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Inside IAQ

EPA's Indoor Air Quality Research Update

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(See Page 12 for Call for Papers)

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Inside IAQ is distributed twice a year by the Office of Research and Development's National Risk Management Research Laboratory's (NRMRL) Air Pollution Prevention and Control Division (APPCD). Indoor air quality (IAQ) research conducted by APPCD's Indoor Environment Management Branch (IEMB) is highlighted. If you would like to be added to or removed from the mailing list, please mail, fax, or e-mail your name and address to:

Inside IAQ, Attn. Kelly Leovic
U.S. EPA (MD-54)
Research Triangle Park, NC 27711
Fax: 919-541-2157
E-mail: kleovic@engineer.aeerl.epa.gov

IEMB's LARGE CHAMBER

IEMB has designed and installed a state-of-the-art large chamber in their Research Triangle Park Facility. The room-sized (30-m^3) stainless steel test chamber and sophisticated analytical instrumentation will permit characterization of emissions from products and processes that cannot readily be studied using small chambers. The new facility will enable researchers to study, under highly controlled environmental conditions, indoor pollution episodes such as interior painting and use of other consumer products that impact IAQ. These types of processes often result in high initial personal exposures and also load other surfaces (i.e., sinks) such as carpets, wall coverings, and ceiling tiles with pollutants that may be re-emitted to the indoor air over a long period of time.

The test chamber's versatile air distribution system (Figure 1) permits researchers to simulate home or office air distribution patterns and test in-room and in-duct air cleaning devices. System design permits single pass, partial, or complete recirculation of highly filtered air that is supplied to the chamber through glass ducting. Chamber temperature, air exchange rate, relative humidity (RH), and pressure are automatically set and controlled by a computer.

Many of the basic elements of the large chamber design have been incorporated into large chambers constructed in Canada and Australia. Initial experiments conducted in the large chamber will include tests to evaluate the performance of EPA's chamber and determine comparability with these other chambers. Future collaborative research will be directed toward development and validation of test methods and indoor air models as well as investigation of important sources and control strategies.

Currently, IEMB is conducting tests to fine tune the chamber. Tests that are underway are designed to evaluate critical factors that may influence experiments. These tests are designed to evaluate the 1) ability of the chamber control system to maintain a wide variety of temperature and RH set points; 2) air velocities within the chamber at different flow conditions; 3) mixing of pollutants at low, elevated, and normal temperatures and at high and low air flow rates; and 4) adsorption of volatile organic compounds (VOCs) by chamber walls, air duct walls, and components of the air-conditioning system.

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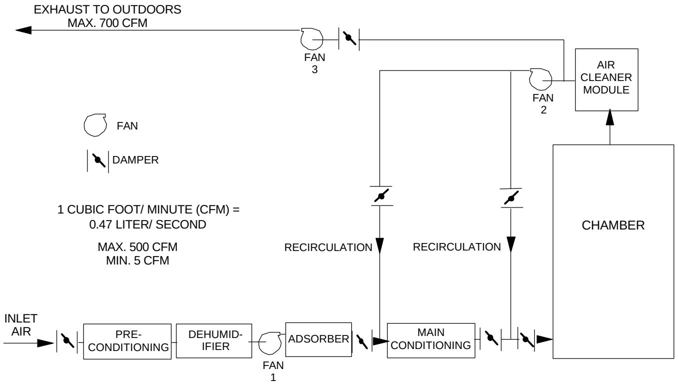

Figure 1. Schematic of IEMB's Large Environmental Chamber

Results indicate that the automated control system can maintain temperatures over a range of 15 to 30°C with RHs ranging from 30 to 70% when chamber air is recirculated through the air-conditioning system. As expected, when the chamber is operated in single pass, low flow mode, the temperature inside the chamber varies with the air temperature of the room housing the chamber. Mixing tests indicate that pollutants introduced into the chamber mix rapidly and do not appear to "short circuit" between the inlets near the floor and the outlet in the ceiling. Chamber wall loss tests have demonstrated insignificant to slight adsorption of several typical indoor air contaminants when the chamber is operated in single pass mode (no recirculation of air through the chamber air-conditioning system). These results indicate that wall effects in the large chamber are very small compared to wall effects that have been observed in small test chambers. Adsorption of low volatility and polar compounds has been observed when chamber air is recirculated through the air-conditioning system. These effects are manageable and are not expected to interfere with use of the chamber to characterize sources and develop source management methods that result in reduced exposure to indoor air pollutants. Future issues of *Inside IAQ* will provide updates on tests conducted in the chamber. (EPA Contacts: Mark Mason, 919-541-4835, mmason@engineer. aeerl.epa.gov and Betsy Howard, 919-541-7915, bhoward@ engineer.aeerl.epa.gov)

EFFECTS OF HVAC FAN CYCLING ON THE PERFORMANCE OF PARTICULATE AIR FILTERS

Heating, ventilating, and air-conditioning (HVAC) system components have been identified as potential emission sources that may affect IAQ under some conditions (*HVAC Systems as Emission Sources Affecting Indoor Air Quality: A Critical Review,* EPA-600/R-95-014; NTIS PB95-178596, February 1995). Emissions include dust, dirt, and other airborne particles entrained from outdoor air (OA) and from air recirculated from the occupied spaces. These contaminants accumulate on HVAC surfaces including the filtration systems. Dirty or loaded filters have been associated with total particle and bioaerosol shedding as the system fan cycles on and off.

Filters are installed in HVAC systems by design engineers for two primary reasons: 1) protection of system components (fans, motors, control devices, etc.) from the degrading effects of dust and dirt, and 2) reduction of occupant exposure to airborne particles and bioaerosols. It has been suggested that dirty or loaded filters may be associated with total particle and bioaerosol shedding as the HVAC system fan cycles on and off.

IEMB and the University of Minnesota performed research to determine the shedding contribution from loaded filters (see *Effects of Fan Cycling on the Performance of Particulate Air Filters Used for IAQ Control* on page 9). Fiberglass and synthetic organic media bag filters were tested using two laboratory test duct setups. Each test duct was 2 by 2 ft (0.6 by 0.6 m). The blower fan, which was cycled on and off, was configured as a draw-through system that challenged the filters with 100% OA. Total airborne particle counts were made with an optical particle counter, and viable bioaerosol counts were obtained with a slit impactor with a rotating plate. Filter surface microorganism samples were obtained with growth plates. The two filters tested were a fiberglass bag filter with a rated dust spot efficiency of 85% and a synthetic organic media bag filter with a rated dust spot efficiency of 65%. Both filters have eight pleated pockets.

The filters were loaded with outdoor aerosols with the fan running continuously except for the time when the fan cycling data were obtained. Initial tests on clean filters were inconclusive so the tests reported here were made after the filters had been loaded for approximately 1 year.

(Continued on Page 3)

Figures 2 and 3 illustrate typical total particle concentrations measured upstream and downstream from the fiberglass filter when the fan was cycled off and on. Figures 4 and 5 show the bioaerosol collected versus time by the slit impactor downstream from the fiberglass filter when the fan was cycled. Results from the synthetic organic filter are similar. Table 1 shows the results of a surface sampling test using Inhibitory Mold Agar (IMA) growth media.

Figure 2 shows that the particle concentration in the upstream duct (i.e.,OA) does not change during the fan cycling. In some of the runs, the concentration dropped when the fan was turned off. However, the total concentration in these runs was much higher than the values shown in Figure 2 and settling losses were significantly higher.

The downstream concentration of particles in Figure 3 shows a trend found in most of the tests. When the fan is turned off, the air velocity through the filter gradually decreases as the fan wheel slows to a stop. Media filters become more efficient when the velocity through them is reduced as the particles have longer residence time to diffuse to the filter media. Therefore, the particle concentration downstream of the filter decreases shortly after the fan is turned off. The fan discharges air through a set of open dampers and a short duct section directly outdoors. With the fan off, outdoor contaminants can diffuse into the discharge duct. This causes the concentrations on the downstream side of the filter to increase. Note that the downstream concentration at readings 10 and 11 on Figure 3 are still much lower than the upstream levels shown in Figure 2. Long term tests with the fan off indicated that the downstream concentrations never reach upstream concentrations. This is caused by settling and diffusion to surfaces between the filter and outdoors. When the fan is restarted, the downstream particle concentrations rapidly return to the level before the fan was stopped.

Results from one of the viable bioaerosol tests are shown in Figures 4 and 5. Concentrations of colony forming units (CFUs) are high immediately after the impactor is started and the access door closed. This is caused by room air entering the ductwork downstream of the filter because the duct is at a negative pressure with respect to the room. Particles may also be dislodged from the duct surfaces and perhaps the filter when the door is closed. Shortly after the door is closed, the downstream bioaerosol counts decrease to nearly zero. The counts remain low during the fan cycling. There are a few random counts but no repeatable pattern of bioaerosol concentrations was observed.

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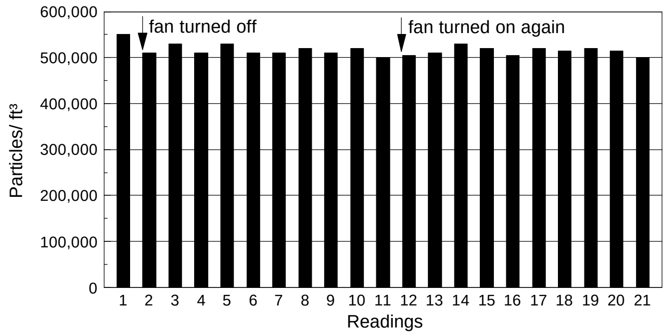

Figure 2. Total particle concentration versus time upstream from the fiberglass filter (31 seconds between successive readings) (1 ft^3 = 28 L)

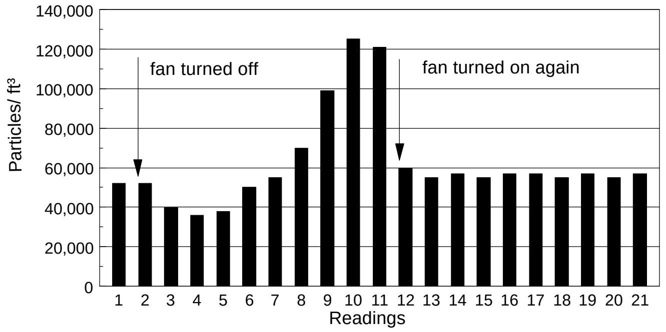

Figure 3. Total particle concentration versus time downstream from the fiberglass filter (31 seconds between successive readings) (1 ft^3 = 28 L)

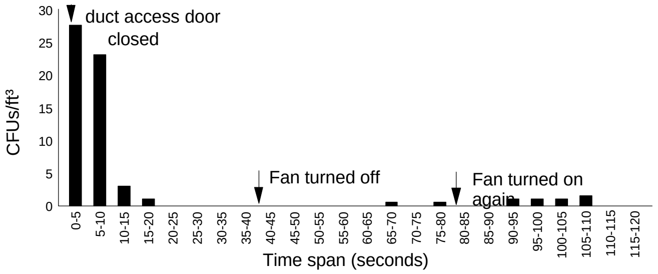

Figure 4. Total bioaerosol concentration versus time downstream from the fiberglass filter (IMA media) (1 ft^3 = 28 L)

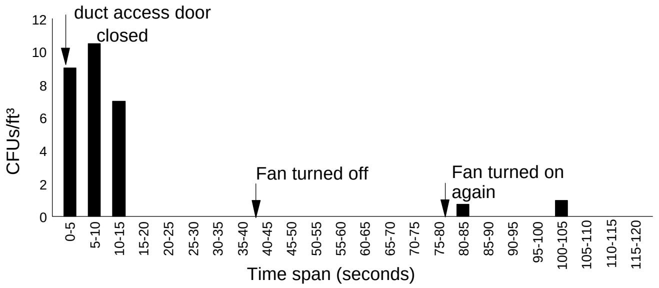

Figure 5. Total bioaerosol concentration versus time downstream from the fiberglass filter (Standards Method Agar media) (1 ft^3 = 28 L)

Table 1 shows the results of one of the surface sampling tests for both the fiberglass and synthetic organic filters using IMA media. The microbial counts upstream of the filters are high on the filter surface and on the bottom surface of the duct. Counts are lower on the side walls of the duct. Downstream, the counts are very low almost everywhere indicating good bioaerosol removal by both bag filters.

In conclusion, no statistically significant particle shedding from the bag filters was observed by either the optical particle counter or the viable bioaerosol slit impactor when the fan was cycled. These results are different from previous research; however, the filter media and types may have been different. When the fan was turned off, total particle concentrations downstream of the filter decreased initially followed by a marked increase. This can be explained by an increase in filter capture efficiency at low air velocity and by diffusion of outdoor particles into the discharge ductwork when the fan was off. Surface samples for viable fungi and bacteria generally indicated high levels on the upstream sides of the filters and on the upstream duct surfaces but very low counts downstream. (EPA Contact: Russ Kulp, 919-541-7980, rkulp@engineer. aeerl.epa.gov)

Table 1. Surface Sampling Test Results (IMA Media)

Filter Type	Location	Sample	Results *
Fiberglass	Upstream	Bag 5, upper end	overgrowth
Fiberglass	Upstream	Bag 5, lower end	overgrowth
Fiberglass	Upstream	Side duct wall	moderate growth
Fiberglass	Upstream	Side duct wall (door)	moderate growth
Fiberglass	Upstream	Bottom duct wall	overgrowth
Fiberglass	Downstream	Bag 5, upper end	no growth
Fiberglass	Downstream	Bag 5, lower end	no growth
Fiberglass	Downstream	Side duct wall	no growth
Fiberglass	Downstream	Side duct wall (door)	low growth
Fiberglass	Downstream	Bottom duct wall	low growth
Synthetic Organic	Upstream	Bag 5, upper end	overgrowth
Synthetic Organic	Upstream	Bag 5, lower end	overgrowth
Synthetic Organic	Upstream	Side duct wall	moderate growth
Synthetic Organic	Upstream	Side duct wall (door)	moderate growth
Synthetic Organic	Upstream	Bottom duct wall	overgrowth
Synthetic Organic	Downstream	Bag 5, upper end	low growth
Synthetic Organic	Downstream	Bag 5, lower end	no growth
Synthetic Organic	Downstream	Side duct wall	no growth
Synthetic Organic	Downstream	Side duct wall (door)	no growth
Synthetic Organic	Downstream	Bottom duct wall	moderate growth

* low growth = 1-10 CFUs
moderate growth = 11-30 CFUs
overgrowth = colonies merge together

REDUCING INDOOR AIR EMISSIONS FROM ENGINEERED WOOD PRODUCTS

Research over the past two decades has shown that engineered wood products can be emission sources for many organic compounds. Emissions can arise from the engineered wood (both the wood and resin); finishing materials applied to the engineered wood for decorative purposes such as finished wood veneer, ink prints, and paper overlays; and glues used to fasten pieces of finished engineered wood together. Research Triangle Institute is working cooperatively with IEMB to characterize indoor emissions from engineered wood products and to identify and evaluate pollution prevention approaches for their manufacture that may reduce indoor emissions.

As part of the project, emissions have been characterized from four types of finished engineered wood: 1) particleboard finished with melamine; 2) particleboard finished with vinyl; 3) finished veneered hardboard; and 4) finished veneered particleboard. The test samples were obtained directly from the manufacturing line at the finishing plant. The finished samples were cut into small coupons (3 by 3 in., 7.44 by 7.44 cm) and placed in 1-gal. (3.785 L) steel containers with one coupon per container. The containers were transported to Research Triangle Institute within 24 hours of collection.

Figure 6 shows 24-hour emission rates of total VOCs from each of the substrates. The finished veneered particleboard and hardboard have substantially higher emission rates of total VOCs compared to the vinyl and melamine particleboard. As seen in Figure 7, 31-day emission rates of formaldehyde from the finished substrates were also higher than 24 hr emissions rates of formaldehyde from the melamine and vinyl particleboard (217 and 275 µg/m^2/hr compared to 53 and 71 µg/m^2/hr).

Additional testing indicated that surface finishes applied to the veneered particleboard and hardboard were a significant source of emissions from the finished board (Figure 8). These tests also showed that particleboard was also a significant source of emissions from the finished veneered particleboard.

Two studies are currently underway to evaluate low-emitting surface finishes and engineered wood materials. The goal is to identify low-emitting materials that may be substituted for the existing finishes and engineered wood to reduce emissions from the finished board. (EPA Contact: Kelly W. Leovic, 919-541-7717, kleovic@engineer.aeerl.epa.gov)

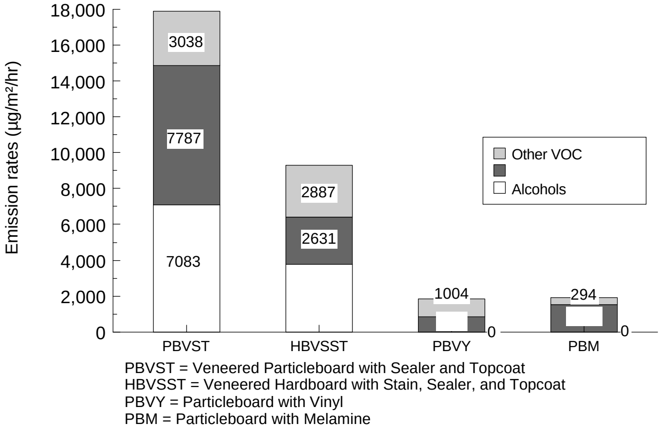

Figure 6. Emission Rates of Total VOCs from Selected Types of Finished Engineered Wood after 24 Hrs

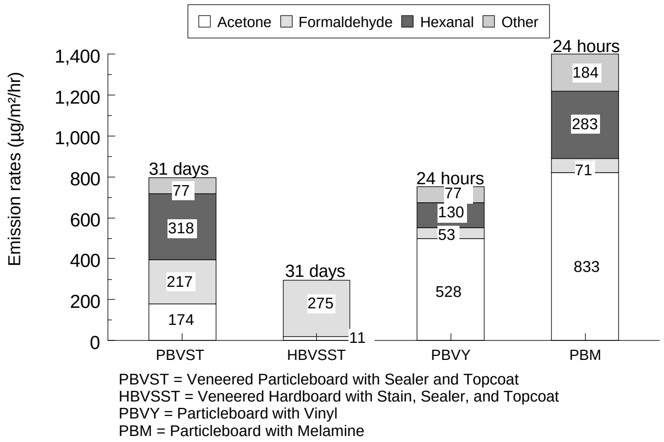

Figure 7. Comparison of Aldehyde and Ketone Emission Rates at 24 Hrs and 31 Days

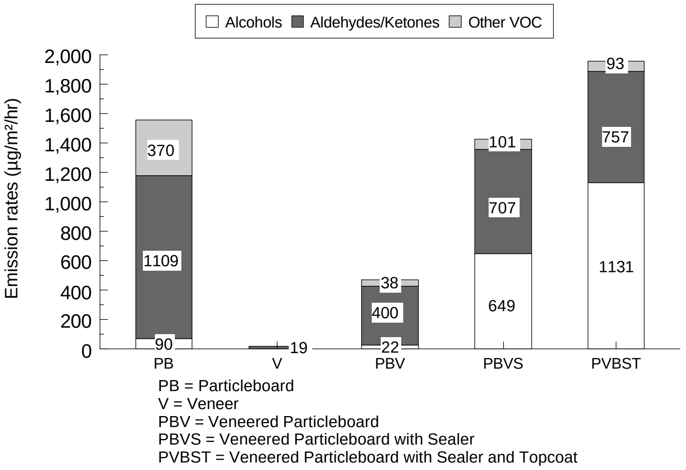

Figure 8. Emission Rates of Total VOCs from Various Components of Finished Veneered Particleboard (31 Days)

COST-EFFECTIVENESS OF ALTERNATIVE IAQ CONTROL TECHNIQUES

IEMB is developing technical guidance that will assist users in selecting and designing the most cost-effective combination of IAQ control options in any specific circumstance. The initial guidance will be general guidance for commercial and institutional buildings, based on a limited number of case studies. The first case study to be conducted under this program has been partially completed.

A case study involves: 1) detailed definition of all key building, HVAC, source, occupancy, and IAQ-related parameters for the particular scenario to be studied; and 2) a sensitivity analysis estimating the cost-effectiveness of ventilation, air cleaning, and specific source management steps as each of these parameters is varied.

The initial case study has addressed an existing 3-story office building with an area of 10,000 ft^2 (930 m^2) per story. To consider a range of possible interior configurations, the first and third floors were assumed to consist of enclosed offices around the perimeter, while the second floor was open, containing modular workstations. A suitable HVAC system was specified for the building, and a variety of typical VOC emission sources were distributed throughout the building. The incremental changes in total annual costs (including annualized capital costs as well as operating and maintenance costs) and the incremental changes in annual VOC exposure to occupants at various locations within the building, calculated as the IAQ control approaches, were systematically varied. The parameters varied in this sensitivity analysis included: the amount of OA provided by the HVAC system; the efficiency of a retrofit carbon-sorption VOC air cleaner; and the extent of source management (which in this case consisted of the use of low-emitting VOC sources).

The results for increased OA and for VOC air cleaners are presented in Figure 9 for the case study building. The y-axis shows cost-effectiveness, defined as the dollar cost per unit reduction in individual exposure during the first year of building occupancy – i.e., the total incremental cost for the IAQ control step during the first year, divided by the reduction in VOC exposure to the average occupant (expressed as mg/m^3-hr) during that year. Cost-effectiveness is shown as a function of the percentage reduction in exposure, relative to the baseline (“no-control”) case, to identify the more efficient control measures.

Source management is not shown in Figure 9, since the costs of “low-emitting” materials are difficult to estimate. This figure will be used to determine what premium *could* be paid for low-emitting materials before that source management step would no longer be cost-competitive with increased ventilation and air cleaning.

The baseline case corresponds to an OA supply of 5 cfm/person (2.35 L/sec), and no VOC air cleaning. The five circles on the curve for increased OA ventilation in Figure 9 correspond to increases in the OA supply to 20, 40, 60, 80, and 100 cfm/person (9.4, 18.8, 28.2, 37.6, and 47 L/sec). The three points marked on each curve for the air cleaning system show the effects if the fixed charge of carbon in the system were assumed to provide an average VOC removal efficiency of 12, 50, or 88% over each of the indicated carbon lifetimes.

The cost of air cleaning will depend significantly on the frequency with which the carbon sorbent needs to be replaced. That frequency, in turn, will depend on the nature and the concentration of the VOCs. Due to this uncertainty, a parametric family of curves is included for air cleaning, showing the effect of alternative carbon replacement frequencies. As shown in the figure, replacement at more frequent intervals results in a substantial increase in cost. It is reasonable to assume that the higher percentage reductions will require more frequent replacement, and that the lower reductions will require less frequent replacement.

The curve for increased ventilation shows a significant increase in cost as the percentage reduction in exposure is increased above 80% (corresponding to 80-100 cfm or 37.6 - 47 L/sec OA/person). This results from an increase in HVAC retrofit capital cost when one increases to 100 cfm/person (47 L/sec).

Figure 9 suggests that, for building-wide VOC reductions below about 70% in the study building during its first year, increased OA ventilation is likely the more reasonable approach, costing about \$3 to 4 per mg/m^3-hr reduction in individual exposure. For building-wide reductions of 70 to 80%, VOC air cleaning could be competitive or perhaps even slightly less expensive – with costs of about \$2.50 to 4 per mg/m^3-hr – if the air cleaner is able to reliably achieve the stated VOC removals with carbon lifetimes longer than 3 months. For very high reductions in exposure – above 80% – it might be expected that the costs with either ventilation or air cleaning might increase to about \$7 per mg/m^3-hr. In the case of ventilation, this increase results from the required replacement of existing HVAC equipment; in the case of air cleaning, it results from the expected increase in carbon replacement frequency. (EPA Contact: Bruce Henschel, 919-541-4112, bhenschel@ engineer.aeerl. epa.gov)

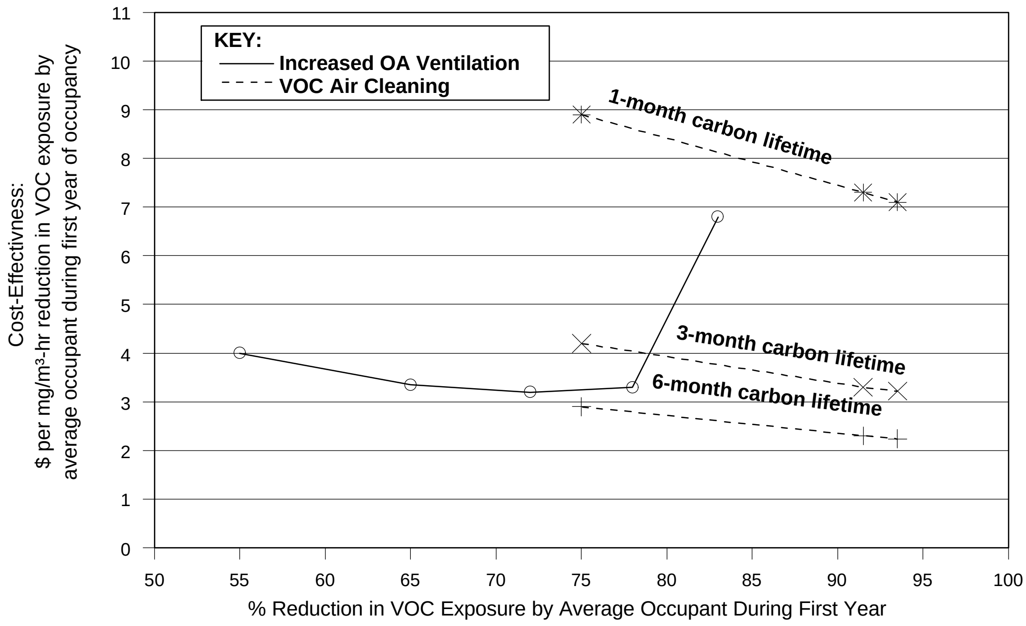

Figure 9. Cost-effectiveness of Increased OA Ventilation and of VOC Air Cleaning in the 3-story Office Building (Assumptions: Equipment Lifetime - 10 years; Interest Rate - 7%; Cost of Electricity - $0.06/kWh)

QUALITY ASSURANCE FOR EPA'S IAQ RESEARCH

IEMB research covered in *Inside IAQ* responds to EPA quality assurance (QA) requirements mandated by EPA Order 5360.1, which establishes policy and program requirements for the conduct of QA for all environmentally related measurements performed by or for EPA. Its primary goal is to ensure that all measurements supported by EPA produce data of known quality.

IEMB researchers use systematic planning to develop acceptance or performance criteria for data collection whether it is collected in the laboratory, in the field, or is produced by models using information obtained from the literature.

Many of IEMB's research programs are carried out in on-site facilities which include small chambers, a large chamber, and a test house. All IEMB facilities have established fully functional facility operating manuals as guidance documents to operations. These facility manuals describe laboratory design specifications and equipment, personnel capabilities and work capacity, planning protocols, operating procedures, QA and quality control requirements, and health and safety requirements. They also contain test plan matrices including schedules and milestones. They are living documents kept current, and once a year they are formally reviewed and updated.

IEMB extramural research occurs off-site using the services of contractors or cooperators. This work is performed via contracts, cooperative agreements, or interagency agreements (IAGs). Research using "in-kind" resources can occur via cooperative research and development agreements (CRADAs) or memoranda of understanding (MOU). When cooperating with other federal agencies or organizations, EPA works with the agency or organization to establish adequate QA requirements.

IEMB personnel produce various work products. Research results are disseminated in published reports, at technical meetings, or in the technical literature. EPA publications that report measurement data contain sections discussing the quality of the data in the report. The quality section discusses data quality indicators such as accuracy (measurement system bias), precision, completeness, representativeness, and comparability of data. In quality research, standard sampling and analysis methods are used where feasible, although because of the cutting edge nature of some research, some methods may be developed as the work progresses. Instruments are calibrated, and quality control checks are performed periodically to keep the measurements on track. Audits may be performed by QA personnel as an independent check on performance. All of these topics may be among the indicators of quality discussed in the QA section of published reports.

Another product of IEMB research is computer models which can predict the possible outcomes of various environmental measurements using as input the often vast databases on the subject in the technical literature. Care is taken that the mathematical manipulations of the data produced by the software are those intended. (EPA Contact: Shirley Wasson, 919-541-1439, swasson@ engineer.aeerl. epa.gov)

EMISSIONS OF CARBONYL COMPOUNDS FROM LATEX PAINT

Emissions of carbonyl compounds from an interior latex paint were investigated in IEMB's test house. A white flat latex paint purchased from a local store was applied to the walls of a bedroom in the test house. The windows were open for the first 4 hours, and a box fan was placed in one of the windows. To determine the concentrations of carbonyl compounds, air samples were collected on dinitrophenylhydrazine (DNPH) cartridges and analyzed by high performance liquid chromatography (HPLC). The OA samples were taken in the backyard; indoor samples were taken from the painted bedroom and the den area of the house.

Three carbonyl compounds were consistently found in the OA samples and seven in the indoor samples (see Table 2). Trace amounts of methacrolein [methacrylaldehyde CH=C(CH3)CHO] were found in the OA samples. Crotonaldehyde (2-butenal, CH3=CHCHCHO) was found in the indoor air samples after paint application, but only in the painted room on day 1. Low levels of butanone (methyl ethyl ketone, CH3COCH2CH3) and butanal (CH3CH2CH2CHO) were found in indoor samples before and after painting.

During this test, indoor concentrations of carbonyl compounds were higher than outdoor concentrations. After paint application, indoor formaldehyde concentrations in the painted bedroom increased slightly (less that 30%). Among the seven carbonyl compounds listed in Table 2, only the acetaldehyde concentration changes were significant (see Figure 10). The levels of carbonyl compound concentrations in the den are consistently lower than those in the bedroom. However, all the indoor carbonyl compound concentrations decreased to the background indoor levels within 24 hours. (EPA Contact: John Chang, 919-541-3747, jchang@ engineer.aeerl.epa.gov)

Table 2. Carbonyl Compounds Measured Indoors and Outdoors During Latex Paint Application *

Compound	Outdoors	Inside (Before Test)	Inside (During Test)
Formaldehyde	Yes	Yes	Yes
Acetaldehyde	Yes	Yes	Yes
Acetone	Yes	Yes	Yes
Propanal	No	Yes	Yes
Benzaldehyde	No	Yes	Yes
Pentanal	No	Yes	Yes
Hexanal	No	Yes	Yes

* Minimum Quantification Limit = $\frac{1.35\mu g}{m^3}$

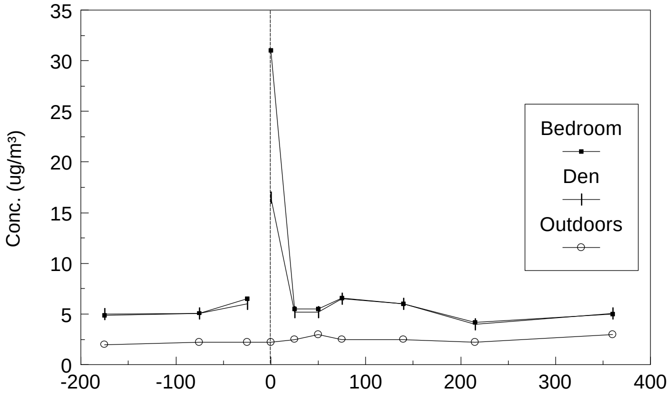

Figure 10. Acetaldehyde Concentration Profile (paint was applied at 0 hours)

GLOSSARY OF ACRONYMS

APPCD-Air Pollution Prevention & Control Division
CFM-Cubic Feet per Minute
CFU-Colony Forming Units
CRADA-Cooperative Research and Development Agreement
DNPH-dinitrophenylhydrazine
FS-Floating Slab
HPLC-High Performance Liquid Chromatography
HVAC-Heating, Ventilating, and Air-Conditioning
IAG-Interagency Agreement
IAQ-Indoor Air Quality
IEMB-Indoor Emissions Management Branch
IMA-Inhibitory Mold Agar
MOU-Memoranda of Understanding
NRMRL-National Risk Management Research Laboratory
NTIS-National Technical Information Service
OA-Outdoor Air
QA-Quality Assurance
RAETRAD-Radon Emanation and Transport into Dwellings
RH-Relative Humidity
SSW-Slab-In-Stem Wall
VOC-Volatile Organic Compound

This section provides summaries of recent publications on EPA's indoor air research. The source of the publication is listed after each summary. Publications with NTIS numbers are available (prepaid) from the National Technical Information Service (NTIS) at : 5285 Port Royal Road, Springfield, VA 22161, 703-487-4650 or 800-553-6847.

Demonstration of Radon Resistant Construction Techniques, Phase II-Subslab mitigation systems were installed (in accordance with draft standards) in 15 new Florida houses in 1992. Soil radon levels ranged from just under 500 to over 8000 pCi/L. Evaluation of the systems showed that: 1) all systems extend negative pressure to practically all areas under the slab; 2) slabs tended to crack less than expected; and 3) intact vapor barriers under new houses prevent radon intrusion through slab cracks in most instances, but slab pipe penetrations not sealed in accordance with standards can contribute to relatively high indoor radon levels. Eleven mitigation systems were installed using ventilation matting, and four systems used a wellpoint suction pipe. Both systems performed well if carefully installed. The highest indoor radon level with the mitigation system capped off was 5.6 pCi/L over 48 hours. Ten houses were under 2.9 pCi/L and did not require activation of their mitigation systems. Five houses required activation of their mitigation systems. All houses are currently under 2.9 pCi/L. Source: EPA Report, EPA-600-R-95-159, NTIS PB96-121512, November 1995. (Lead Author: James L. Tyson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl. epa.gov)

Entrainment by Low Air-Liquid Ratio Effervescent Atomizer Produced Sprays-This paper describes entrainment into sprays produced by an aerosol consumer product dispenser that allows substitution of water for VOC solvents and air for hydrocarbon propellants. Experimental data are analyzed, along with measured momentum rate data. The analysis shows that dimensionless entrainment by sprays produced using this type of atomizer is accurately predicted, using: 1) distance along the spray axis; 2) exit orifice diameter; 3) spray momentum rate at the exit orifice; 4) density of the entrained air; 5) entrained gas mass flow rate; 6) mass flow rate of liquid exiting the dispenser; and 7) an entrainment number whose value is 0.15 ± 0.056. Source: Proceedings of Institute for Liquid Atomization and Spray Systems, May 1996. (Lead Author: Jeff J. Sutherland; EPA Contact: Kelly W. Leovic, 919-541-7717, kleovic@engineer .aeerl.epa.gov)

Evaluation of Radon Emanation from Soil with Varying Moisture Content in a Soil Chamber-Measurements of the emanation coefficient and diffusion of radon in soil contained in a 2 by 2 by 4 m chamber using a range of moisture contents are described. In addition, equal amounts of well-mixed over-dried soil were placed in 20 L aluminized gas-sampling bags, and after approximately 1 month of in-growth, radon samples were taken, after which water was added, and another period of in-growth and sampling followed. The emanation coefficients and radon concentrations in the gas bag experiment were observed to increase with increasing moisture content and then decrease before reaching saturated conditions. The emanation and diffusion effects on the radon concentration soil gradient were identified for this sandy soil having approximately 200 Bq kg^{-1} radium and a soil density of 1682 kg m^{-3}. Source: Accepted for publication in Environment International, Alexandria, VA, January 1996. (Lead Author and EPA Contact: Marc Y. Menetrez, 919-541-7981, mmenetrez@ engineer.aeerl. epa.gov)

Growth Evaluation of Fungi (*Penicillium and Aspergillus ssp.*) on Ceiling Tiles-The potential for fungal (Penicillium and Aspergillus ssp.) growth on four different types of ceiling tiles was evaluated in static chambers. It was found that even new ceiling tiles could support fungal growth when at equilibrium with a RH as low as 85% and corresponding moisture content greater than 2.2%. Used ceiling tiles appeared to be more susceptible to fungal growth than new ones. In the 70% RH chamber with wetted tiles under slow-drying, non-equilibrium conditions, fungi could still proliferate as long as the moisture level in the ceiling tiles was adequate. Fungal growth could be limited if the wetted ceiling tiles were dried quickly and thoroughly. Source: Atmospheric Environment, 29, 17, 2331-2337, 1995. (Lead Author and EPA Contact: John Chang, 919-541-3747, jchang@ engineer.aeerl.epa.gov)

HVAC Systems as a Tool in Controlling Indoor Air Quality: A Literature Review-This report reviews the literature on the use of HVAC systems to control IAQ. One conclusion of the review is that HVAC systems often contribute to indoor air pollution because of 1) poor system maintenance, 2) overcrowding or the introduction of new pollution-generating sources within buildings, and 3) the location of OA intakes near ambient pollution sources. Additionally, failure to trade off between energy conservation and employee productivity may result in increased IAQ problems. Source: EPA Report, EPA-600/R-95-174, NTIS PB96-140561, December 1995. (Lead Author: Max M. Samfield; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl .epa.gov)

Measurement of Indoor Air Emissions from Dry-Process Photocopy Machines- A standard test method to measure emissions from office equipment is being developed in order to investigate pollution prevention approaches for reducing emissions (e.g., ozone, VOCs, and particles). Initial results from four dry-process photocopy machines indicate that the method provides acceptable performance for characterizing emissions, can adequately identify differences in emissions between machines, and is capable of measuring both intra- and inter-machine variability in emissions. The compounds with the highest emission rates overall were ethylbenzene (28,000 μg/hour), *m,p*-xylenes (29,000 μg/hour), *o*-xylene (17,000 μg/hour), 2-ethyl-1-hexanol (14,000 μg/hour), and styrene (12,000 μg/hour). Although many of the same compounds tended to be emitted from each of the four photocopiers, the relative contribution of individual compounds varied considerably between machines, with differences greater than an order of magnitude for some compounds. Ozone emissions ranged from 1,300 to 7,900 μg/hour. Source: Journal of the Air & Waste Management Association, September 1996 (Lead Author & EPA Contact: Kelly W. Leovic, 919-541-7717, kleovic@engineer.aeerl. epa.gov)

Re-Entrainment and Dispersion of Exhausts from Indoor Radon Reduction Systems: Analysis of Tracer Gas Data- Tracer gas studies were conducted around four model houses in a wind tunnel and one house in the field to quantify re-entrainment and dispersion of exhaust gases released from residential radon reduction systems. Field re-entrainment tests suggest that active soil depressurization systems exhausting at grade level can contribute indoor radon concentrations 3 to 9 times greater than systems exhausting at the eave. With a high exhaust concentration of 37,000 Bq/m^3, the indoor contribution from eave exhaust re-entrainment may be only 20 to 70% of the national average ambient level in the U.S. (about 14 Bq/m^3), while grade-level exhaust may contribute 1.8 times the average. The grade-level contribution would drop to only 0.18 times ambient if the exhaust were 3,700 Bq/m^3. Wind tunnel tests of exhaust dispersion outdoors suggest that grade-level exhaust can contribute mean concentrations beside houses averaging 7 times greater than exhaust at the eave, and 25 to 50 times greater than exhaust midway up the roof slope. With 37,000 Bq/m^3 in the exhaust, the highest mean concentrations beside the house could be less than or equal to the ambient background level with eave and mid-roof exhausts, and 2 to 7 times greater with grade exhausts. Source: *Indoor Air*, 5(4):270-284 (1995). (Lead Author and EPA Contact: D.B. Henschel, 919-541-4112, bhenschel@engineer.aeerl. epa.gov)

Residential Radon Resistant Construction Feature Selection System-This report describes a proposed residential radon resistant construction feature selection system that consists of engineered barriers to reduce radon entry. Proposed standards in Florida require radon resistant features in proportion to regional soil radon potentials. The effectiveness of different radon control features was estimated from new laboratory measurements, analyses of new and previous house studies, and mathematical model simulations. The laboratory measurements characterized five polyethylene subslab membranes. The analyses showed that both monolithic-slab (mono) and Slab-in-Stem Wall (SSW) foundation designs can passively control indoor/subslab radon ratios to average levels that are slightly lower than measurements in other houses the previous year, and two to four times lower than ratios from earlier studies. The mono design offers about twice as much passive radon resistance as SSW designs. A Florida radon protection map was developed to show where the active and passive features are needed. Source: EPA Report, EPA-600/R-96-005, NTIS PB96-153473, February 1996. (Lead Author: Kirk K. Nielson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl.epa.gov)

Site-Specific Characterization of Soil Radon Potentials-Empirical measurements suggest that the precision of soil radon measurements is marginal, leaving an uncertainty of about a factor of 2 in site-specific estimates. Although this may be useful for some applications, it probably is inadequate for most decisions about construction of radon-resistant features. More detailed site characterization (soil borings and measurements of radium, emanation, moisture, and permeability profiles) can improve precision; however, the additional expense may not be justified in comparison to the cost of installing the features. Field tests of soil radon flux and moisture measurements were conducted at 26 house sites in Polk County, Florida, to evaluate their utility in predicting site-specific radon potentials. Results showed localized trends in radon potential that compared well with mapped radon potentials in some cases, but not in others. For the 26 houses, the site-specific radon potentials averaged twice the potentials from the generalized radon maps. Source: EPA Report, EPA-600/R-95-161, NTIS PB96-140553, November 1995. (Lead Author: Kirk K. Nielson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl.epa.gov)

Status of EPA's Bioresponse-Based Testing Program-Since 1990 EPA has been investigating the feasibility of using biological methods based on human, animal, or *in vitro* responses to characterize sources of indoor air emissions. The "bioresponse" methods being evaluated measure odor and sensory irritation of mucosal tissues in the eyes, nose, and upper airways. Chambers for creating controlled emissions from sources are basically the same as those used for traditional studies of emission rates and chemical compositions. Studies of human subject responses to known odorous or sensory irritant chemicals using nose-only, eye-only, facial, and whole-body exposures are providing baseline data against which animal and *in vitro* results will be validated. The animal and *in vitro* methods being investigated measure changes in respiratory patterns and chemosensory evoked potentials. The status of current and future projects is reported. Source: American Society of Testing & Materials publication STP1287, 1996. (Lead Author and EPA Contact: W. Gene Tucker, 919-541-2746, gtucker@engineer.aeerl. epa.gov)

Test Cell Studies of Radon Entry-This report compares slab-in-stem wall (SSW) with floating slab (FS) construction practices, measures radon transport and entry for model testing, develops protocols relevant to depressurized radon measurements, and determines the effect of high radium fill soil on indoor radon. The indoor radon concentrations in the FS cell were 3.5 times higher than those in the SSW cell. These results agreed with predictions by a radon entry and transport (RAETRAD) model. Whole building stresses and slab area and crack length radon entry were measured, and they yielded comparable results. Experiments in the fill study suggest that the amount of emanating soil radium is a good predictor for radon entry into a structure. Source: EPA Report, EPA-600/R-96-010, NTIS PB96-153549, February 1996. (Lead Author: Ashley D. Williamson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl. epa.gov)

CONTACTS IN IEMB

Name	Research Areas	Phone	E-mail
Michael C. Osborne	Branch Chief	919-541-4113	mosborne@*
John C. S. Chang	Biocontaminants, VOC Source/Sink Characterization, VOC Emissions Modeling	919-541-3747	jchang@*
D. Bruce Henschel	Cost Analysis of IAQ Control Techniques, Building Energy Modeling, Radon Reduction in Existing Houses	919-541-4112	bhenschel@*
Betsy M. Howard	Pollution Prevention, Particle Board, Large Chamber Testing, Conversion Varnishes	919-541-7915	bhoward@*
Mark A. Mason	Bioresponse Methods Development, Chemical Source Characterization, Large Chamber Testing	919-541-4835	mmason@*
Marc Y. Menetrez	Large Building Measurements (IAQ, Ventilation, Building Dynamics HVAC, Diagnostic Strategy)	919-541-7981	mmenetrez@*
Ronald B. Mosley	Indoor Air Pollutants Originating in Soil, Mathematical Modeling, Indoor Particles, Soil Contaminants	919-541-7865	rmosley@*
Richard B. Perry	Radon Diffusion Measurement, Test Method Development, Ventilation Systems Research	919-541-2721	rperry@*
Leslie E. Sparks	IAQ and Exposure Modeling, Air Cleaners, Indoor Particles	919-541-2458	lsparks@*
W. Gene Tucker	Control of IAQ, ASHRAE Standard 62, Bioresponse Methods, Source Emissions, Indoor/Outdoor Particles	919-541-2746	gtucker@*
James B. White	Development of Low-Emitting/Low-Impact Sources, IAQ Emission Source Catalog & Database, IAQ & Life Cycle Assessment, Environmental Resources Guide, Expert Systems for Facilities Design & Operation Development of CADD-based LCA for IAQ, Textiles	919-541-1189	jwhite@*

* (all E-mail @) engineer.aeerl.epa.gov

Call for Papers

Engineering Solutions to Indoor Air Quality Problems

The second biennial *Engineering Solutions to Indoor Air Quality Problems* Symposium, an international symposium cosponsored by the Air & Waste Management Association and EPA's National Risk Management Research Laboratory, will be held July 21-23, 1997, 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
- Indoor Air Source Management
- Low Emitting/Low Impact Materials Development (Pollution Prevention)
- Biocontaminant Prevention and Control
- Indoor Air Cleaning Methods
- Ventilation
- HVAC Systems as Sources of Indoor Air Pollution
- Air Duct Cleaning
- Particles in Indoor Air
- Indoor Air Quality Modeling
- Costs of Managing Indoor Air Quality

The two and a half-day 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 also planned.

Send abstracts of 200-300 words by January 10, 1997 to: Kelly W. Leovic, U.S. EPA, MD-54, Research Triangle Park, NC 27711; Telephone (919) 541-7717; Fax (919) 541-2157; E-mail: kleovic@engineer.aeerl.epa.gov. Abstracts should include paper title and author(s) names, address(es), and phone, fax number(s), and e-mail address (if applicable).

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