United States
Environmental Protection
Agency

Office of Research
and Development
Research Triangle Park, NC 27711

EPA/600/N-95/007 Fall/Winter 1995

EPA

Inside IAQ

EPA's Indoor Air Quality Research Update

***We Apologize* for the delay...**
Due to the printing and distribution moratorium imposed while EPA was operating under continuing resolutions, we were unable to distribute this Fall/Winter 1995 issue as originally scheduled.

In This Issue Page

Evaluation of an IAQ Source Management Strategy for a Large Building 1
EPA Examines Indoor Emissions from Conversion Varnishes 2
Review of Concentration Standards and Guidelines for Fungi in Indoor Air 4
Two Case Studies Evaluating HVAC Systems as Sources of Bioaerosols 4
Effect of Ventilation on Radon Levels in a Municipal Office Building 6
Indoor Air Bibliographic Database 7
Using Animal Models to Understand Human Susceptibility to Indoor Air 8
Reducing Indoor Air Emissions from Aerosol Consumer Products 10
Summaries of Recent Publications 12
Summaries of "Engineering Solutions to IAQ Problems" Symposium Papers .. 13
Glossary of Acronyms 16

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 of e-mail your name and address to:

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

EVALUATION OF AN IAQ SOURCE MANAGEMENT STRATEGY FOR A LARGE BUILDING

EPA's Air Pollution Prevention and Control Division (APPCD) developed an approach to IAQ management in buildings that is based upon the assumption that exposure to indoor air pollutants can be minimized given sufficient knowledge and control of sources, sinks, and building ventilation. This assumption implies that the source emissions and building ventilation data are available in a form that can be used to predict exposure using computer simulation models. Although the approach is simple in concept, successful application may depend upon the quality and quantity of source and ventilation data available as well as the efficacy of the models that relate source emission and ventilation characteristics to exposure.

In a pioneering effort, the State of Washington implemented a proactive IAQ program to ensure healthful work environments in four planned new office buildings. Key components of the program were designed to minimize occupant exposure to indoor air pollutants in the newly constructed buildings by ensuring adequate ventilation, utilization of low emitting products in construction and furnishing, staged loading to minimize cross contamination of fleecy surfaces during construction and use of a 90-day 100% outdoor air (OA) flush-out prior to occupancy.

In 1992, APPCD conducted a pilot investigation of the source management and control program as implemented in design and construction of one of the buildings: the Natural Resources Building (NRB). The NRB is a six-story mixed use office building with over 320,000 square feet (97,536 m^2) of occupiable space. Our goals were to collect a broad spectrum of data in the NRB that would enable us to develop a focussed study to evaluate the IAQ and cost effectiveness of the product selection, building flush-out, and ventilation strategies used in design and construction of the next building

(Continued on Page 2)

Radon Mitigation Research Update

APPCD's annual publication, the *Radon Mitigation Research Update*, will no longer be published. Updates on EPA's radon research will now be included in *Inside IAQ*. If you were on the mailing list for the *Radon Mitigation Research Update* and would like to receive *Inside IAQ*, please send your name and address to the location listed at the left.

(Continued from Page 1)

to be constructed by the State under the IAQ program. Though we were unable to conduct the follow-on study, we did collect a great deal of information that is instructive for design and application of this type of proactive IAQ program.

Product source emissions characterization data that were generated to demonstrate compliance with the State's maximum acceptable concentrations per product were collected from private laboratories that conducted emissions tests and from other sources in custody of the data. The data consisted of small- and large-chamber emissions test results, material safety data sheets (MSDS), and/or compliance certifications for 78 products that were proposed and/or used in the NRB. Product categories included adhesives and sealants, business machines, ceiling materials, floor coverings, fireproofing, furniture, wall coverings, heating, ventilation, and air-conditioning (HVAC) system components, paints and coatings, and wall systems. Product loading data (number of products or surface area per floor) were obtained for 15 products including work stations, ceiling materials, floor coverings, seating, and tables.

Measurement of IAQ

Building air quality data were collected at sites within the building and outdoors at completion of construction, during the flush out, and after occupancy. The sites were selected to investigate air quality differences between and within floors as well as those within and outside the building. Over 200 different individual volatile organic compounds (VOCs) were tentatively identified in the indoor air samples over the course of the study. As is seen in Figure 1, total volatile organic compounds (TVOCs) concentrations remained relatively constant during the flush-out. Three compounds, tetradecane, pentadecane, and hexadecane, dominated the indoor air VOC concentrations at the sites where sampling stations were located. The sum of the three compounds averaged 36 ± 4%, 77 ± 6%, and 61 ± 12% of TVOCs on the first, fourth, and sixth floors, respectively, over the first 120 days of the study (Figure 2). The ratio of the sum of these three compounds to TVOCs dropped by a factor of 10 by day 266.

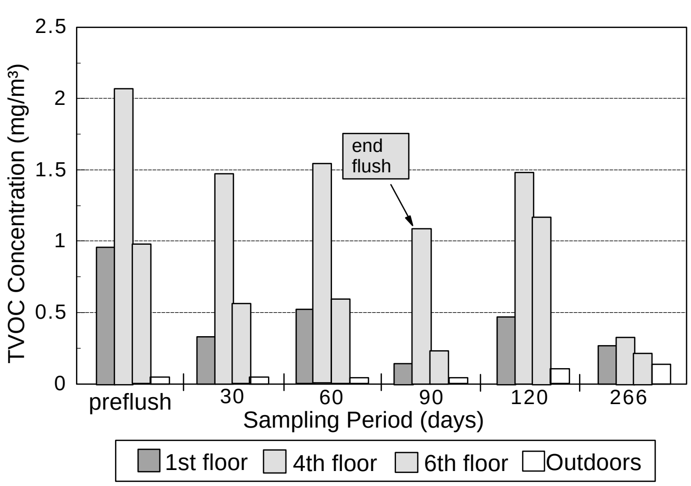

Figure 1. TVOC concentrations in the NRB

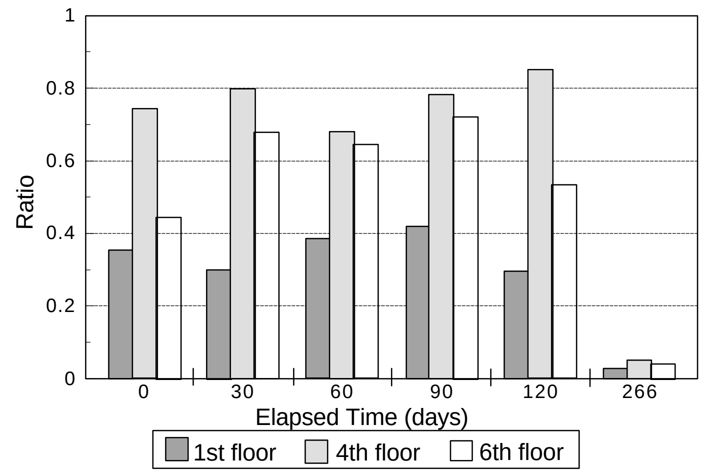

Figure 2. Ratio of the sum of the C_{14}- C_{16}n-alkanes to TVOCs.

The known dominant source of these compounds, a carpet tile, was installed on the second, third, fourth, and fifth floors. At day 120, the characteristic carpet tile emissions constituted 80% of the TVOCs on the fourth floor where TVOC concentrations were greater than 1.5 mg/m^3. Thus, a single source may be responsible for TVOC emissions that exceed the State's target that no product contribute more than 0.5 mg/m^3 to TVOC loading in the building 30 days after installation. Between days 120 and 266, the ratio of the carpet tile hydrocarbons to TVOC drops from 0.8 to below 0.05 at the fourth floor site, indicating a significant decrease in source strength. Small chamber emissions tests of carpet tile submitted for compliance testing and a quality control sample removed from the building suggest significant sample to sample variability and demonstrate the predominance and slow emissions decay pattern of the C_{14} - C_{16} hydrocarbons.

Attempts to predict indoor VOC concentrations from source emissions and building ventilation data were unsuccessful. Emissions data derived from compliance statements, MSDS sheets, and single-point 24 hour emissions tests did not provide sufficient data for modeling. Longer term testing (96 hour) of carpet tile samples was indicative of the slow emissions decay rates as well as variability among samples.

We were unable to determine the value of the 90-day flush-out from the data collected in the pilot study. The limited data available suggest that the OA flush rate was 12 to 45% lower than the target 100% OA intake rate. Given the apparently slow emissions decay rates for the product apparently responsible for a significant portion of the elevated building VOC concentrations, it appears that the primary value of the flush-out period was to shorten the period of time that occupants were exposed to the elevated VOC concentrations related to the source of these emissions. From the source and building VOC data, it cannot be determined whether the elevated concentrations in the building are due to direct emissions from the carpet tiles or some other product that has not been tested but was installed in the building.

Conclusions

The State's IAQ program was successful in raising the awareness of product manufacturers to emissions from their products. Results of the pilot study demonstrate that intra-product sample variability and long term emissions data may be required in order to manage indoor VOC levels by source selection. A strategy to ensure that installed products are representative of products tested for compliance also may be necessary for implementation of this type of program. A thorough evaluation of this approach to IAQ management would require more accurate, longer term source characterization data, more frequent building pollutant characterization, and building ventilation system data. Finally, information characterizing adsorption and desorption of VOCs emitted from sources is required to evaluate the impact of sinks on VOC contaminant levels. (EPA Contact: Mark Mason, 919-541-4835, mmason@engineer.aeerl.epa.gov)

EPA EXAMINES INDOOR EMISSIONS FROM CONVERSION VARNISHES

Conversion varnishes are clear varnishes commonly used as coatings on wooden cabinets and, less frequently, on furniture. They do not cure by drying, as do many coatings, but rather by a chemical reaction, creating a durable water- and chemical-resistant coating that protects the wood during its use. Preliminary results from two studies indicate the potential of these varnishes to emit formaldehyde and other VOCs into the indoor environment.

The first study, being conducted by the Research Triangle Institute under cooperative agreement with EPA, is examining the emissions from engineered wood products into the indoor environment and ways to prevent them. Several different engineered wood products used to make kitchen cabinets were tested. Preliminary results show significantly higher emissions of both formaldehyde and volatile organics from the cabinet components that were finished with conversion varnishes (formaldehyde emission rates ranged from 2,000 to 5,800 $\mu g/m^2h$, organics from 4,600 to 11,00 $\mu g/m^2h$) than from engineered wood components laminated with vinyl or melamine (formaldehyde emission gates ranged from 50 to 90 $\mu g/m^2h$, organics from 400 to 1,400 $\mu g/m^2h$). The remainder of this project will focus on evaluating alternatives to standard conversion varnishes that have lower VOC emissions.

The second study, being conducted in-house at APPCD, involves small chamber testing of conversion varnishes during curing and aging. In a preliminary test conducted on one commercially available varnish, the total mass of formaldehyde emitted was 1% of the mass of varnish applied. The formaldehyde emission profile fit the second order decay model:

$$E(t) = E_0/(1 + ktE_0)$$

where:

- $E(t)$ = the emission factor as a function of time;
- E_0 = 29.0 $\mu g/m^2h$ is the initial emission factor;
- k = 0.00361 m^2/mg is the second-order decay rate constant; and
- t = time after the beginning of the test.

The total mass of VOCs emitted during the test period (250 hours) was 44% of the mass of varnish applied, calculated as toluene. The predominant VOC compounds were xylene at 34% and isobutanol at 5% of the mass of varnish applied. Additional tests will be conducted on other commercially used varnishes and to determine the effect on emissions of multiple coats and coating different substrates. (EPA Contact: Betsy Howard, 919-541-7915, bhoward@engineer.aeerl.epa.gov)

REVIEW OF CONCENTRATION STANDARDS & GUIDELINES FOR FUNGI IN INDOOR AIR

Exposure to fungal aerosols clearly causes human disease. However, methods for assessing exposure remain poorly understood, and guidelines for interpreting data are often contradictory. APPCD, together with the Harvard School of Public Health, is reviewing and comparing existing guidelines for indoor airborne fungi, discussing limitations of existing guidelines, and identifying research needs that should contribute to the development of realistic and useful guidelines.

Existing guidelines are exclusively based on baseline data (rather than health effects data), and are absolute (listing numbers), relative (comparing indoors to outdoors), or a combination of the two. Regulations controlling fungal aerosols have been published only by the Russian Federation. The U.S. Occupational Safety and Health Administration (OSHA) has proposed a standard that is under review. Other guidelines have been proposed or sponsored by North American and European government agencies. Finally, some of the most often quoted guidelines have been proposed by individuals based on either prospective sampling studies or personal experience. Guidelines range from less than 100 colony forming units (CFU)/m^3 to more than 1000 CFU/m^3 (total fungi) as the upper limit for non-contaminated indoor environments.

Some major problems with existing guidelines lie in the lack of connection to human dose/response data, reliance on short-term grab samples analyzed only for culture, and absence of standardized protocols for data collection, analysis, and interpretation. Research needs include the study of human responses to specific fungal agents, development and widespread use of standard protocols using available sampling methodologies, and the development of long-term, time discriminating personal samplers that are inexpensive, easy to use, and amenable to straightforward, relevant analysis. (EPA Contact: John Chang, 919-541-3747, jchang@engineer.aeerl.epa.gov)

TWO CASE STUDIES EVALUATING HVAC SYSTEMS AS SOURCES OF BIOAEROSOLS

An overall goal of the APPCD Ventilation Research Program is to increase our understanding of how HVAC systems can act as sources of indoor air pollution and to develop appropriate design, operation, and maintenance practices to reduce human exposure. For the past 2 years, EPA, in conjunction with the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE), has been identifying and quantifying emission sources from HVAC systems.

In the last issue of *Inside IAQ* (EPA/600/N-95/004, Spring/Summer 1995, pp. 9-10, 15), a report was discussed (EPA-600/R-95-014; NTIS PB95-178596) that showed all currently identifiable emission sources from HVAC systems that have been reported and published. These included intrinsic emission sources such as fibers and products from metal degradation; emission sources resulting from contamination including dust, cleaning compounds, biocides, and microbial growth; and system design/operation such as entrainment/reentrainment, transport, and improper building pressurization.

Microbial contamination has been an important area of this research. Studies show that fungi, bacteria, and other micro-organisms from indoor and outdoor sources may accumulate inside HVAC systems. With an appropriate substrate and sufficient moisture, these microorganisms may survive and multiply, and bioaerosols may be distributed throughout the building by the HVAC system. Bioaerosols are airborne microbial contaminants, including viruses, bacteria, fungi, algae, and protozoa plus the reproductive units, metabolites, and particulate material associated with these microorganisms.

Two case studies were performed to evaluate whether HVAC systems contain microbial sources that affect bioaerosol concentrations in occupied spaces and to compare sampling approaches that might be used in IAQ investigations.

The first was a three-story office building constructed in 1988. It is 29,200 ft^2 (2717 m^2) and has a typical variable-airvolume (VAV) medium pressure HVAC system that is well maintained. The second, also three-story, was constructed in 1966. It is 23,700 ft^2 (2200 m^2) and is served by a low pressure perimeter induction system and interior multizone system that is not as well maintained.

Bioaerosol emissions in the HVAC systems were examined by making both upstream and downstream measurements at major components, including OA intakes, air handling units (AHUs), duct liners, mixing plenums, fans, supply and return ducts, filter banks, diffusers, heat exchangers, condensate drains, and perimeter induction units.

For the first building, visual inspections showed that surfaces of ducts and other HVAC components in contact with the air stream were relatively clean with little dust accumulation. There were no signs of water or microbial contamination. Infiltration of OA occurred during HVAC system night shutdown due to stack effect, exhaust fan operation, and improper damper positions. These energy losses may increase the chances of condensation that could act to deposit spores and other bioaerosols in the ductwork.

For fungi, the concentration in bulk samples averaged 11 CFU/mg with the highest concentrations in the return air duct linings and in the dust at filters. Concentrations at HVAC components downstream of the filters were lower, indicating that the filter was helpful. A total of 22 fungal taxa were identified in the bulk samples. *Cladosporiun, Penicillium, Alternaria,* and non-sporulating fungi were the most common. *Cladosporium* was the dominant taxa found in HVAC system particulate matter collected. Proportions of *Aspergillus, Penicillium, Alternaria,* and non-sporulating fungi were fairly constant throughout the HVAC system.

For bacteria, the concentrations averaged 24 CFU/mg with the greatest concentrations (11,420 CFU/mg) found on the supply fan housing. The next highest concentrations were found on the central return air duct.

Airborne sampling for fungi averaged 48 CFU/m^3 in the HVAC systems, 43 CFU/m^3 in the indoor air, and 17 CFU/m^3 outdoors. *Cladosporium* was the dominant taxon in the HVAC samples, and *Penicillium* and non-sporulating fungi in the indoor air. These concentrations are generally low compared to other studies. Airborne bacteria averaged 226 CFU/m^3 in the HVAC system, 252 CFU/m^3 in the indoor air, and 87 CFU/m^3 in the outdoor air. The highest concentrations (848 CFU/m^3) were found in the central return at the return air fan. This is consistent with findings at return air grilles throughout the building. Bacteria concentrations are more uniform throughout the building than fungi since the occupants are a major contributor.

In the second building, HVAC system conditions did not appear as clean as the first building. There was accumulation of dust and debris in and around the mechanical room and on the exterior surfaces of the HVAC systems. Ductwork had some open drill holes where negative air pressure could draw in air from the mechanical equipment room. There were oil slicks on the concrete floor and condensate ran from the AHU to a floor drain. Visual inspection of the interior system components showed that dust accumulation was generally low; however, a damp musty odor was evident when the AHU was off. No moisture damage was visible.

Fungi concentrations in bulk samples averaged 5 CFU/mg. This is much lower than comparative measurements in the first building. The researchers suspect that concentrations were lower due to the accumulation of inorganic debris. Concentrations at all sites were low. Researchers identified 20 total fungal taxa with *Cladosporium* being dominant in HVAC bulk samples.

Bacteria concentrations were highest in the OA duct and the perimeter induction units. Low concentrations were found in the supply air duct. Intermediate levels were found in the return air duct.

Air samples showed very little contribution to bioaerosol levels as fungi concentrations in the HVAC were generally low (58 CFU/m^3). Office spaces had similar levels (44 CFU/m^3). However, when the fan section was manually disturbed, the fungi levels were very high (greater than 8,075 CFU/m^3) as was the case with the bacteria concentrations (86,000 CFU/m^3).

Conclusions

A number of comparisons can be made between the two buildings. Typically the bulk samples yielded two to four times as many fungi taxa as air samples, but the majority of fungal taxa were identified using both types of sampling techniques. However, proportions of species or taxa varied considerably. These differences are significant and seem to suggest that building sampling may be indicative of higher numbers of actual taxa or species available as a source of bioaerosols and air sampling.

Bulk sampling appears sufficient to identify microbial reservoirs in HVAC systems, and air sampling of disturbed reservoirs can confirm actual or potential releases. However, due to spatial variability in settling, deposition, moisture, etc., multiple sites in HVAC ducts and AHUs should be sampled to obtain representative concentrations in surface and bulk measurements.

The quantification of bioaerosol emissions based on impaction measurements taken upstream and downstream of HVAC components may not be effective since short sampling periods are not representative of the temporal variability commonly found in emissions. Additionally, it is also difficult to capture any existing HVAC spatial variability; component access is typically difficult; and the need for low velocity (fan shut off) alters the flow regime and thus the entraimment and suspension of potential bioaerosols. Measurements taken at terminal units, however, are easily obtained and may indicate whether the HVAC system is discharging bioaerosols (EPA Contact: Russell N. Kulp, 919-541-7980, rkulp@ engineer.aeerl.epa.gov)

EFFECT OF VENTILATION ON RADON LEVELS IN A MUNICIPAL OFFICE BUILDING

APPCD, together with the Florida Department of Community Affairs and Southern Research Institute, is conducting research to help assess the impact of building design, construction, and operating features (e.g., mechanical systems) on radon and other indoor air pollutants. The research will help APPCD better understand the effects of various building features on IAQ and will also provide information to support the Florida Standard for Radon Resistant Construction in Large Footprint Structures.

Building Description

An extensive characterization and parametric assessment study was conducted in a typical Florida multistory commercial building. Indoor radon levels were above the EPA guideline of 4 pCi/L and ranged from 4 to 15 pCi/L. The building has 149,000 ft^2 (45,415 m^2) of floor space distributed over five stories with an atrium that extends from the ground floor up to a glass skylight. Each of the first fours opens out into a balcony around the atrium. The atrium opening is enclosed completely on the fifth floor. The building foundation is slab-on-grade with supporting pilings under the slab and grade beams in some locations. The slab thickness is 6 in. (15.2 cm) with pilings that penetrate the sub-surface soil to an undetermined depth. The building has 11 AHUs, with 2 each on floors two through five and 3 on the first floor.

First, the HVAC system was inspected thoroughly, and a certified test and balance contractor measured actual flow distribution in the mechanical subsystems. Based on the inspection of the HVAC system and continuous monitoring, several deficiencies were noted which would be expected to adversely affect radon levels, other IAQ factors, or energy consumption. Specifically, OA air flow rates were far below design values on the first and fourth floors; maximum supply air flow rates are below design values on all but the fifth floor; the building generally operates under negative pressure; and there is an excessive pressure imbalance between zones, especially on the first floor.

Measurement of IAQ Parameters

A series of measurements were made during several cycles of building operation between May and August 1994. For continuous measurements, IAQ data stations were used to monitor radon, differential pressures, room temperatures, relative humidities, and carbon dioxide (CO_2) concentrations in each of 13 zones. The 13 data stations were distributed 2 per floor on the top four floors, with 5 stations distributed in several zones on the first floor. Ten additional continuous radon monitors were located on the first floor.

As shown in Table 1, baseline radon concentrations in the building averaged approximately 8.1 pCi/L on the first floor and 3.1 pCi/L on the upper floors, with a building average of 4.1 pCi/L. The data in Table 1 also show that radon concentrations were essentially unaffected by varying the OA damper from minimum to maximum (columns two and three). Measurements of the building air change rate over this period ranged from 0.15 to 0.25 hr^{-1}, indicating that varying the OA damper settings also has little effect on the building ventilation rate. This suggests that ventilation in this building is primarily by direct leakage across openings in the building shell and is driven by local pressure differentials between specific indoor zones and the outdoors. The observed magnitude of HVAC-induced pressure imbalance among the first floor zones is enough to expect that a significant portion of the observed infiltration/exfiltration is derived from this source. Based on these measurements, researchers concluded that too little induced OA was coming into the building to significantly affect ventilation in comparison to the gains and losses of air through the building shell induced by depressurization and pressure imbalance.

In consultation with the building owners, a temporary system that consisted of three in-line fans was installed in the first floor AHUs. The purpose was to determine if forced ventilation could increase the air exchange rate and decrease radon entry on the first floor.

As shown in the final three columns of Table 1, first floor radon concentrations were progressively reduced with addition of increased amounts of forced OA for ventilation. With the greatest supply of OA (1900 cfm), the first floor radon levels dropped to 4.8 pCi/L, approximately 60% of the baseline concentration. Radon reductions on upper floors, where additional OA was not supplied, were not as dramatic as the first floor. Other measures of building ventilation rate effects, such as peak excess CO_2, also show a net dilution effect on both first and upper floors, indicative of increased ventilation during the “fan on” periods. These measurements are consistent with the fan operation adding roughly 1200 cfm (14-22%) to the previous 5500-8500 cfm of infiltration/exfiltration.

Conclusions from Case Study

This study demonstrates control of indoor radon levels by introducing additional OA on the first floor only of a large, relatively open, multistory building. The results indicate that the greatest relative reductions in radon levels were on the first floor where baseline radon levels were the highest. This study thus demonstrates the potential for a targeted dilution strategy in which OA is delivered to only one portion of a relatively open building while interzonal floor-to-floor effects are contained or minimized. (EPA Contact: Marc Y. Menetrez, 919-541-7081, mmenetrez@engineer.aeerl.epa.gov)

Table 1. Average radon levels under various operational modes (pCi L^{-1})

Location	Baseline	Max OA	Min OA	2 OA Fans (700 cfm)	3 OA Fans (1000 cfm)	3 OA Fans (1900 cfm)
1st Floor	8.1	7.4	7.9	6.6	5.6	4.8
Floors 2-5	3.1	3.2	3.4	3.4	3.1	2.8
Building	4.1	4.0	4.3	4.0	3.6	3.2

INDOOR AIR BIBLIOGRAPHIC DATA BASE

The National Center for Environmental Assessment (NCEA) published a revised version of the *Indoor Air - Bibliographic Data Base* in 1994. The bibliographic data base is an extensive bibliography of reference materials on IAQ. The data base is organized by key word, lead author, and citations. A more current copy of the bibliographic data base is available on computer diskette through EPA. The hard copy version of the data base is available through the NRMRL's Technology Transfer and support Division (513-569-7562) and the National Technical Information Service (NTIS) (703-487-4650). (EPA Contact: Beverly Comfort, 919-541-4165, comfort.beverly@epamail.epa.gov)

Organizational Changes **OFFICE OF RESEARCH AND DEVELOPMENT (ORD)**	
CURRENT ORGANIZATIONAL TITLES	Formerly
National Risk Management Research Laboratory/ Air pollution Prevention and Control Division/ Indoor Environment Management Branch (Mike Osborne, 919-541-4113)	Air and Energy Engineering Research Laboratory/Radon Mitigation Branch and Indoor Air Branch
National Exposure Research Laboratory/ Human Exposure Research Division (Gerald Stelma, 513-569-7384)	Environmental Monitoring and Sampling Laboratory
National Health and Environmental Effects Research Laboratory (Sue McMaster, 919-541-3844)	Health Effects Research Laboratory
National Exposure Research Laboratory/ Human Exposure and Field Research Division (Miriam Rodon-Naveira, 919-541-3075)	Atmospheric Research and Exposure Assessment Laboratory
National Center for Environmental Assessment (Beverly Comfort, 919-541-4165)	Environmental Criteria and Assessment Office
National Risk Management Research Laboratory/ Technical Transfer and Support Division (513-569-7562)	Center for Environmental Research Information

USING ANIMAL MODELS TO UNDERSTAND HUMAN SUSCEPTIBILITY TO INDOOR AIR

Often, the signs and symptoms of exposure to indoor air contaminants appear in only a few of the many exposed individuals, even though exposure levels appear to be similar. This suggests that differences in individual susceptibility play an important role in determining responses to exposure.

Historically, the development of animal models has greatly facilitated the study of a variety of biological and toxicological problems. Many of the common signs and symptoms of indoor air exposure apparently involve direct effects on the nervous system or are mediated directly or indirectly by the nervous system. These considerations prompted EPA's National Health and Environmental Effects Research Laboratory (NHEERL) to hold a workshop on animal models of nervous system susceptibility to indoor air contaminants. The workshop was held in October 1994 in Chapel Hill, North Carolina, and included a number of national and international scientific experts.

The purpose of the workshop was to provide scientific input into EPA's research planning process with regard to the development of animal models to determine susceptibility to indoor air pollutants. The workshop included: 1) human clinical and epidemiological evidence regarding exposures and outcomes; 2) possible experimental designs and modeling; 3) determining differences in susceptibility; and 4) proposed experiments and modeling for testing hypotheses.

Clinical and Epidemiological Evidence

The human clinical conditions discussed were multiple chemical sensitivity (MCS), sick building syndrome (SBS), and building-related illness (BRI). BRI is the best defined and involves building contaminants of known identity which produce definitive health outcomes. One example of BRI is legionnaires' disease. SBS, less well defined, involves experienced illness which is alleviated upon leaving the building. Often the causes of SBS are unknown. The health problems reported in SBS vary, but often include a number of subjectively experienced symptoms. MCS is least well specified. In MCS, a diffuse array of symptoms are reportedly triggered by exposure to a variety of different chemicals, and are not necessarily restricted to any particular location or class of compounds. As with SBS, the health outcomes in MCS are based on reports of subjective discomfort or illness for which there are few or no corresponding clinical signs of illness or dysfunction. There is no consensus in the medical community about the existence of MCS, and the lack of objective evidence of impairment represents a major impediment in the development of animal models of such conditions in a traditional sense.

One conclusion from the workshop was that better characterizations of the human conditions are needed. However, many workshop participants stated that the enigmatic nature of the human clinical conditions did not preclude the development of animal models, because valid test methods and corresponding animal models currently exist for many relevant outcomes. These methods and models could be used to test a variety of hypotheses. regarding susceptibility to indoor air contaminants.

Possible Experimental Designs and Models

Traditional experimental approaches tend to emphasize measures of central tendency, and minimize the influence of individual subjects deviating far from population norms. One approach proposed to identify susceptible individuals was to examine those subjects already at the extremes of the normal distribution of test scores, and to determine whether they might be most susceptible to exposure.

Another experimental approach addressed the goal of identifying genetic contributions to susceptibility. This approach involved the study of genetically defined inbred strains of laboratory animals, which could be ranked for sensitivity to exposure. This would provide a repeatable supply of individuals with a predetermined susceptibility, thus facilitating the identification of genetic factors that influence susceptibility.

Quantitatively, it was suggested that variability in response outcome be considered as the focus of, rather than a detractor from, the research effort. Sources of individual variability include differences in uptake of chemicals, pharmacokinetic distribution to target sites, and response to the agents. Variability can be both a within-subject, as well as a between-subjects, consideration because the susceptibility of an individual may vary substantially over time. It is important to establish dose-response relationships for definitive outcomes in order to establish legitimate cause-and-effect relationships.

Determining Differences in Susceptibility

Several hypotheses were discussed concerning how susceptibility to exposure may be acquired or altered in otherwise normal individuals. One potential mechanism involves classical conditioning, in which the temporal pairing of a previously neutral stimulus (conditioned stimulus) with a biologically active stimulus (unconditioned stimulus) results in a learned association. The previously neutral stimulus alone then elicits the biological response. Once the association is established, a biological response could be triggered by exposure to levels of stimuli which previously had no effect. The responses to classically conditioned stimuli, however, typically diminish rather quickly without continued pairingsof the conditioned and unconditioned stimuli, which is not obviously present in MCS. Another type of learning, operant conditioning, involves the elicitation of responses which are followed by either positive or negative consequences. Responses that are “reinforced” in this fashion may be much longer lived. A number of experiments have shown that susceptibility to chemical treatment can be altered substantially by operant conditioning.

Stress may also influence the susceptibility to a chemical treatment through the consequences of activation of a complex neuroendocrine system. Personal and social factors may alter the response to stress, and the resultant health consequences can involve multiple bodily sites and disorders.

Neural plasticity, defined as modifications in the functional properties of a neurological system as a result of experience, may also serve as a source of increased sensitivity to chemical exposure.

Finally, a phenomenon know as time-dependent sensitization, which involves progressive and enduring enhancement of behavioral and biochemical responsiveness to chemical treatment, could also underlie augmented susceptibility.

Testing of Hypotheses

Many symptoms reported following exposure to indoor air contaminants involve sensory complaints (odor or irritation), cognitive or behavioral changes including frank avoidance of odors or environments, and inflammation. Specific experimental models of these topics were discussed. The function of the trigeminal and olfactory systems could be investigated both electrophysiologically and behaviorally. The measurement of respiratory depression following exposure can be used to test hypotheses regarding the irritancy of inhaled substances.

The perception of odor varies greatly among individuals, and can be influenced by psychological factors such as expectancy and learning. The concentrations which animals will terminate exposure vary both between and within animals as a function of exposure history. Neuro-immune interactions are also important to consider, and might be profitably studied using immuno-deficient mice or other well-characterized models.

It was demonstrated that several hypotheses of the development of susceptibility could be profitably examined experimentally using existing animal models. One important point was that animal models need not replicate every aspect of the human condition, but are of value if they focus on a single facet for study. The importance of selecting species-appropriate endpoints in animal models was emphasized.

Animal models that specifically address issues related to IAQ include the sensory aspect of odor and irritation perception, behavioral avoidance of contaminated atmospheres, and neurogenic inflammation. A research program based on animal models would augment and complement continued efforts to better characterize the human conditions. These research efforts would likely improve the ability to assess the risks of exposure of susceptible individuals to indoor air environments, as well as in other exposure situations of concern to EPA. Source: EPA Report, MS-95-264-USEPA, 1995. (EPA Contact, Ken Hudnell, 919-541-7866, hudnell@am.herl.epa.gov)

REDUCING INDOOR AIR EMISSIONS FROM AEROSOL CONSUMER PRODUCTS

Because aerosol consumer products, such as those used for personal care, pest control, and cleaning, are commonly used in the indoor environment, APPCD is supporting research to 1) better understand personal exposures to aerosol consumer products, and 2) to develop pollution prevention techniques to reduce exposures. A group of Industry Partners is actively involved in the research to ensure that the results will be practical for industry.

Developing Measurement Methods and Models

Georgia Tech and the University of Illinois are working together to develop measurement methods and models for manufacturers to use to develop a better understanding of aerosol behavior. This improved understanding can then be used by manufacturers to develop and produce more efficacious and less toxic aerosol consumer products.

Georgia Tech is developing a Mass Spectrometer (MS)/MS system for the chemical characterization of representative aerosol products. They are also measuring particle sizes for various spray patterns using a Malvern Analyzer and are developing an electron mobility analyzer for future work on particle sizing in conjunction with the MS system. The MS/MS system eliminates the need for collection and concentration techniques and chromatographic separations, and is particularly sensitive to polar compounds. As a result, the system is well suited for real-time, direct analysis of aerosol consumer products. The University of Illinois is developing techniques and instrumentation capabilities to measure aerosol transport and distribution in rooms. A model is also being developed to predict aerosol behavior in rooms. Researchers at the University of Illinois are currently analyzing the spray patters of representative aerosol products using particle image velocimetry (PIV) techniques. Figure 3 illustrates PIV data showing aerosol particle concentrations at various distances from the spray nozzle.

The ultimate outputs from this project include: 1) indoor air characterization data on emissions from representative aerosol consumer products as a function of time; 2) methods, technology, and models to measure and predict emissions and personal exposures from use of aerosol products indoors; and 3) pollution prevention techniques and guidelines for the manufacture and use of these products.

Innovative Spray Nozzle Design

In another project, Purdue University has developed and demonstrated an innovative spray nozzle design for use with precharged aerosol containers. This design is similar to one previously developed and demonstrated at Purdue for pump- and trigger-dispensed aerosol products.

The new dispenser design (Figure 4) allows manufacturers to reformulate selected aerosol consumer products (e.g., personal care, hair care, degreasers, and hard surface cleaners) using water and air in place of VOC solvents and hydrocarbon propellants in precharged systems, while still maintaining acceptable product delivery characteristics.

Laser diffraction measurements made at Purdue indicate that the new dispenser design produces product droplets in the desired size range. Data demonstrate that Sauter Mean Diameters (SMDs) are within experimental error of 70 μm for air to liquid ratios (ALRs) as low as 70%. Reducing the ALR below 0.75% results in a rapid increase in the mean drop size. The data also indicate little sensitivity of mean drop size to viscosity over the range considered in this study (0.020 to 0.080 kg/m-s, or 20 to 80 cP).

Data also show that air consumption is below target values and supply pressures are acceptable. Dispenser performance is relatively insensitive to product formulation, as described by its viscosity and surface tension. This simplifies manufacturing since a single dispenser design can then be used with a wide array of products.

Current research at Purdue is addressing three questions necessary to provide rational design guidelines to industry. First, when the product exits the dispenser, how does it break up into ligaments and drops? Second, to what extent does the spray entrain surrounding air? Third, what challenges must be met during intermittent nozzle operation? Pulsed holography and PIV are being used to acquire the necessary data to answer these questions. (EPA Contact: Kelly Leovic, 919-541-7717.)

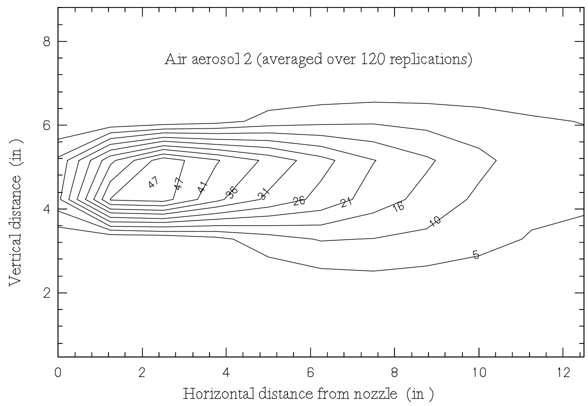

Figure 3. Time averaged concentration contour plots of aerosol particles (1 in. = 2.54 cm).

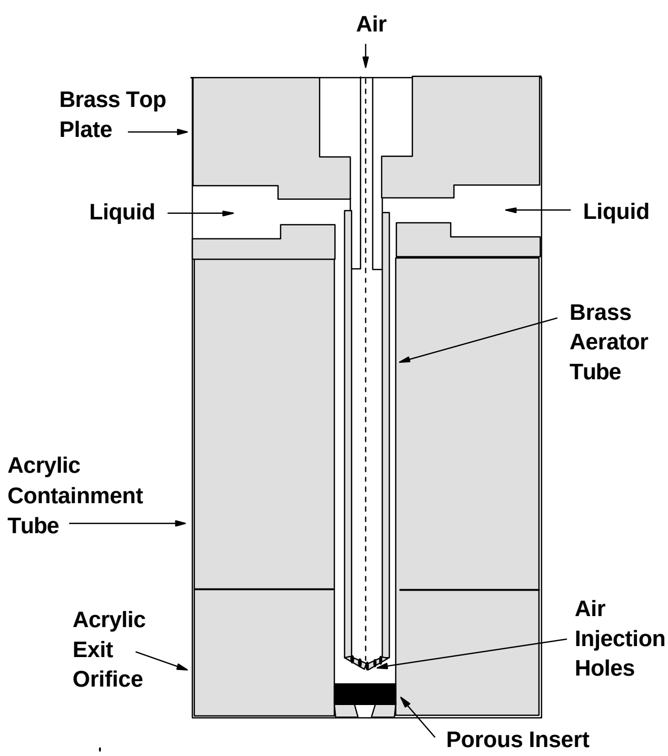

Figure 4. Prototype of new dispenser developed by Purdue University

THE INDOOR AIR QUALITY INFORMATION CLEARING HOUSE (IAQ INFO)

IAQ INFO is an easily accessible, central source of information on indoor air quality. It is supported by EPA's Office of Air and Radiation's Indoor Environment Division.

IAQ INFO can provide information on many aspects of indoor air quality:

- Indoor air pollutants and their sources
- Health effects of indoor air pollution
- Testing and measuring indoor air pollutants
- Constructing and maintaining homes and buildings to minimize IAQ problems
- Existing standards and guidelines related to IAQ
- General information on Federal and State Legislation

IAQ INFO contains:

- Citations and abstracts on more than 2,000 books, reports, newsletters, and journal articles
- An inventory of publications prepared by the Federal government, including fact sheets, pamphlets, directories, training materials, and reports
- Information on more than 150 government research, public interest, and privte sector organizations in the IAQ field

You may call a toll-free number to speak to an information specialist, Monday through Friday, 9:00 a.m. to 5:00 p.m. EST. After hours, you may leave a voice message, or you may inquire by fax or mail anytime.

IAQ INFO
P.O. Box 37133
Washington, DC 20013-7133
1-800-438-4318
202-484-1307
Fax: 202-484-1510

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 at : 5285 Port Royal Road, Springfield, VA 22161, 703-487-4650 or 800-553-6847. EPA papers presented at the *Engineering Solutions to Indoor Air Quality Problems* symposium held in July 1995 are summarized beginning on page 13.

Laboratory Assessment of the Permeability and Diffusion Characteristics of Florida Concretes: Phase II. Field Samples and Analyses-The report summarizes a study that establishes the capability to measure concrete's permeability and diffusivity and to correlate the physical parameters of the concrete to the measured diffusion and permeability coefficients. For both permeability and diffusivity, the amount of water added to the mix at the site was directly and positively related and identified as a possible major factor. The total amount of sand and stone in the mix was possibly correlated to the permeability. A third possible correlation involved the amount of fly ash or the cement to fly ash ratio. Source: EPA Report, EPA/600/R-95/103 (NTIS PB95-243168), July 1995. (Lead Author: R. Snoddy; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@engineer.aeerl.epa.gov)

Statewide Mapping of Florida Soil Radon Potentials, Vol. 1, Technical Report, Vol. 2, Appendices A-P-The report gives results of statewide mapping of Florida soil radon potentials. The maps provide scientific estimates of regional radon potentials that can serve as a basis for implementing radon-protective residential building standards. Source: EPA Report, EPA-600-R-95-142a & 142b (NTIS PB96-104351 & -104369), September 1995. Lead Author: Kirk K. Nielson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@engineer.aeerl.epa.gov)

Ozone Generators in Indoor Air Settings-This report addresses typical questions posed by both consumers and professionals about the effects of ozone as an IAQ ameliorative. Source: EPA Report, EPA-600/R-95-154. (NTIS PB 96-100201), October 1995, (Lead Author and EPA Contact: Ray Steiber, 919-541-2288, rsteiber@engineer.aeerl.epa.gov)

Lumped-parameter Model Analyses of Data from the 1992 New House Evaluation Project–Florida Radon Research Program-The report documents analyses of Phase 2 data from the Florida Radon Research Program's (FRRP's) New House Evaluation Project that were performed using a lumped-parameter model. The analyses focused primarily on empirically characterizing the radon resistance of the house/soil interface for different foundation designs. The analyses were also aimed at comparing the effectiveness of active and passive radon protection features. Source: EPA Report, EPA/600/ R-95/090 (NTIS PB95- 243077), July 1995. (Lead Author: Kirk K. Nielson; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@engineer.aeerl.epa.gov)

Design and Testing of Sub-slab Depressurization for Radon Mitigation in North Florida Houses, Part I-Performance and Durability; Vol. 1, Technical Report; Vol. 2, Data Appendices-The objectives of this study were to develop and test the use of a soil depressurization computer model as a design tool, to optimize the sub-slab soil depressurization design for North Florida houses, and to observe system performance and durability. Radon concentrations, originally on the order of 10-30 pCi l^{-1} were reduced to below 4 pCi L^{-1} in all nine houses studied. The systems retained effectiveness during the 3-18 month durability observations. Source: EPA Report, EPA-600/R-95-149a & 149b(NTIS PB96-103585 & -103593), September 1995. (Lead Author: C. E. Roessler; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@ engineer.aeerl.epa.gov)

Relative Sensitivity of the Ocular Trigeminal, Nasal Trigeminal and Olfactory Systems to Airborne Chemicals-Thresholds for eye irritation and odor resulting from exposure to ketones and alkylbenzenes are discussed. Eye irritation thresholds are well above odor thresholds, and both sensory thresholds declined with carbon chain length. Also, eye irritation thresholds were remarkably close to nasal pungency thresholds obtained previously in persons lacking olfaction (i.e., anosmics) Source: *Chemical Senses*, Vol. 20, No. 2, pp. 191-198, 1995. (Lead Author: J. Enrique Cometto-Muñiz; EPA Contact: Ken Hudnell, 919-541-7866, hudnell@am.herl.epa.gov)

Evaluation of Building Design, Construction, and Performance for the Control of Radon in Florida Houses: Evaluation of Radon Resistant Construction Techniques in Eight Houses-The eight houses in this study were built following Florida's radon resistant construction standard. The study shows that operation of well designed and constructed HVAC systems does not significantly affect indoor radon, regardless of the pressures induced between interior air zones. Source: EPA Report, EPA-600/R-95-114 (NTIS PB95-253910), July 1995. (Lead Author: D. E. Hintenlang, Univ. of Florida; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@engineer.aeerl.epa.gov)

Soil and Fill Laboratory Support–1992, Radiological Analyses, Florida Radon Research Program-Analyses performed on soil and fill samples included moisture, radium-226, and radon emanation coefficient determinations for 164 samples representing 21 sites. Central Florida (Polk County) sites were characterized by elevated radioactivity fill over a wide rand of substrate concentrations. Source: EPA Report, EPA-600-R-95-145, September 1995. (Lead Author: C.E. Roessler; EPA Contact: David C. Sanchez, 919-541-2979, dsanchez@engineer.aeerl.epa.gov)

An international symposium, *Engineering Solutions to Indoor Air Quality Problems*, was held July 24-26, 1995, in Research Triangle Park, North Carolina. The symposium was cosponsored by APPCD and the Air & Waste Management Association (A&WMA). Topics included: source characterization, source management and pollution prevention, ventilation and modeling, air cleaning, and biocontaminant control. There were over 200 attendees from around the world, including researchers from the government, private sector, industry, and academia. Summaries of APPCD-sponsored papers presented at the Symposium are below.

Proceedings from the symposium will be published by the A&WMA and EPA in late 1995. To obtain a copy of the proceedings, contact the A&WMA at 412-232-3444 or NTIS at 703-487-4650. The next symposium will be held in 1997 in Research Triangle Park. An announcement and call for papers will be sent to everyone on the *Inside IAQ* mailing list.

Aerosol Filtration Efficiency of In-Duct Air Cleaners-A test method has been developed for measuring the fractional aerosol filtration efficiency of air cleaners. The method provides a reliable and accurate means of measuring air cleaner fractional efficiencies over the particle diameter size range of 0.01 to 10 μm. The fractional efficiency of several common air cleaners was evaluated: fiberglass furnace filters, paper-media filters, and several types of electronic air cleaners. Results show that filtration efficiency is highly particle size dependent over the 0.01-10 μm size range. Filtration efficiency was also seen to be dependent upon flow rate and the dust load condition of the air cleaner. (Lead Author: James T. Hanley; EPA Contact: Leslie E. Sparks, 919-541-2458, lsparks@engineer.aeerl.epa.gov)

Air Exchange Measurements in an IAQ Test House-Air exchange rates in an IAQ test house have been determined by using tracer gas techniques. It was found that, with all windows and outside doors closed, the variation of air exchange rate covered a six-fold range: from as low as 0.18 per hour to as high as 1.1 per hour. The major factors that affect air exchange include: weather conditions, operation of the heating and air conditioning system, closing or opening interior doors, and changes in house structure. (Lead Author: Zhishi Guo; EPA Contact: Leslie Sparks, 919-541-2458, lsparks@engineer.aeerl.epa.gov)

Characterization of Aerosol Consumer Products-This paper discusses the development of a mass spectrometer (MS) interface that will allow for the real-time characterization of both the particulate and gaseous phases of an aerosol consumer product. An electron mobility analyzer is being designed to define to particle size of the aerosol droplets. This is being interfaced with an atmospheric triple quadrupole MS for the gaseous characterization. Preliminary data on particle size of the aerosol products and on gaseous characterization are included. See article on page 10. (Lead Author: Charlene W. Bayer; EPA Contact: Kelly Leovic, 919-541-7717, kleovic@engineer.aeerl.epa.gov)

Characterization of the Usefulness of the Field and Laboratory Emission Cell (FLEC) for the Evaluation of Emissions from Engineered Wood Products-A series of tests was designed to evaluate the performance of the FLEC as applied to the testing of emissions from engineered wood products. The objective was to determine appropriate parameters for testing the emissions of formaldehyde and other possible aldehydes, ketones, and VOCs. Commercially available household products (e.g., kitchen cabinets) constructed from different types of engineered wood with various laminates and coatings were tested. (Lead Author: Nancy F. Roach; EPA Contact: Elizabeth M. Howard, 919-541-7915, bhoward@engineer,aeerl.epa.gov)

A Comparison of Design Specifications for Three Large Environmental Chambers-Large (room-sized) environmental test chambers are currently being constructed by three government organizations (U.S. EPA, National Research Council Canada, and Australia's Institute of Minerals, Energy, and Construction) to characterize sources of indoor air pollution. The chambers, while intended for similar purposes, have been designed and constructed to different specifications. A study will compare the design and performance of these chambers in order to develop a better understanding of how they can be best used for IAQ measurements. (Lead Author & EPA Contact: Betsy M. Howard, 919-541-7915, bhoward@engineer.aeerl.epa.gov)

Developing Guidance for Considering Cost-Effectiveness when Selecting and Designing IAQ Control Approaches-APPCD is undertaking a program to develop a practical methodology that will facilitate cost-effectiveness considerations in selecting among alternative IAQ control options. This paper describes an initial effort where the methodology will be tested by using it to conduct a sensitivity analysis for a 4-story office building. The cost-effectiveness of ventilation, air cleaning, and source management will be compared as key variables associated with the building, the HVAC system, and the IAQ control system are systematically varied. Lead Author & EPA Contact: D.B. Henschel, 919-541-4112, bhenschel@engineer.aeerl.epa.gov)

The Effect of Relative Humidity on Gaseous Air Cleaner Media Performance: Toluene Adsorption by Activated Carbon-Performance characteristics of activated carbon as a gas-phase air cleaner media were examined. Toluene breakthrough curves at relative humidities (RHs) from below 5 to 80% were obtained. RH appears to have negligible influence on the adsorption of toluene below 50%. By 75% RH, the adsorption of the toluene is decreased. The linearity of the log-log relationship between the concentration and the 10% breakthrough time for lower concentration challenges indicates that high concentration breakthrough data can be used to predict breakthrough time for lower concentration challenges. (Lead Author: M. K. Owen; EPA Contact: Leslie Sparks, 919-541-2458, lsparks@ engineer.aeerl.epa.gov)

Effects of Altered Ventilation on Radon and IAQ Variables in a Five-Story Municipal Office Building-This paper summarizes a study of a multistory office building where radon and other air quality parameters were monitored as the HVAC systems were modified. See article on page 6. (Lead Author: Ashley D. Williamson; EPA Contact: Marc Y. Memetrez, 919-541-7981, mmenetrez@ engineer. aeerl. epa. gov)

Effervescent Atomization at Low Air/ Liquid Ratios-A new type of consumer product aerosol dispenser that uses water instead of VOC solvents and air in place of hydocarbon propellants is described. The primary feature of this dispenser is the elimination of VOC carrier liquids and hydrocarbon propellants from a variety of consumer products. The aerosol dispenser is insensitive to product fluid physical properties (surface tension and viscosity) which in turn allows a single design to be employed for a wide variety of products. See article on page 10. (Lead Author: J. Sutherland; EPA Contact: Kelly Leovic, 919-541-7717, kleovic@engineer.aeerl. epa.gov)

Energy Impacts of Compliance with ASHRAE Standard 62-1989 in a Hot & Humid Climate-The main objectives of this study were to ascertain the energy impacts associated with increasing OA for compliance with ASHRAE Standard 62-1989 and to investigate the relative energy efficiencies of the building systems and operations and maintenance procedures. Manual computations and computer simulations were made to calculate energy consumption. (Lead Author: Pete Rojeski; EPA Contact: Russ N. Kulp, 919-541-7980, rkulp@ engineer.aeerl.epa.gov)

Evaluation of an Indoor Air Quality Source Management Strategy for Large Building Construction-In conjunction with the State of Washington, a pilot study was conducted to evaluate the air quality, building performance, and loading data that influence the ability to predict IAQ from product emissions testing and building operation data. See article on page 1. (Lead Author & EPA Contact: Mark Mason, 919-541-4853, mmason@ engineer.aeerl.epa.gov)

Increases in Levels of Breathable Fine Particles Due to the Application of Carpet Fresheners in a Suburban Home-The paper details the results of a study in which two carpet fresheners were applied to the carpet of a suburban home. The data show that there is a measurable increase in breathable fines after each application, but that the increase is transitory, lasting no more than 8 to 24 hours. (Lead Author & EPA Contact: Raymond W. Steiber, 919-541-2288, rsteiber@engineer. aeerl.epa.gov)

Measurement of Indoor Air Emissions from Office Equipment-EPA, Research Triangle Institute, and a group of office equipment manufacturers have developed a test method for measuring indoor air emissions from office equipment. The method is intended to characterize emissions from office equipment and to support identification of potential pollution prevention strategies. The paper describes the test method including: chamber construction, clean air supply, operational and control systems, sample collection and analysis equipment, standards generation and calibration systems, and performance characteristics. Preliminary test results from two dry-process photocopy machines are also included. (Lead Author & EPA Contact: Kelly W. Leovic, 919-541-7717, kleovic@ engineer.aeerl.epa.gov)

Microbiological Screening of the Indoor Air Quality in a Large Building-A microbiological screening study of a non-compliant five-story office building in Florida was conducted to generate baseline measurements that could be used to study the impact of ventilation systems design and operation on microbiological contamination. This paper presents the results from that microbiological screening study. See article on page 4. (Lead Author: D. W. Van Osdell; EPA Contact: Russ N. Kulp, 919-541-7980, rkulp@engineer. aeerl.epa.gov)

A Novel, Full-Scale, Whole-Field, Optical Diagnostic Technique for Improvement of Indoor Air Quality-A novel, full-scale, whole-field, optical diagnostic technique and instrumentation have been developed to study aerosol transport in the indoor environment. The purpose is to better understand aerosol consumer products and to develop pollution prevention strategies to reduce exposure. Both instantaneous structures and statistical properties of air flow have been calculated to determine quantitatively the characteristics of indoor air flow. See article on page 10. (Lead Author: Michael M. Cui; EPA Contact: Kelly W. Leovic, 191-541-7717, kleovic@engieering. aeerl.epa.gov)

Ongoing Evaluation of Sources and Factors affecting Emissions from Engineered Wood Products-This project is characterizing indoor air emissions from engineered wood products and identifying and evaluating pollution prevention approaches for reducing indoor air emissions from these products. The research is being conducted in five phases: (1) evaluate existing data and testing methodologies; (2) convene a research planning meeting; (3) select high-priority emissions sources; (4) evaluate high-priority emission sources; and (5) develop and demonstrate pollution prevention approaches for reducing indoor air emissions from selected high-priority sources. This paper presents the results of Phases 1 through 3. (Lead Author: Sonji L. Turner; EPA Contact: Betsy Howard, 919-541-7915, bhoward@engineer.aeerl. epa.gov)

VOC Removal at Low Contaminant Concentrations Using Granular Activated Carbon-Beds of granular activated carbon are the most commonly used air cleaning technology for VOCs. However, design and operating data at the low concentrations encountered indoors are scarce, and extrapolation to those concentrations has not been demonstrated. Small-scale carbon beds have been challenged with single contaminants at concentrations ranging from 4 0 4000 mg/m^3. Results suggest that higher concentration, single component breakthrough tests, which are short and easily obtained, may be extrapolated to low concentrations. (Lead Author: D. W. VanOsdell; EPA Contact: Leslie E. Sparks, 919-541-2458, lsparks@engineer. aeerl.epa.gov)

A Study of the Structures of Spray Cones Utilizing Digital Particle Image Velocimetry-This paper discusses the dynamic physical properties of a spray cone using PIV techniques. The dynamic structures of aerosol size, concentration, and velocity are included. The results can be used to improve the efficiency of aerosol products, to understand the characteristics of the transport mechanism, and to develop pollution prevention strategies. See article on page 10. (Lead Author: Michael M. Cui; EPA Contact: Kelly W. Leovic, 919-541-7717, kleovic@engineerl.aeerl. epa.gov)

Susceptibility of Fiberglass Duct Lining to Fungal (Penicillium Chrysogenum) Growth-A series of experiments, each lasting 6 weeks, was conducted in static environmental chambers to evaluate the conditions that support the growth of a fungus, *penicillium chrysogenum*, on fiberglass duct lining. Two different fiberglass duct liners and one fiberboard duct, all newly purchased, were evaluated following inoculation with *P. chrysogenum*. The studies demonstrated that the xerophilic mold, *P. chrysogenum*, amplified under conditions of high RH even on newly purchased duct lining, and that either wetting or dirtying increased material susceptibility. To prevent the growth of *P. chrysogenum*, dust accumulation and/or RH needs to be properly controlled in the HVAC duct. (Lead Author: K. K. Foard; EPA Contact: John C. W. Chang, 919-541-3747, jchang@engineer.aeerl.epa.gov)

Sampling and Analysis of VOCs for Indoor Air Source Characterization-This paper discusses a number of issues related to sampling and analysis of VOCs that need to be addressed in the design and performance of source characterization testing for small chambers, large chambers, test houses, and in the field. (Lead Author: Roy Fortmann; EPA Contact: Mark Mason, 919-541-4835, mmason@engineer. aeerl.epa.gov)

Short and Long Term VOC Emissions from Latex Paint-Latex paint (interior, water-based) is being evaluated in order to develop methods for predicting emissions of VOCs over time. Painted gypsum board is placed in dynamic flow-through test chambers. Results show that most of the Texanol® emissions occur within the first few days, and emissions of ethylene glycol occur over several months. This behavior indicates that evaporative mass transfer processes dominate the short term emissions, while long term emissions are limited by diffusion processes within the gypsum board. (Lead Author: Kenneth Krebs; EPA Contact: Bruce A. Tichenor, 919-541-2991, btichenor@engineer.aeerl.epa. gov)

Review of Concentration Standards, Guidelines, and Proposals for Indoor Fungi-This paper provides a complete review of current standards, guidelines, and proposals for levels of indoor fungi. See article on page 4. (Lead Author: Carol Y. Rao; EPA Contact: John C. W. Chang, 919-541-3747, jchang@ engineer. aeerl. epa.gov)

Glossary of Acronyms

AHU-Air Handling Unit
ALR-Air to Liquid Ratio
APPCD-Air Pollution Prevention and Control Division
ASHRAE-American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
A&WMA-Air and Waste Management Association
BRI-Building-related Illness
CFU-Colony Forming Units
EPA-U.S. Environmental Protection Agency
FLEC-Field and Laboratory Emissions Cell
FRRP-Florida Radon Research Program
HVAC-Heating, Ventilating, and Air-Conditioning
IAQ-Indoor Air Quality
MCS-Multiple Chemical Sensitivity
MS-Mass Spectrometer
MSDS-Material Safety Data Sheets
NHEERL-National Health and Environmental Effects Research Laboratory
NRB-Natural Resources Building
NRMRL-National Risk Management Research Laboratory
NTIS-National Technical Information Service
OA-Outdoor Air
ORD-Office of Research and Development
OSHA-Occupational Safety and Health Administration
PIV-Particle Image Velocimetry
RH-Relative Humidity
SBS-Sick Building Syndrome
SMD-Saunter Mean Diameter
TVOC-Total Volatile Organic Compound
VAV-Variable Air Volume
VOC-Volatile Organic Compound

United States
Environmental Protection Agency
Air Pollution Prevention and Control Division
MD-54
Research Triangle Park, NC 27711

FIRST CLASS MAIL
POSTAGE AND FEES PAID
EPA
PERMIT No. G-35

Official Business
Penalty for Private Use
$300

EPA/600/N-95/007, Fall/Winter 1995

An Equal Opportunity Employer