

Penicillium/Aspergillus. The proportion of Penicillium spores indoors is usually elevated compared to outdoor levels. This increase appears to be more pronounced in buildings with extensive moisture damage.

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AIR INLET VELOCITY PROFILE: AN IMPORTANT FACTOR IN COMPUTATIONAL FLUID DYNAMIC SIMULATION OF INDOOR CONTAMINANT DISPERSION. E. Lee, C. Feigley, University of South Carolina, Columbia, SC.

Determining airborne contaminant transport and distribution in buildings is often essential for understanding indoor air quality problems. Computational fluid dynamics (CFD) has been used increasingly to simulate airflow and contaminant transport processes, but many simulation efforts have not been wholly successful. Thus, understanding the factors affecting the accuracy of such simulations is critical. The goal of this study was to test and validate CFD approaches for simulating the dispersion of gases and vapors. Tracer gas concentrations were measured at points in a three-dimensional grid throughout a 1-m × 0.3-m × 0.7-m chamber using a photoionization detector. Air flowrates were scaled using kinematic similarity criteria to represent a full-sized room at two realistic Reynolds numbers ($Re = 500$ and 5000). Also, chamber tracer concentration was simulated using CFD, initially assuming that air inlet velocity was normal to and uniform across the inlet face. The simulated three-dimensional distribution of tracer gas concentration matched measured patterns moderately well at the high Re , but significant differences in these patterns were observed at the low Re . Measured air velocity was found to vary substantially across the inlet face and the velocity profile differed for the Re numbers tested. Thus, another set of CFD simulations accounting for inlet velocity variation was performed. For the high and low Re numbers respectively, the average differences between measured and CFD concentrations were 41% and 55% assuming uniform inlet velocity, but only 9% and 1% using measured inlet velocity profiles in the simulations. Graphical comparisons revealed that CFD underestimated observed concentrations for both inlet boundary condition treatments, but use of measured inlet velocity profiles produced much better agreement with observed concentration levels and spatial patterns. These results suggest that use of realistic air inlet boundary conditions is important for accurate CFD simulation of contaminant dispersion in rooms and other enclosed spaces.

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INDOOR AIR QUALITY TOOLS; EDUCATION, PREVENTION AND INVESTIGATION. P. Maynard, University of California, Berkeley, Berkeley, CA; L. Morris, University of California Santa Cruz, Santa Cruz, CA.

Industrial Hygienists at the University of California, Environment Health and Safety offices feel that indoor air quality (IAQ) problems should be addressed in a consistent manner following best practices. A work group was created to focus on IAQ and prepare a guidance document that could be used by the nine campuses and three national laboratories in the University of California. The seven members of the work group met and had monthly

conference calls for approximately 2 years. The resulting work product is a 90-page document titled "Indoor Air Quality Tools; Education, Prevention and Investigation." The collaboration allowed industrial hygienists to focus on common IAQ problems, and share knowledge, experience and solutions. Many of the work group's experiences and successes are incorporated into the details of the IAQ Tools document. "IAQ Tools" is available at www.ehs.ucsc.edu/ih/IAQC/iaq/IAQC.html. The document is divided into proactive and reactive sections. The five proactive chapters include topics such as organization, HVAC design, operation, maintenance, and how to control microbial growth. The reactive section gives suggestions on how to conduct an IAQ investigation, and includes a number of forms and flowcharts that promote a consistent approach to the confusing practice of IAQ investigations. The reactive section also includes information and fact sheets on what occupants' can do to improve the air quality of their work spaces. The systematic approach described in the document provides structure and logical endpoints to IAQ investigations which otherwise might be difficult to conclude. The University of California Indoor Air Quality work group continues to meet to discuss technical topics and controversial subjects, and to share case studies. The plan is to keep the web-based document "IAQ tools" up to date with the latest proactive and reactive information on indoor air quality.

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MEASUREMENTS OF AIRBORNE MICROORGANISMS AND MVOCS AT AN ELEMENTARY SCHOOL IN WEST VIRGINIA. P. Gao, R. Boylstein, S. Berardinelli, G. Feather, E. Hruzdo, G. Kullman, NIOSH, Morgantown, WV.

Exposure to airborne microorganisms was investigated in relationship to health complaints among teachers at an elementary school in West Virginia. The school, constructed during the 1920's, is a four-story brick building of about forty classrooms. The basement had evidence of water leaks/incursions. A Health Hazard Evaluation (HHE) was conducted at the school during 1999. A questionnaire survey showed that employees who worked in the basement area reported higher occurrence of asthma-like respiratory symptoms than employees who worked on the 1st or 2nd floor of the school. Almost all employees from the basement area (89%) reported wheezing and shortness of breath with wheezing during the last 12 months, and 66.7% reported taking medication for breathing problems. Air samples were taken to determine microbial volatile organic compounds (MVOCs), culturable fungi and bacteria, and total fungal spores in air, respectively. Sampling locations included three rooms in the basement area, a classroom on the ground floor, and a classroom on the 2nd floor. Samples were also taken outside the school for comparison. MVOC concentrations were determined to be 724 to 1,876 ng/m³. Culturable airborne fungi and bacteria ranged from 132 to 1095 CFU/m³ and 230 to 892 CFU/m³, respectively. Total airborne fungal spores ranged from 840 to 5,694 spores/m³. The basement area had a unique representation of Basidiomycetes and Aspergillus species, and had higher representation of bacterial species not found in the ambient or 1st and 2nd floor air samples. Regression analyses yielded the highest correlation ($R^2 = 0.66$) between MVOC levels and total culturable bioaerosols (fungi and bacteria), when compared to the correlation between MVOC levels and culturable airborne fungi ($R^2 = 0.58$) or bacteria ($R^2 = 0.39$) alone.

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IH EVALUATION OF HVAC SYSTEMS IN IAQ INVESTIGATIONS. T. Kallio, S. Rhodes, Council Rock Consulting, Inc., Columbia, MD; T. Traum, Council Rock Consulting, Inc., McLean, VA.

Inadequate ventilation was identified as a contributing factor of health complaints in 53% of the buildings investigated by NIOSH from 1971 to 1989. A review of 1362 building investigations conducted by Health and Welfare Canada (1984-1989) revealed that inadequate ventilation was contributory in 52% of the problems. It is obvious that HVAC system performance and maintenance is a major component of indoor air quality. We have developed and implemented a "HVAC System Evaluation Program" to assist the IH in the performance of a complete and accurate HVAC system assessment. This program overcomes jargon, system drawing communication, and survey completeness issues while improving report quality and findings communicability.

One of the goals in developing this assessment tool is to eliminate confusing jargon. Describing HVAC systems with a common "language" enables concise, accurate reporting of observed conditions and facilitates the development of sound and understandable recommendations. To ensure that all available information on the building and its ventilation system is obtained, a pre-inspection survey form is submitted to the facilities manager/building engineer. This form, returned to the industrial hygienist for review prior to the site inspection, provides basic building and systems information as well as alerts the IH of potential obstacles in the path of a complete and successful evaluation. To facilitate documentation of HVAC systems within the building, standardized diagrams of basic HVAC systems are marked-up to record the system components and observed conditions. A system specific checklist focuses the IH on critical components and operating parameters of the system. HVAC system documentation is supported with informational photographs.

This program and associated materials have resulted in the development of concise, readable, factual, and universally understood ventilation assessments for IAQ surveys. Further, this program can result in cost savings through reduced rework, improved quality and accuracy, and readily validated and defensible recommendations.

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AN INVESTIGATION OF SIZE-SPECIFIC PARTICLE CONCENTRATIONS USING A REAL-TIME MONITOR IN A HOSPITAL SETTING. L. Sabatino, C. Rao, M. Berakis, K. Kreiss, NIOSH, Morgantown, WV.

Indoor air quality investigations would benefit from direct reading instruments that can quickly identify potential sources. Aerosols are an important factor in many IAQ investigations, being associated with both chemical and microbial contaminants. Particles with aerodynamic diameters <1 micrometer may be a health concern. Since size distributions and concentrations are variable, a convenient size-selective particle monitor for indoor environments is needed. Particle monitoring was conducted in an 8-story hospital. During the sampling period, forest fires burned approximately 60 miles away. Depending upon weather conditions, the city had clear and smoke-filled days. Seventeen indoor and one outdoor locations were monitored. GRIMM real-time data-logging dust monitors were used to

evaluate particle concentrations for 24 hours at each of the locations. Fifteen size fractions were measured ranging from 0.3 micrometer to 20 micrometer. Outdoor GRIMM particle counts averaged 2.8×10^5 particles/liter (p/L) with 99% of the particles sized below 1 micrometer (cut point > 0.3 micrometer; min 6.5×10^4 p/L-max 1.8×10^6 p/L) on the smokiest day. These coincided with indoor averages of 1.6×10^5 p/L (96.6% <1 micrometer) on the upper floor, and 2.4×10^5 p/L (99.8% <1 micrometer) on the lower floor of the building. On non-smoky days, average measurements for most sites were one order of magnitude lower. However, the size distributions differed. 94% of the particles on both the upper and lower floors were less than 1 micrometer while 96% were <1 micrometer outdoors. Areas of complaints within the hospital were associated with sites that had consistently elevated particle counts in reference to the outdoor site. Size specific particle concentrations may be more relevant to indoor air quality complaints than the classical gravimetric measurements for airborne dust. They are also more useful since they can instantaneously be obtained and immediately lead investigators to problem areas in large buildings.

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A SIMPLE SURVEY METHOD FOR QUICK SCREENING OF IAQ AND ASTHMA SYMPTOMS. I. Kudla, Occupational Health Clinics for Ontario Workers Inc., Don Mills, ON, Canada; J. Oudyk, Occupational Health Clinics for Ontario Workers Inc., Hamilton, ON, Canada.

In response to symptom complaints of unionised workers, a government labor department ordered a symptom survey of occupants at a large courthouse contaminated with mold. The analysis and results of the survey were time sensitive in order to decide whether the building should remain open or closed during remediation. The English version of the Swedish "MM-040-EA Indoor Climate Work Environment Questionnaire" along with a four-item asthma screening questionnaire developed by Venables et al., were selected as investigation instruments. A one-page (double-sided) survey was distributed to 288 occupants and 82.9% responded within the one week deadline. Relative risk ratios were calculated comparing respondents' symptom prevalence with published data for buildings without air quality problems. Relative risk ratios exceeded 5.00 for cough, throat and skin symptoms experienced on at least a weekly basis. One-third (76) of the respondents satisfied a NIOSH "sick building syndrome" symptom case definition. Even more (94) screened positive to the asthma screening questions, 60 of whom reported never having been diagnosed with asthma. Comments written on the survey form indicated aggravation of pre-existing asthma and recent diagnosis of new onset asthma. The results were presented within 8 days of the survey response deadline. These survey instruments performed very well and were easily analysed in a very short time frame. It is an effective tool for validating building occupants' concerns and supplements the traditional aspects of an IAQ evaluation. These surveys are recommended to hygienists in similar situations facing tight deadlines.

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FINDINGS FROM A NIOSH IEQ INVESTIGATION. G. Burr, K. Martinez, NIOSH, Cincinnati, OH.

Background: In March 2000, NIOSH conducted an indoor environmental quality (IEQ) evaluation in a two-story office building located in South Carolina. Workers were concerned about exposure to carbon monoxide (CO), as well as mold in the building. Their symptoms included headache, sinus problems, and upper respiratory problems. Methods: Measurements of carbon dioxide (CO₂), CO, temperature, and relative humidity (RH) were made and the ventilation systems were visually examined. Dust samples were collected by micro-vacuuming sections of carpet and "sticky" tape samples were collected using the adhesive side of the tape to pull spore structures and hyphae from the growth surface. Areas suspected of water damage were probed with a moisture meter. Twelve of the 115 employees volunteered for informal interviews. Results: The highest CO₂ concentrations ranged from 1030 to 1190 parts per million (ppm), suggesting that parts of the building was receiving insufficient outside air (OA). Temperature and RH levels ranged from 69 to 75°F, and 35 to 53%, respectively, within the thermal comfort parameters recommended by the American Society of Heating, Refrigerating, and Air-Conditioning Engineers. CO concentrations ranged up to 2 ppm. Micro vacuum samples did not reveal high fungal concentrations, however bacterial levels ranged up to 5.9×10^6 colony forming units per gram of collected dust, mainly Gram negative species. Tape samples of suspect fungal colonies revealed *Cladosporium*, *Ulocladium*, and trace levels of *Stachybotrys chartarum*. The highest moisture readings were beneath exterior windows while carpeted areas were predominantly dry. Of the 12 employees interviewed, most reported respiratory problems, congestion, fatigue, and headache. Conclusions: There was inadequate amounts of OA provided to some offices. Localized microbial reservoirs existed and there were numerous ongoing moisture incursion conditions. It was unclear, however, how these related to the health complaints described by the interviewed employees. Recommendations were provided to further improve ventilation and eliminate the wet conditions conducive to microbial growth.

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CASE STUDY INVOLVING TEACHER SYMPTOMS AFTER SEVERE WATER DAMAGE IN A CONNECTICUT ELEMENTARY SCHOOL. K. Gilbert, G. Cormier, Occupational Risk Control Services, New Britain, CT.

An evaluation was performed at a Connecticut elementary school in response to teacher complaints that included mild headaches, nasal stuffiness, chest pain, and sinus infections. The onset of symptoms began soon after a water pipe leak occurred in a carpeted room adjacent to the Gymnasium, saturating the floors prior to the December holiday break. The number of teachers experiencing symptoms increased and the symptom severity worsened when they returned for a workshop after the holiday break.

Our hypothesis was that occupant symptoms were caused by fungal growth and amplification and migration of bioaerosols from the water-damaged areas into adjacent classrooms in the school. Cultureable fungal air samples using an Anderson N-6 sampler and MEA agar were taken outside and in eight locations of the school. Air sampling results indicated that specific species of fungi were found in the water-damaged and adjacent areas but were not found in the samples taken outside or in classrooms away from the water-damaged area.

Monitoring for carbon dioxide, carbon monoxide, temperature, and relative humidity was also conducted. Carbon dioxide levels exceeded the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) recommendation in six (6) of the 26 locations monitored.

This evaluation concluded that the cause of the occupant symptoms was the microbial growth and amplification in the water-damaged areas and a lack of fresh outside air. Recommendations were made to remove the hardwood floor and cork base in the Gymnasium and carpets in the two adjacent rooms under full containment and negative pressure and increase the amount of fresh air brought into the building by opening windows during occupied hours.

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RADON SORPTION OF BUILDING MATERIALS. C. Lungu, M. Kingsley, University of Minnesota, Minneapolis, MN.

This study investigates the influence of building material sorption on the concentration dynamics of a radon surrogate gas. An important factor in the radon dynamics which can change significantly its indoor concentration and persistence is its adsorption and subsequent desorption onto/from various building materials. Because of the difficulties encountered in creating constant radon emission sources as well as in measurement of radon concentration, due to its short-life and daughter products, radioactive xenon (Xe-133) has been chosen as a radon surrogate in this study, xenon having similar physical and chemical characteristics with radon. To test the ability of building materials to act as radon sinks, a $45 \times 35 \times 35$ stainless steel small environmental test chamber was constructed in which three types of building materials were tested. The insulated, temperature controlled chamber allowed the injection of xenon into a clean air stream creating various xenon concentrations inside the chamber. The xenon activity-concentration was monitored using a flow-through ionizing chamber connected at the test chamber outlet. After the steady state was reached, the gas flow was interrupted and the building material samples were left inside the closed chamber for at least 12 hours. The airflow through the chamber was then reinstated and the output activity-concentration continuously monitored until undetectable levels were reached. The area under the desorption curve was obtained and the amount of xenon retained into the building material was calculated. Among the three building materials tested: carpet, ceiling tile and gypsum wallboard the most significant sink effect was exhibited by the ceiling tile (1.5 to 3.2 mg/m²) followed by the carpet (0.7 to 1.8 mg/m²) and by the almost insignificant sorption characteristics of wallboard (0 to 0.4 mg/m²). The tests were conducted at 23°C and at a relative humidity of 45%.

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CARDIOVASCULAR RESPONSE OF WEARING AN INDUSTRIAL BACK BELT. J. Davis, R. Thomas, Auburn University, Auburn, AL.

The purpose of this preliminary investigation was to determine the effects of two conditions: Belted

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