs. Most prominent is the occurrence of biological growth and bioaerosol generation in the presence of moisture provided by air washers and other recirculating water systems, inadequate humidity control, poorly designed humidifying systems, insufficient cooling coil maintenance, and condensate drain pans. EPA is currently conducting research into these areas to identify and quantify sources of indoor pollution from HVAC systems. Most of this work is being done cooperatively with ASHRAE.

! The proper use of gas-phase filtration equipment to provide good IAQ is an area of increasing interest by IAQ practitioners. How to field test the effectiveness of these devices is an obstacle to their application. Working with ASHRAE, research into field test methods is currently being performed. The objectives are to provide design engineers with information on proper design and application of gas-phase filtration for IAQ.

! An important consideration in the Ventilation Research Program is the energy costs to implement ventilation standards. This is especially important in geographical areas that are subject to hot and humid conditions and where operating and energy costs can increase due to increased outdoor air usage. Research into these costs is currently being performed in a large building in Florida. The objective is to determine the incremental costs associated with varying the quantity of outdoor air. Variations in outdoor air range from 5 to 20 cfm/person (0.142 to 0.566 m^3/m/person). Computer simulations and field verification are utilized to understand the energy impacts.

Acceptable IAQ is a rising expectation by the general public. It is the overall goal of the Ventilation Research Program to utilize its resources and expertise to reduce indoor human exposure by providing improved HVAC systems that are energy conserving and that provide healthful productive environments (EPA Contact: Russell N. Kulp, APPCD, 919-541-7980)

IAQ Information Clearinghouse

Additional information on indoor air is available through the Indoor Air Quality Information Clearinghouse maintained by EPA's Indoor Air Division. The Clearinghouse can be contacted by phone at 800-438-4318 or 301-585-9020, or by fax at 301-588-3408.

Table 4 Emission Sources and Problems Identified in HVAC Systems

SOURCES and PROBLEMS	***TYPICAL EXAMPLES***
Intrinsic emission sources	
Seals, Caulks, Adhesives	Offgassing of VOCs, deterioration
Fibers	Asbestos, fiber shedding
Metal degradation products	Deterioration and entrainment of coatings, platings, metal surfaces
Lubricating oils, etc.	Fans, motors in the air stream
Ozone	Release by electrostatic air cleaners
Emission sources resulting from contaminations	
Dust	Construction material, skin cells, etc., with accumulation possibly leading to microbial contamination, VOC sorption-desorption, and low flows
Other organic debris	Leaves, bird droppings
Growth of microoganisms	Growth and aerosolization of bioaerosols and VOCs from microorganisms at sites including: cooling coils, drain pans, drains, traps, sumps, filters, insulation, duct surfaces, plenums, humidifiers, evaporative coolers, cooling towers
VOC sinks	Filters, sound absorbers, insulation materials, deposited dust
Cleaning compounds and Biocides	Biocides, disinfectants, deodorizers
Boiler steam	Anticorrosives, biocides, slimicides, oxygen-scavenging or filming chemicals, anti-corrosives, pH control neutralizers
Design/operational effects on IAQ	
Entrainment and Re-entrainment	Leaks, polluted outdoor air, building exhaust
Rotary heat exchangers	Sorption-desorption of VOCs
Building pressurization	Intake of polluted outdoor air
Transport	Odor, VOC and particle migration
Climate control	High humidity
Ventilation and Air exchange	Inadequate dilution of internal sources, inadequate outdoor air
Cleaning procedures	Inadequate filter maintenance, clogged condensate drains and traps, open traps, inadequate access to air handling units

Solutions Research

EPA Begins Air Duct Cleaning Research

Can air duct cleaning improve IAQ? Can cleaning the HVAC system reduce operating costs? When should an HVAC system be cleaned? How effective is air duct cleaning? These are some of the questions that EPA will be investigating as part of a new research effort into IAQ and air duct cleaning (ADC). Working with representatives from the air duct cleaning industry and a number of insulation manufacturing companies, EPA is embarking on an initial 2-year ADC research program. The program will concentrate primarily on residential systems. Determining the impacts on IAQ and energy is the primary goal.

This research was prompted by a growing concern that consumers are sometimes led to believe that cleaning the home heating and air-conditioning (HAC) system can provide many benefits such as improved IAQ, increased energy efficiency, and prolonged system life. Currently there is little scientific data to support these claims.

To lay out this research plan, EPA held a workshop in December 1994. The workshop was attended by several industry groups, including: the National Air Duct Cleaning Association (NADCA), the Association of Specialists for Cleaning and Restoration, International (ASCR), and the North American Insulation Manufacturers Association (NAIMA). The primary focus of the workshop was to develop a plan for the EPA-funded ADC research. In the first year of research, EPA plans to design and construct a full scale residential system test facility, complete with air handling unit, supply and return air ductwork, registers and diffusers, and controls.

Using the test facility, EPA plans to test the effectiveness and impact of the three most commonly used cleaning technologies currently applied to non-porous and insulated surfaces: 1) contact vacuuming, 2) air washing, and 3) power brushing. Contact vacuuming generally involves the use of a portable vacuum cleaner that is hand-operated with direct contact between the brush head and the interior duct surfaces to dislodge and remove dirt and debris. Air washing introduces compressed air directly on the surface or component to loosen the dirt and debris. Power brushing uses rotating bristle brushes to directly loosen dirt and debris from the duct surface. In all of these methods, the duct section(s) being cleaned is subjected to negative pressure with a "negative air system." This allows the efficient collection and removal of all dislodged contaminants.
The test facility will include a commercially available residential HAC system. Early design discussions suggest the need for a 1.5 to 2 ton (18,000 to 24,000 Btuh) HAC system operating approximately at 400 to 600 cfm (11.3 to 17.0 m^3/m). The distribution system (ductwork and terminal units) will be designed with "slip-in, slip-out" features to allow different interior surfaces and configurations to be tested.

To perform these various cleaning experiments, the facility must first be "loaded" with a representative contaminant. To accomplish this, EPA has obtained actual duct dust from local ADC companies which will be used to load the system to predetermined levels. Once the system is loaded, tests can be performed to evaluate cleaning technologies on selected non-porous and insulated ductwork sections, or on selected system components such as heating and cooling coils.

In addition, energy consumption analyses will be performed to get a clearer idea of the level of energy savings. The workshop attendees were interested in performing microbiological mitigation tests and suggested introducing a selected microbiological contaminant into a section of ductwork or system component and performing evaluations of mitigating capabilities of the three cleaning technologies (biocides will not be tested). Most of what is done in the test facility will have to relate to the research planned for the second year. In the second year, EPA will perform a field study using nine actual homes. The purpose is to confirm and validate the test facility findings with field generated data. The homes that will be used in the field study will be selected using criteria developed by EPA and coordinated with industry. Some of the criteria that need to be considered are: 1) smoking or non-smoking, 2) pets or no pets, 3) HAC system type and configuration, and 4) age of the home. In addition, EPA has proposed using a local ADC company that is a NADCA member for the field study.

After the field study, industry has suggested looking at how commercial HVAC systems are cleaned and the IAQ and energy impacts. EPA agrees with this assessment and plans to continue to work with industry to assess and meet the research needs of the consumer and industry. (EPA Contact: Russell N. Kulp, APPCD, 919-541-7980)

<u>Solutions Research</u>

Cost Analysis of IAQ Control Techniques

This new project is developing practical guidance to help evaluate the cost-effectiveness of IAQ control techniques under different conditions. The guidance will provide criteria to help the user:

- select between IAQ control options (e.g., ventilation, air cleaning, and source management); or

- select the preferred design and operating characteristics within a given control option.

General guidance will be the near-term product of this cost analysis. Site-specific analysis will be required by the user in any particular application. For example, this guidance would address the following type of design question: for a given type of new office building, what is the general cost-effectiveness of the following alternative steps for reducing exposure to VOCs during initial degassing, or during VOC spills or other episodes?

- Alternative 1: Design the HVAC system for increased ventilation.

- Alternative 2: Incorporate provisions for VOC air cleaning.

- Alternative 3: Implement source management into the building design (e.g., source elimination, source substitution, or localized exhaust ventilation).

For this study, cost-effectiveness is defined as the incremental unit increase in life cycle cost per unit reduction in exposure, expressed as a function of the absolute reduction achieved in exposure.

The initial approach for this study will be to conduct a series of well-defined case studies addressing alternative building types. For each building type, a sensitivity analysis will be carried out, estimating the cost-effectiveness of the alternative IAQ control approaches as the following variables are systematically varied:

- building (e.g., floor plan, interior partitions);
- nature and location of sources (e.g., initial source term and decay rate);
- HVAC system (e.g., in existing systems, available excess coil and fan capacity, or space for incorporation of additional filter banks); and
- IAQ control system (e.g., the amount of additional ventilation to be provided, the capacity of the air cleaner, or the exact nature of the source management step).

The initial effort will include two components: 1) development of the preliminary methodology for the cost analysis; and 2) testing of this preliminary methodology, applying it to a specific case, to determine whether refinements to the methodology are necessary.

A number of tasks will be addressed in developing the preliminary methodology:

- Listing of the alternative classes of building types to be addressed, and their associated types of HVAC systems.
- Definition of the specific scenarios to be addressed during the study.
- Determination of the criteria for determining "effectiveness" (e.g., how exposure will be calculated, or what measures of exposure will be used).
- Determination of how the cost-effectiveness results and guidelines can best be presented.

The scenario for the initial case study to test this methodology will be a new small office building where ventilation, air cleaning, and source management are being weighed for VOC control during the building design.

The methodology development effort has begun with an initial effort to list the categories of commercial and institutional buildings to be considered. (Residential and industrial buildings are expected to be addressed in a later phase.) An initial listing of building categories is shown in Table 5. (EPA Contact: Bruce Henschel, APPCD, 919-541-4112)

Table 5 Categories of Commercial and Institutional Buildings Under Consideration for IAQ Cost Analysis Study

Building Category	Key Features
Commercial Office Space	
Single Office	1 story
Multiple Office	2 to 3 stories
Office Complex	4 to 7 stories
Office Tower	10+ stories
Educational	
Secondary School (Multiple Building)	1 to 2 story, detached buildings
Secondary School (Enclosed)	1 to 2 story, single building
College Building (Liberal Arts)	4 to 7 story classroom bldg. with no special HVAC requirements
College Building (Science)	4 to 7 story building with laboratories
Retail Sales and Service	
Specialty Store	1 story with no special HVAC requirements
Restaurant	1 story, kitchen
Auto Service Center	1 story building
General Merchandise	1 story building
Department Store	2+ stories
Strip Shopping Mall	
Enclosed Shopping Mall	

Building Category	Key Features
Medical Services	
Single Medical Office	1 story
Multiple Medical Offices	2 to 4 stories
Community Hospital	1 to 3 stories <100 beds
Medical Center	4 to 10 stories >100 beds
Extended Medical Care Facility	1 to 10 stories, patients needing minimal care
Nursing Care Retirement Facility	1 floor, daily nursing care
Entertainment/Recreation	
Sports Recreation Facility	1 or 2 story, health club
Theater/Auditorium	1 story, seating 200+
Arena	Seating 10,000+
Lodging	
Motel	1 to 2 story, detached buildings
Hotel	Multi-story single building
Transportation	
Rail/Bus Terminal	
Airport Terminal	
Enclosed Parking Garage	
Correctional Facilities	
Prison	

Summaries of Recent Publications

This section provides summaries of recent publications by EPA's Indoor Air Research Program. The summaries are organized into the following sections: Source Characterization and Solutions. The source of the publication is listed with each summary. Publications with NTIS numbers are available (prepaid) from the National Technical Information Service at: 5285 Port Royal Road, Springfield VA 22161, 703-487-4650 or 800-553-6847.

Source Characterization

Comparing the Field and Laboratory Emission Cell (FLEC) with Traditional Emissions Testing Chambers - Performance of the FLEC was evaluated as applied to emissions from floor wax and latex paint. Tests included validation of the repeatability of the test method, evaluation of the effect of different air velocities on source emissions, and a comparison of FLEC versus small chamber characterization of emissions. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author: Nancy F. Roache, EPA Contact: Bruce A. Tichenor, 919-541-2991)

Considerations on Revisions of Emissions Testing Protocols - The ASTM Standard Guide for Small-Scale Environmental Chamber Determinations of Organic Emissions from Indoor Materials/Products (D 5116) was first published in 1990 and is due for review and revision in 1995. This paper addresses several issues that should be considered in the revision: the effect of air velocity on emissions; the "edge effect" (e.g., substrate size can affect emission rate); emission factor estimation (e.g., to include a wider range of models and different methods by which the model parameters are determined); and loss of volatile components from the source during sample preparation. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author: Zhishi Guo, EPA Contact: Bruce A. Tichenor, 919-541-2991)

Evaluation of Emissions from Latex Paint - This paper discusses EPA research on the evaluation of indoor air emissions from latex paint. (See related article "Evaluation of Emissions from Latex Paint," on page 2.) Source: Proceedings of Low- and No-VOC Coating Technologies 2nd Biennial International Conference, March 13-15, 1995, Durham, NC. (Lead Author & EPA Contact: Bruce A. Tichenor, 919-541-2991)

Indoor Air Research: Characterizing Air Emissions from Indoor Sources - This brochure provides an overview of EPA's indoor air source characterization research. Source: EPA Publication EPA/600/F-95/005, February 1995. (Lead Author & EPA Contact: Kelly Leovic, 919-541-7717)

Overview of Source/Sink Characterization Methods - Methods and models for characterizing indoor sources and sinks are discussed in this paper. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author & EPA Contact: Bruce A. Tichenor, 919-541-2991)

Design and Characterization of a Small Chamber for Chemical and Biological Evaluation of Sources of Indoor Air Contamination - A 34 L source emissions chamber that can be used in determining chemical emissions and biological response to product emissions was evaluated. The chamber, which mates directly to the 2.3 L mouse exposure chamber specified by ASTM E981-84, was found to be without significant leaks and background emissions that have been noted in experiments using aquariums as chambers. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author & EPA Contact: Mark A. Mason, 919-541-4835)

Source Testing and Data Analysis for Exposure and Risk Assessment of Indoor Pollutant Sources-Ideally, experiments to determine source emissions should run long enough to capture all of the emissions from the source. Unfortunately, such testing is not practical for many types of sources such as pressed wood products and many other building materials. In these cases, the source emission models and consequent risk assessment must be based on incomplete knowledge of the total source emissions. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author & EPA Contact: Leslie E. Sparks, 919-541-2458)

Solutions

Air Infiltration Measurements Using Tracer Gases: A Literature Review - This is a literature review of air infiltration measurements using tracer gases, including sulfur hexafluoride, hydrogen, carbon monoxide, carbon dioxide, nitrous oxide, and radioactive argon and krypton. Sulfur hexafluoride is the most common tracer gas, primarily because its presence may be accurately measured in the ppb range, while most of the other gases used may be accurately measured in the ppm range. The report also describes a computer-controlled injection system. Source: EPA Report, EPA/600/R-95/013 (NTIS PB95-173225), January 1995. (Lead Author, Max M. Samfield; EPA Contact: David Sanchez, 919-541-2979)

Characterization of Environmental Chambers for Evaluating Microbial Growth on Building Materials - This chapter discusses the development of prevention and control strategies for biocontaminants in indoor air using static chambers with characterized environmental conditions of RH, temperature, and light to study the ability of fungi to grow on a variety of building materials. Duplicate chambers were prepared for each RH: 33%, 54%, 70%, 85%, and 97%, and the growth of *Penicillium glabrum* on aged ceiling tile removed from offices was studied. The second series of tests used wetted block, representing ceiling tiles involved in flooding or other events, under two sets of conditions. In the first condition, the air inside the chambers was quiescent, while the second condition involved slight air movement. Additional tests using the static chambers should identify limiting environmental factors for multiple microorganisms and a variety of building materials. Source: Health Implications of Fungi in Indoor Environments, Air Quality Monographs-Vol. 2, Elsevier, 1994. (Lead Author: K. K. Foarde; EPA Contact: John C. S. Chang, 919-541-3747)

Design and Operation of a Dynamic Test Chamber for Measurement of Biocontaminant Pollutant Emission and Control - A room-size dynamic test chamber has been constructed to study the conditions and factors that influence biocontaminant emissions and dissemination. The chamber was designed to conduct three types of microbiological experiments: 1) growth on various building materials, 2) emission and deposition experiments, and 3) both room-type and in-duct tests of air cleaners. Protocols for aerosol dispersion, uniformity evaluation, and flow and air exchange characterization are discussed along with a microbiological decontamination protocol. Source: Proceedings of ASTM Symposium "Methods for Characterizing Indoor Sources and Sinks," Sept. 25-28, 1994, Washington, D.C. (Lead Author: Douglas W. VanOsdell; EPA Contact: John C. S. Chang, 919-541-3747)

Development of a Lumped-Parameter Model of Indoor Radon Concentrations - The report describes a simplified, lumped-parameter model to characterize indoor radon concentrations from data that are more readily available than those required for existing mathematical models. The lumped-parameter model was developed from numerous sensitivity analyses with the more detailed *RA*don *E*manation and *TRA*nsport into *D*wellings (RAETRAD) model and from analyses of trends from empirical data sets. The model analyses established radon dependence on soil parameters, house size, floor cracks and openings, and indoor air pressures. Source: EPA Report, EPA/600/R-94/201 (NTIS PB95-142048), November 1994. (Lead Author: Kirk K. Nielson; EPA Contact: David Sanchez, 919-541-2979)

EPA Radon Mitigation Research Update - This publication highlights EPA's research on radon mitigation. It provides the radon mitigation community with timely and useful information in five research areas: Innovative and Supporting Research, Existing Houses, New House Construction, Schools and Other Large Buildings, and Ventilation. Source: EPA Publication, EPA/600/N-94/011, August 1994. (Lead Author & EPA Contact: Kelly Leovic, 919-541-7717)

Evaluation of Fungal Growth (*Penicillium Glabrum*) on a Ceiling Tile - Laboratory research employing static chambers is studying the impact of different equilibrium RHs and moisture conditions on the ability of a new ceiling tile to support fungal growth. Amplification of the mold, *Penicillium glabrum*, occurred at RHs above 85 to 90%. Conversely, at lower RHs, decreases were detected. The issue of survival vs.die-off may be important in the control of fungal contamination in building materials. Source: In Proceedings of "Indoor Air: An Integrated Approach," Gold Coast, Australia, Nov. 27-Dec. 1, 1994 (Lead Author & EPA Contact: John C. S. Chang, 919-541-3747)

Feasibility of Characterizing Concealed Openings in the House-Soil Interface for Modeling Radon Gas Entry - This report examines the feasibility of characterizing the total effective size of openings in the house-soil interface that permit indoor radon entry. Since many of these foundation openings are concealed by the building structure or consist of porous regions, they are characterized indirectly by their radon permeability rather than by direct observation. A lumped parameter model, based on the detailed RAETRAD model for radon entry, is the basis of the feasibility study. Sensitivity analyses conducted with the lumped-parameter model demonstrate a characteristic pattern of increasing indoor radon concentrations with increasingly negative indoor air pressures. With sensitivity analyses, the lumped-parameter model indicates that the dominant parameters affecting indoor radon levels are the size of the foundation openings, the pressure-driven radon entry velocity, and the ventilation parameters for the house superstructure. Source: EPA Report, EPA-600/R-95-020 (NTIS PB95-178414), February 1995. (Lead Author: Kirk K. Nielson; EPA Contact: David Sanchez, 919-541-2979)

HVAC Systems as Emission Sources Affecting Indoor Air Quality: A Critical Review - A critique of the literature reveals that few studies are well-controlled, comprehensive, and quantitative. Significant gaps in the data are highlighted and procedures are suggested to improve the characterization of bioaerosol and VOC emissions sources. Based on the available literature, several HVAC components are cited fairly frequently as emission sources, and there is broad agreement regarding their significance. The components include biological growth and bioaerosol generation in the presence of moisture provided by air washers and other recirculating water systems, poor humidity control, poorly designed humidifying systems, and poorly maintained cooling coils and drip pans. IAQ problems appear to be exacerbated by dust accumulation and by the presence of fibrous insulation. The importance of good design and operation of HVAC systems, including the appropriate placement and maintenance of air intakes, building pressurization, and local exhaust in source areas, is also well accepted. More limited data implicate dust (resulting from inadequate filtration maintenance of filters) as a sink and secondary source for VOCs. Source: EPA Report, EPA-600/R-95-014 (NTIS PB95-178596), February 1995. (Lead Author Stuart Batterman. EPA Contact: Russell N. Kulp, 919-541-7980)

Office Equipment: Design, Indoor Air Emissions, and Pollution Prevention Opportunities - The report summarizes available information in the literature on office equipment design; indoor air emissions of organics, ozone, and particulates from office equipment; and pollution prevention approaches for reducing these emissions. Dry and wet process photoimaging machines (copiers, printers, and faxes), spirit duplicators, mimeograph machines, digital duplicators, diazo (blueprint) machines, computers and computer terminals, and impact matrix printers are covered. (See related article, “EPA Researches Office Equipment” on page 6.) Source: EPA Report, EPA-600/R-95-045 (NTIS PB95-191375), March 1995. (Lead Author: Bob Hetes; EPA Contact: Kelly Leovic, 919-541-7717)

Radon Generation and Transport in Aged Concrete - This report gives results of a characterization of radon generation and transport in Florida concretes sampled from 12- to 45-year-old residential slabs. It also compares measurements from the aged concrete samples to previous measurements on newly poured Florida residential concretes. Radon generation in the aged slabs is characterized in terms of concrete radium concentrations and radon emanation coefficients, and radon transport is characterized by radon diffusion coefficients and air permeability coefficients. Source: EPA Report, EPA-600/R-95-032 (NTIS PB95-181590), February 1995. (Lead Author: Vern C. Rogers; EPA Contact: David Sanchez, 919-541-2979)

Radon Generation and Transport Through Concrete Foundations - The Florida Radon Research Program (FRRP), sponsored by EPA and the Florida Department of Community Affairs, is developing the technical basis for a radon-control construction standard. Results of the research conducted under the FRRP are presented in several technical reports. This report summarizes a project that examined radon generation and transport through Florida residential concretes. The concretes are characterized by radium concentrations, radon emanation coefficients, radon diffusion coefficients, and permeability coefficients. Source: EPA Report, EPA/600/R-94/175 (NTIS PB95-101218), September 1994. (Lead Author: Vern C. Rogers; EPA Contact: David Sanchez, 919-541-2979)

Radon Mitigation Research: Improved Technology for Environmental Protection - This brochure summarizes the impact of EPA’s research on radon mitigation in the U.S. It also includes background information on radon and radon mitigation. Source: EPA Report, EPA/600/F-94/035. (Lead Author and EPA Contact, Kelly Leovic, APPCD, 919-541-7717)

The RAETRAD Model of Radon Gas Generation, Transport, and Indoor Entry - The report describes the theoretical basis, implementation, and validation of the RAETRAD model, a conceptual and mathematical approach for simulating radon (^{222}Rn) gas generation and transport from soils and building foundations to the indoor environment. It has been implemented in a computer code of the same name to provide a relatively simple, inexpensive means of estimating indoor radon entry rates and concentrations. Source: EPA Report, EPA/600/R-94/198 (NTIS PB95-142030), November 1994. (Lead Author: K. K. Nielson; EPA Contact: David Sanchez, 919-541-2979)

RAETRAD Version 3.1 User Manual - This report is a user’s manual for the RAETRAD computer code. RAETRAD is a two-dimensional numerical model to simulate radon entry and accumulation in houses from its calculated generation in soils, floor slabs, and footings and its movement by diffusion and advection through soil and concrete pores and openings. User input defines nominal house size and foundation parameters, concrete properties, and soil properties, including their distributions of radium, moisture, and related properties. Source: EPA Report, EPA/600/R-94/195 (NTIS PB95-139689), November 1994. (Lead Author: Kirk K. Nielson; EPA Contact: David Sanchez, 919-541-2979)

Soil Radon Potential Mapping of Twelve Counties in North-Central Florida - This report describes the approach, methods, and detailed data used to prepare soil radon potential maps of 12 counties in North-Central Florida. The maps were developed under the FRRP to provide a scientific basis for implementing radon-protective building construction standards in areas of elevated risk and avoiding unnecessary regulations in areas of low radon risk. Source: EPA Report, EPA/600/R-94/218 (NTIS PB95-159869), December 1994. (Lead Author: Kirk K. Nielson; EPA Contact: David Sanchez, 919-541-2979)

Glossary of Acronyms

ADC-Air Duct Cleaning
AEERL-Air and Energy Engineering Research Laboratory (now APPCD)
AHU-Air Handling Unit
APPCD-Air Pollution Prevention and Control Division
AREAL-Atmospheric Research & Exposure Assessment Laboratory (now HEFRD)
ASCR-Association of Specialists for Cleaning, Restoration, International
ASHRAE-American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASTM-American Society for Testing & Materials
A&WMA-Air and Waste Management Association
BEE-Butoxyethoxyethanol
CFU-Colony Forming Unit
DF-Dermatophagoides farinae
DP-D. pteronyssinus
ECAO-Environmental Criteria and Assessment Office (now NCEA)
EM-Euroglyphus maynei
EMSL-Environmental Monitoring Systems Laboratory (now HERD)
EPA-U.S. Environmental Protection Agency
FLEC-Field and Laboratory Emissions Cell
FRRP-Florida Radon Research Program
HAC- Heating and Air-Conditioning
HEFRD-Human Exposure and Field Research Division
HERD-Human Exposure Research Division
HERL-Health Effects Research Laboratory (now NHEERL)
HVAC-Heating, Ventilating, and Air-Conditioning
IAQ-Indoor Air Quality
NADCA-National Air Duct Cleaning Association
NAIMA-North American Insulation Manufacturers Association
NCEA-National Center for Environmental Assessment
NERL-National Exposure Research Laboratory
NHEERL-National Health and Environmental Effects Research Laboratory
NRMRL-National Risk Management Research Laboratory
NTIS-National Technical Information Service
ORD-Office of Research and Development
RAETRAD-Radon Emanation and Transport into Dwellings
RH-Relative Humidity
TSA-Trypticase Soy Agar
TVOC-Total Volatile Organic Compound
VDT-Video Display Terminal
VOC-Volatile Organic Compound

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