2G.1

Development and Validation of a Model to Predict Aerosol Breathing Zone Concentrations During Common Outdoor Activities. JONATHAN THORNBURG, G. Gordon Brown, RTI International; John Kominsky, Environmental Quality Management, Inc.

Research has been conducted on aerosol emission rates during various activities as well as aerosol transport into the breathing zone under idealized conditions. However, there has been little effort to link the two into a model for predicting a person's breathing zone concentration. This research developed a model to calculate the breathing zone concentration produced by common outdoor activities. The model combined aerosol physics and fluid dynamics principles to develop a set of mass balance equations applicable to activities of varying intensity and duration.

The model consisted of four distinct modules. The first module defined the characteristics of the person, their activity, and their location. The second and third modules calculated the aerosol emission rate generated and the aerosol transport efficiency to the breathing zone, respectively, for a specific activity. Activities simulated included motorcycle riding, yard work, and child's play. The equations used in modules 2 and 3 depended on whether the turbulence intensity generated by the activity. The fourth module calculated the resulting breathing zone concentration.

Whenever possible, published data were used as model input independent parameters. If data were not available, a range of input values were assumed. Monte Carlo simulation applied to the model equations generated a probability output distribution for comparison with experimentally measured results and to perform a sensitivity analysis on the independent parameters.

Scenario model output distributions were either normal or log-normal, depending on the distribution of the most influential input variables. The modeled output distributions successfully bracketed the range of experimentally measured breathing zone concentrations. However, the modeled breathing zone concentration range during certain activities was 1000 times broader than the other scenarios because of the positive interaction between highly significant input variables.

Although this work was reviewed by U.S. EPA and approved for publication, it may not necessarily reflect official Agency policy.

2G.2

Demonstrating the Benefits of a Technician Training Program for a Successful Longitudinal Research Study.
Jerermy Seagraves, Andrew Dart, JONATHAN THORNBURG, Jeff Portzer, Charles Rodes, RTI International; Don Whitaker, Ron Williams, U.S. EPA.

A longitudinal research project like the Detroit Exposure and Aerosol Research Study (DEARS) requires a comprehensive technician training program to assure collection of high quality data to address study hypotheses. More than 40,000 exposure samples (representing surveys, passive gas monitors, and active particulate matter samplers) were collected over six sampling seasons. Additionally, the training had to flexibly address a range of technician skill levels and adapt to staff turnover. Accordingly, the training program was upgraded seasonally to keep pace with changing project and personnel requirements.

The DEARS training program followed four stages. The introductory stage consisted of self-guided review of a comprehensive training manual. This manual contained a project overview and abridged versions of all Research Operating Procedures (ROPs). Technicians subsequently were taught equipment and survey use, sample archival, and basic aerosol physics in an interactive class environment. The third phase was collection of samples and surveys at two residences for three days. This stage allowed new staff to practice with all equipment and witness common sample collection problems under the guidance of experienced personnel. Training culminated with new and veteran technicians working together during the first week of real sample collection. This multi-stage approach reinforced critical thinking skills and reduced technician errors when collecting real samples during the remainder of the sampling season.

Comprehensive training for all technicians contributed substantially to the success and overall cost-effectiveness of DEARS. Technicians quickly adapted to increases in workload without extending the sampling periods or increasing the number of personnel. Most importantly, increased data capture rates correlated with refinement of the training program without an increase in project cost. This framework also proved very effective for training technicians with disparate backgrounds and experience.

2G.3

DNS of Aerosol Motion in a Model Room. XINLI JIA, John B. McLaughlin, Goodarz Ahmadi, Clarkson University; Jos Derksen, Delft University of Technology.

This talk will present results for the computed trajectories of aerosols in a model room with a displacement ventilation system. The fluid velocity fields used in the trajectory computations were obtained from a DNS using the Somers formulation of the lattice Boltzmann method (LBM). The Somers formulation is significantly more complex than the BGK formulation of the LBM, which is much more commonly used. The Somers formulation has two primary advantages over the BGK formulation that make it more suitable for simulations of indoor air pollution. First, it is more stable. It has been used by one of the co-authors (J.D.) to perform LES of stirred tanks at Reynolds numbers, based on the impeller size and speed, up to . Second, the Somers formulation permits one to perform DNS of natural convection for a broad range of Prandtl numbers. Simulations can be done only for Pr=0.5 for the BGK formulation, and the set of lattice vectors must be expanded to solve the energy equation. This talk will focus on isothermal conditions, but a few results will be shown that include natural convection. Using the computed flow fields, the trajectories of aerosols ranging in size from 2 to 20 micrometers are computed. The equation of motion includes gravity and nonlinear drag. The particles are uniformly dispersed in the inlet vent and then tracked until they either deposit on a solid surface or exit through the outlet vent. The spatial distributions of deposited particles will be discussed and the roles of gravity and particle inertia will be assessed. Although the size of the model room is of order 2 meters, the Somers formulation permits DNS with realistic inlet velocities at Reynolds numbers of order 104. We will discuss the use of DNS to test LES and RANS simulations of indoor air pollution.

2G.4

Resuspension of Dust Particles in a Chamber and the Associated Factors. JING QIAN, Andrea R. Ferro, Clarkson University.

Resuspension experiments were conducted in a full-scale experimental chamber to investigate particle resuspension from human activities. Three types of flooring (vinyl tiles, new carpet, and old carpet) and two ventilation (mixing and displacement) configurations were tested during the experiment. The floorings were seeded with 0.1-10 micro-meter Arizona Road Test particles. Size-resolved resuspension rate was estimated from an air-surface compartment model using real-time particle concentration data. Resuspension rates are in the range of 10^{-5}-10^{-2} hr^{-1} for particles in size ranges of 0.8-10 micro-meter, with higher resuspension rates associated with larger particles. Resuspension via walking activity varied from experiment to experiment. A \heavy and fast\ walking style was associated with a higher resuspension rate than a less active style. The ventilation condition could affect the resuspension on the same scale as the person-to-person variability. Given the same floor loading of the test particles, resuspension rates for the carpeted floor were on the same order of magnitude but significantly higher than those for the hard floor.

2G.5

Exposure to Indoor PM: Effects of Climatic and Cultural Influences. VIVIANA ACEVEDO-BOLTON, Lynn Hildemann, Stanford University.

Air quality standards designed to protect human health are based on outdoor levels, yet we spend almost 90% of our time indoors. The concentrations and chemical characteristics of outdoor particulate matter (PM) are often not representative of what we are exposed to indoors - penetration losses reduce the infiltration of PM from outdoors, while indoor sources elevate indoor PM levels.

The concentration and composition of indoor PM, including both chemical and biological measures, have not been well characterized in homes located in different climates. This project focuses on the differences found between a temperate climate (San Francisco Bay Area, CA) and a tropical climate (Singapore), and the effects that both outdoor climate and building design and operation may have on indoor air quality. We hypothesize that we will see higher concentrations in Singapore of: (1) bioaerosols, (2) elemental carbon, and (3) sulfate; and elevations in Bay Area homes of (4) resuspended dust and (5) indoor/outdoor (I/O) ratios of particles and their components.

The levels and composition of PM in a home can be influenced by many factors, such as outdoor diesel use (in Singapore), ventilation conditions (HVAC in Singapore vs. natural ventilation in the Bay Area), floor type (carpet in Bay Area vs. no carpet in Singapore), shoe removal (in Singapore), and different indoor sources. Filter samples will be collected to analyze for mass, elemental and organic carbon, water-soluble anions, trace metals, protein, endotoxin (a tracer for molds), and glucan (a tracer for bacteria). This presentation, which focuses on how the study will be designed to test our hypotheses, will include some preliminary results. For example, preliminary indoor results show higher sulfate/nitrate ratios in Singapore, consistent with higher diesel use. Endotoxin levels in Singapore were similar to those found in Bay Area homes.

2G.6

Silver-deposited Activated Carbon Fibers for Bioaerosol Control. KI-YOUNG YOON, Jeong Hoon Byeon, Jae-Hong Park, Chul-Woo Park, Jungho Hwang, Yonsei University.

Bioaerosols are airborne particles of biological origins, including viruses, bacteria, fungi, and all varieties of living materials. In suitable hosts, bioaerosols are capable of causing acute or chronic diseases that may be infectious, allergenic, or toxigenic. Bioaerosols from outdoor air accumulate on filters of heating, ventilating and air conditioning (HVAC) system in large quantities and are able to multiply there under certain conditions. Activated carbon fiber (ACF) filter is widely used in air cleaning to remove hazardous gaseous pollutants because of their extended surface area and high adsorption amount. However, the ACF filters have good biocompatibility and bacteria may breed on the ACF filters, so that the ACF filters themselves becomes a source of bioaerosols. In this study, silver, traditionally well-known as antimicrobial material, was deposited on ACF filters by an electroless deposition method and their efficacy for bioaerosols removal was tested. Physical filtration and biological antimicrobial test were performed and various surface analyses such as scanning electron microscopy, inductive coupled plasma, and X-ray diffraction were used to characterize the prepared ACF filters. Silver-deposited ACF filters showed antimicrobial effects whereas pristine ACF filters did not. Electroless silver-deposition did not influence the physical characteristics such as pressure drop and filtration efficiency of ACF filters. Gas adsorptive ability of silver-deposited ACF filter decreased compared to the pristine one because of the blockage of the micropores of ACF by silver particles. Therefore silver contents on ACF filters need to be optimized to avoid the excessive reduction of adsorptive characteristics of the ACF filter and show effective antimicrobial activity. [This work was supported by grant No. R01-2005-000-10723-0 from the Basic Research Program of the Korea Science & Engineering Foundation.]

2G.7

Personal and Indoor Exposure to PM2.5 and Polycyclic Aromatic Hydrocarbons from Traditional Cooking Practices in Njombe, Tanzania, East Africa. MARI TITCOMBE, Matt Simcik, University of Minnesota.

Exposure to indoor smoke from traditional cooking practices in impoverished countries is responsible for 2.6% of global ill health in human populations, and 1.6 million deaths annually (Desai et. al., 2004). In this study, personal and indoor exposure to $PM_{2.5}$ and Polycyclic Aromatic Hydrocarbons (PAHs) were measured in households in Njombe, Tanzania using open wood fires, charcoal, a mix of charcoal and kerosene, and Liquid Petroleum Gas (LPG) as cooking fuels. Due to cool local climate and often heavy rainfall, cooking in this region is conducted indoors, often in small, poorly ventilated rooms. Results represent work day exposures, or time spent cooking in the home. Preliminary results show $PM_{2.5}$ personal exposures for open wood fire use roughly two orders of magnitude greater than those of LPG users. Personal exposures for charcoal, and charcoal/kerosene users were roughly one order of magnitude greater than those of LPG users, with pure charcoal use having roughly a factor of 5 greater exposures than charcoal/kerosene mix. Significant differences in PAH exposure were also observed. Households using wood fires were shown to have the greatest exposure, followed by charcoal and charcoal/ kerosene users, with the lowest exposures for LPG users. A comparison is made between exposure levels and socioeconomic status of the households tested. In addition, the use of \fuel efficient\ wood stoves for the reduction of $PM_{2.5}$ and PAH exposure was measured in a local secondary school, boarding approximately 800 students. Proper use of \fuel efficient\ wood stoves was shown to sharply decrease personal and indoor exposure of both $PM_{2.5}$ and PAHs for the kitchen sampled.

REFERENCES

Desai, A. M., Mehta, S., Smith, K. R. (2004). Indoor smoke from solid fuels, Assessing the environmental burden of disease at national and local levels. Geneva, World
Health Organization, 2004 (WHO Environmental Burden of Disease Series, No. 4).

2G.8

Correction of Sampler-to-Sampler Comparisons. PATRICK T. O'SHAUGHNESSY, The University of Iowa; Vijay Golla, Western Kentucky University; Jason Nakatsu, Stephen Reynolds, Colorado State University.

Field studies have been conducted which involve side-by-side comparisons of old and new personal aerosol samplers in order to establish a proportional relationship needed to relate findings of studies involving any two samplers. However, the ratios obtained are directly related to the size distribution of the aerosol during the sampling episode and will therefore be different if applied to another setting with a different size distribution. A simple method for correcting a sampler-to-sampler ratio for changes in size distribution was developed by computing a bias factor that relates the measured ratio with a ratio determined from equations that describe the collection efficiency curves of the samplers while taking size distribution into account. Laboratory trials were conducted to determine whether the resulting bias factor is independent of aerosol size distribution. During these studies a 3-piece cassette and respirable cyclone were compared to an inhalable sampler in both a still-air chamber and a moving-air chamber operated at 0.2 and 1.0 m/s. An ISO test dust of various size fractions was generated to produce an aerosol with mass median aerodynamic diameter ranging from 1.4 to 10.1 micro-meters. An organic dust consisting of ground grain material was also applied to the still-air chamber to demonstrate differences between dust types. Results showed that the bias value was significantly different between dust types for both the cyclone/inhalable ($p = 0.001$) and cassette/inhalable ($p = 0.033$) comparisons but was not different between wind conditions for either comparison. All but one comparison had insignificant slopes when comparing the bias value relative to median diameter indicating that the bias value could be used to correct for size distributions in most conditions. However, bias values determined when comparing the cyclone to the inhalable sampler in the still-air condition produced a positive slope for median diameters less than 4 micro-meters ($p = 0.008$).

2G.9

Use of Synthetic-Jet-Based Active Flows to Control Particle Dispersion. JENNIFER ZIEGLER, Michael Amitay, Lupita D. Montoya, Rensselaer Polytechnic Institute.

The present threat of chemical or biological attack from terrorists combined with the current American lifestyle, spent predominantly indoors, presents a real opportunity for developing smart systems for indoor air quality. The goal of the current research is to control the dispersion and movement of a plume of particles, from submicron to supermicron sizes, using synthetic-jet-based active flow control. To test this concept, a dedicated, two foot square, closed chamber was constructed. The chamber configuration includes a particle point source in the center of the floor, synthetic jet actuators on both sides of the source, and a ventilation system along the sidewalls.

The synthetic jet actuators are zero-net-mass-flux in nature but they provide momentum; thus can alter the particles field. The time- and phase-averaged velocity fields of the air and the particles were measured using Digital Particle Image Velocimetry and Particle Tracking Velocimetry. When a pair of synthetic jets was activated, the particle plume was vectored either towards or away from the jets. The vectoring was controlled by changing the phase between the two synthetic jets. When the jet farther from the plume was leading in phase, the plume was vectored towards the jets. When the jet closer to the plume was advanced in phase, it resulted in vectoring of the plume away from jets. Therefore, by controlling the phase and strength of the synthetic jets, the plume was controlled and directed to the chamber's ventilation system to be removed quickly and efficiently. The decrease in concentration was validated using an aerosol sampling probe, through the top of the chamber and connected to an Aerodynamic Particle Sizer. Measurements were taken throughout the chamber at set times after release to generate both spatial and temporal particle distributions.

2G.10

Spatial and Temporal Variability of Particulate Pollutants in Diesel-Powered School Buses. Maxwell A. Martin, Xiaodong Zhou, Ryan LeBouf, Emily L. MacWilliams, Alan Rossner, Peter A. Jaques, ANDREA R. FERRO, Clarkson University.

The characterization of human exposure to diesel particulate matter (DPM) on school buses is an important step in understanding the risks to respiratory disease that children may face throughout the day, both acutely and chronically. To characterize the potential exposures, DPM was measured by mass, particle count and composition in unoccupied buses. Three school buses from the Potsdam, NY school district were instrumented and monitored while the buses drove prescribed routes. Self-pollution and spatial distribution of self-pollution was determined by adding sulfur hexafluoride (SF6) directly to the exhaust and monitoring the SF6 at 8 locations inside the bus using an Innova 1312 Multigas Analyzer and a Mark 3 8-Point Sampler. Composition and size distribution of the DPM was determined using a suite of semi-continuous instruments. The impact of idling and traveling at various speeds was determined by keeping records of bus operation and analyzing the semi-continuous exposure data. An aerosol mapping technique was used to provide the temporal and spatial relationship of DPM on the bus during various operational modes. The mapping is used to optimize the monitoring protocol for occupied bus scenarios to best estimate children's exposures while they are riding, boarding and deboarding the bus and to correlate these real-time exposures with acute health endpoints.

2G.11
Study of Evaporating Droplet Transport and. Mazyar Salmanzadeh, Goodarz Ahmadi, Clarkson University.

Transmission of diseases from one person to another due to coughing and sneezing by emission of droplets that carrying viruses and bacteria in hospital patient rooms is studied. A computational model for simulating the airflow, the thermal and the humidity condition in room was developed and the distributions of evaporating droplet in the hospital room with two beds were studied. The turbulence model was used for continuous fluid phase calculations and the trajectories of the evaporating droplets were evaluated with a Lagrangian method. The particle equation of motion included the viscous drag, the Brownian, the Saffman lift and the gravity forces. Mixing and displacement air distribution systems were considered and trajectories of particles in the range of 1 to 500 microns were simulated. The simulation results suggested that the chance of disease transmission was higher when the mixing ventilation system was used. In addition, the air distribution system does not affect the large particle trajectories.

2G.12
Resuspension of Particulate Matter by the Human Foot.
JACKY ROSATI, U.S. EPA, National Homeland Security Research Center (NHSRC); Alfred Eisner, Alion Life and Environmental Sciences.

Resuspension of particulate matter from flooring surfaces is a little understood process, yet is thought, along with tracking, to contribute significantly to the movement of materials inside a home or office. To investigate what happens when a human foot steps on a flooring surface contaminated with particulate matter, an automated stepping system comprised of a prosthetic foot controlled by electric actuators was developed. The actuators control the speed of the ‘footstep’, as well as the pressure loading. Thus, the turbulence surrounding the foot as well as the pressure exerted on the test surface can be controlled.

Short-pile carpet was seeded with silicon particles. Once loaded, the carpet was placed under this prosthetic foot, and a single step was taken. Particle Image Velocimetry (PIV) was used to study the particle flows under the foot. These PIV images showed that the visible resuspended particles are not released from the carpet as the foot is lifted, but actually fall off the foot after it has moved up off the flooring surface. These falling particles form a cloud under the foot that moves rapidly to the front of the foot during the stepping motion. Particle mean velocities observed under the foot were about 0.5 m/s. Tests were performed using both a cotton sock and a rubber soled shoe. The cotton sock both collected from the carpet and released from the sole of the foot a greater number of particles than the rubber-soled shoe. Further investigation into other types of footwear, flooring surfaces and materials is ongoing.

2G.13

The Effectiveness of an Integrated Energy Recovery Ventilator on the Air Quality in the Bedroom of Asthmatic Children, 5-14 Years, and Their Improved Respiration and Restfulness. PETER A. JAQUES, Andrea R. Ferro, Philip K. Hopke, Clarkson University; Cheryl Gressani, Larry E. Wetzel, Air Innovations, Inc.

Recent estimates show that about 6.4 million children under the age of eighteen years suffer from some form of asthma. Airborne contaminants or allergens exacerbate the illness. Moderate-to-severe asthmatics that obtain relief during restful sleep may gain strength and recover. An efficient prototype air conditioning and filtration system, Integrated Energy Recovery Ventilator (IERV), was used to remove particles and climatize the air in the bedrooms of 45 asthmatic children (5-14 years old). IERVs were deployed in the homes of children diagnosed by the respiratory clinic of a local hospital. The children were split into two equal sized groups for a 3 part case crossover study. In part 1, group A had the cleaners turned on and group B did not. During part 2, both had the cleaners on, and in part 3, Group A turned the cleaners off and Group B kept theirs running. Each experimental period averaged about 6 weeks. Each subject serves as their own control, with an overall 6 weeks of particle exposure and 12 weeks without. The period of the IERV being on, followed by it off, is to evaluate whether the children's reduced inflammation persisted.

2G.14

Relationships Between Indoor And Outdoor Particulate And Gaseous Species In Two Retirement Homes: Implications For Particulate Matter Exposure Assessment. ANDREA POLIDORI, Mohammad Arhami, Constantinos Sioutas, University of Southern California; Ryan Allen, Simon Fraser University; Adam Reff, U.S. EPA; Ralph Delfino, University of California, Irvine.

Hourly indoor and outdoor fine particulate matter ($PM_{2.5}$), organic carbon (OC), elemental carbon (EC), particle number (PN), ozone (O_3), carbon monoxide (CO) and nitrogen oxides (NO, NO_2 and NO_X) concentrations were measured at two different retirement communities in the Los Angeles basin between July 2005 and February 2007 as part of the cardiovascular health and air pollution study (CHAPS), a multi-disciplinary project designed to investigate the effects of micro-environmental exposures to PM on cardiovascular outcomes. These data were used to study the relationships between indoor and outdoor $PM_{2.5}$, its components, their seasonal variations, and their association with gaseous co-pollutants. In particular, the infiltration factor F_{inf}; the equilibrium fraction of the ambient concentration that penetrates indoors and remains suspended) for all measured particulate and gaseous species was determined using four techniques: 1) indoor/outdoor concentration ratios, 2) regression methods, 3) a recursive mass balance model and 4) a customized multi-linear engine model. These methodologies were compared and their effect on the resulting F_{inf} estimates was analyzed. Preliminary correlation and regression analyses showed that 24-h outdoor $PM_{2.5}$ concentrations were highly correlated ($p< 0.0001$) with indoor concentrations of $PM_{2.5}$, but not with indoor particle components or gases. In contrast, outdoor gas concentrations (especially CO, NO_2 and NO_X) were consistently correlated ($p<0.05$) with both indoor gas concentrations and indoor concentrations of PM constituents (EC, OC, and PN). We hypothesize that these outdoor gases are a good exposure surrogate for indoor concentrations of combustion-derived particles, but not for $PM_{2.5}$ mass. Since the CHAPS retirees spend most of their time indoors, it is likely that indoor concentrations are a good proxy for personal exposures. Health effect studies that consider the ambient concentrations of particle and gaseous species as independent variables must be analyzed carefully, since both parameters may be related to components of the $PM_{2.5}$ exposure mixture.

7B.1

Spatial and Compositional Relationships of Indoor Aerosols in the Detroit Exposure and Aerosol Research Study (DEARS). ALAN VETTE, Carvin Stevens, U.S. EPA; Charles Rodes, Jonathan Thornburg, RTI International; Carry Croghan, Ron Williams, U.S. EPA.

The factors influencing residential and human exposures to air pollutants of outdoor origin were assessed in the DEARS by collecting central site and outdoor/indoor residential $PM_{2.5}$ samples. These data indicated that the composition of $PM_{2.5}$ in the Detroit airshed is similar to other Midwest and East-coast U.S. cities with organic carbon (OC) and sulfate being the primary $PM_{2.5}$ components, especially during summer. A dramatic shift in $PM_{2.5}$ composition occurred from summer to winter, however, with nitrate concentrations increasing by a factor of three to four. Indoor nitrate concentrations were only about 50% and 15% of outdoor concentrations during summer and winter, respectively. Although the composition of indoor and outdoor $PM_{2.5}$ was similar, the relative abundance of components differed considerably, especially across seasons. In general, indoor and outdoor $PM_{2.5}$ consisted primarily of OC, sulfate, nitrate and elemental carbon (EC) with silicon (Si) and iron (Fe) constituting the most abundant elements. Potassium (K), calcium (Ca), manganese (Mn), copper (Cu), zinc (Zn) and lead (Pb) were also found at lower levels. Relationships between $PM_{2.5}$ components concurrently measured at a central outdoor monitoring site (Allen Park, MI), and indoors/outdoors at the residences were assessed using linear mixed effects models. The results of these analyses on log-transformed data showed that residential outdoor measurements were generally significantly related to central site measurements ($p<0.05$). The mixed model slopes varied considerably with slopes near unity for more regional components such as sulfate and OC, with considerably lower slopes (<0.5) for crustal elements (Si, K, Ca) and $PM_{2.5}$ components (Mn, Fe, Cu and Zn) possibly impacted by local sources. Several of these elements measured indoors were not significantly related to central site measurements, particularly Si, Mn, Fe, Cu, and Zn.

Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

7B.2

Indoor Air Monitoring in Day-Care Centers. Pei-Shih Chen, YI-LIEN LEE, Ting-Yu Huang, Yu-Han Zhang, Kaohsiung Medical University.

It was reported that the incidence of many infectious diseases in day-care center children were greater than those in homes. Thus, there is a need to assess indoor air quality, especially influenza virus in day-care center. Therefore, the aim of this study is to monitor the airborne influenza A and B virus in day-care centers with different ventilation form. To our knowledge, this is the first study to estimate influenza virus concentration in day-care centers in the world.

Environmental monitoring was held during August 18 to September 18 in 2006. Day-care center A was near a busy traffic street and with natural ventilation and air conditioning while day-care center B was only with air conditioning system and located in a small lane. An air sampler (MAS100) was used to collect cultivable airborne bacteria and fungus. Airborne influenza virus was sampled by three-piece plastic cassette and analyzed by real-time qPCR. Temperature, relative humidity, CO, CO_2, and particles were also measured.

The average concentration of influenza A virus in day-care center A and B was 1.2×10^6 copy-cubic meter and 5.1×10^2 copy-cubic meter, respectively, and the positive rate was 6.7 percent and 66.7 percent, respectively. The concentration of influenza B virus in day-care center A and B was 3.6×10^4 copy-cubic meter and 4.7×10^5 copy-cubic meter, and the positive rate is 10 percent and 30 percent, respectively. It also found out that bacteria concentration have positive correlation with wind velocity and relative humidity in day-care center A, and the fungal concentration have positive correlation with temperature and influenza B virus in day-care B. According to the Indoor Air Quality Recommended Values of Taiwan Environmental Protection Administration, the failure rate of bacteria, CO and CO_2 concentration in day-care center B were all higher than day-care center A.

7B.3

Indoor and Outdoor Concentration of Fine Particles at Control Site in Mumbai City : A Case Study. ABBA ELIZABETH JOSEPH, Seema Unnikrishnan National Institute of Industrial Engineering; Rakesh Kumar, National Environmental Engineering Research Institute.

Particulate Matter (PM) is the general term used for a mixture of solid particles and liquid droplets found in the air and are produced by a wide variety of natural and manmade sources. Recently, the U.S Environmental Protection Agency announced to strengthen EPA's previous daily fine particle standard by nearly 50 percent from 65 to 35 micro gram per meter cube (EPA, 2006). This standard increases protection of the public from short-term exposure to fine particles. Such proactive changes in standards indicate the increasing evidence of its importance with regard to health. According to The world health report 2002 indoor air pollution is responsible for 2.7 percent of the global burden of disease (http://www.who.int/indoorair/en/). Exposure to contaminated indoor air has been identified as a significant cause of health problems affecting the poor in developing countries, especially women and younger children. According to recent estimates in India, indoor exposures to particulates appears to be responsible for more than 7 percent of the national burden of disease (CAI, Asia). The concentration of PM in the India is being estimated with more rigour than before. The present study attempts to monitor indoor and outdoor fine particles in a control site in Mumbai city, India during summer season for 10 days. The fine particles were measured using AirMetrics MiniVol at the rate of 5 liters per minute for 24 hours on a Teflon filter. The concentration of fine particle in indoor area ranged between 35-150 micro gram per meter cube and outdoor area ranged between 20-106 micro gram per meter cube. The indoor outdoors ratios were found to be in the range of 1.2-3.1. The present study will discuss on indoor and outdoor sources and their relationship.

7B.4

Ultrafine and Fine Particulate Matter Variation in Skating Arenas. KELLY SABALIAUSKAS, Greg Evans, University of Toronto; Monica Campbell, Sarah Gingrich, Toronto Public Health; Dave Stieb, Amanda Wheeler, Health Canada; Jeff Brook, Environment Canada.

Indoor concentrations of ultrafine (UFP) and fine (PM2.5) particulate matter are becoming of increased health concern. Skating arenas are unique indoor microenvironments because the ice resurfacing machines typically are powered by fossil fuels. The presence of a combustion source in a location where individuals are likely to be breathing more heavily than outdoors should be of concern; however, relatively few studies have focused on UFP and PM2.5 concentrations in arenas. During the winter of 2006, 4 skating arenas were visited on 3 occasions in downtown Toronto. Measurements were collected outside the arena, in the spectator stands and in the player's bench. Factors that contribute to UFP and PM2.5 concentrations in the arenas were the type and age of the ice resurfacing machines, the frequency of ice resurfacing, the ventilation characteristics of the arena and the spectator stands heaters.

Arena A was the only arena with a natural gas powered ice resurfacing machine and the lowest concentrations of UFP and PM2.5 were observed during flooding. In contrast, Arena D had a 12 year old propane powered machine, the most frequent ice flooding and the highest concentrations of UFP and PM2.5. In Arena C, UFP concentrations measured while the propane powered edging machine was in operation were twice those measured during flooding. With the exception of Arena C, operators remove ice from the boards using a manual ice breaker. With the exception of Arena D, all arenas had large vents with fans in the ceiling. In Arena D, a manual valve needed to be switched in order to open the vent before flooding; however, this was not consistently done thereby allowing UFP and PM2.5 concentrations to accumulate. Finally, Arena A had natural gas powered spectator stand heaters and the UFP concentration increased by a factor of 4 while in operation.

7B.5

Size Characteristics of Airborne Particles and Bioaerosols in Home Environments. QING CHEN, Lynn M. Hildemann, Stanford University.

Exposure to bioaerosols indoors may contribute to the development of adverse health effects such as asthma. Deposition of particles in the respiratory tract depends on size. However, little information is available regarding the size characteristics of indoor bioaerosols. Via biochemical assay techniques, this study evaluated the size characteristics of bioaerosols in home environments, comparing them with outdoor air samples and house dust.

We measured airborne particle, protein, endotoxin, and (1-3)-beta-D-glucan mass concentrations inside 10 single-family homes in northern California. Endotoxin was used to track gram-negative bacterial concentrations, (1-3)-beta-D-glucan to evaluate fungal levels, and protein to reflect overall bioaerosol concentrations. Three size ranges of particles (PM2.5, PM10, and TSP) were collected in duplicate in each home on five occasions (9-12 hrs/sample) over a 3-week period, including one night and four days. Simultaneous outdoor samples were collected for three of the sampling periods, along with viable bacteria and fungi. We also analyzed dust from the carpets and sofas in each home, and documented the house characteristics and occupants' behavior.

Most of the mass concentration of both indoor and outdoor particles and protein was in the fine fraction (PM2.5), while the mass of endotoxin and (1-3)-beta-D-glucan was present mainly in the coarser fractions (PM10-PM2.5 and TSP-PM10). A comparison of paired indoor and outdoor concentrations revealed some significant elevations ($p<0.05$, Wilcoxon signed-rank test) in the indoor air samples, including protein in the coarser fractions (PM10-PM2.5 and TSP-PM10), endotoxin in the respirable fractions (PM2.5 and PM10-PM2.5), and culturable bacteria. Indoor endotoxin levels in the TSP-PM10 fraction also were somewhat elevated ($p<0.10$). The coarser fractions of airborne protein and endotoxin indoors were positively correlated with their levels in dust samples (per gram of dust). Finally, endotoxin levels in TSP were moderately correlated with viable bacteria counts for both indoor samples and outdoor samples.

8B.1

Experimental Measurement Of Particle Resuspension From A Tile Floor By Walking. MARK R. SIPPOLA, Richard G. Sextro, Lawrence Berkeley National Laboratory.

A room-scale experiment was conducted to quantify the fraction of particles in the footprint area that are resuspended with each step by walking people. Dry polydisperse fluorescein powder was deposited onto the pre-cleaned tile floor of a 24.7 m^3 experimental room at an initial loading of 85 mg/m^2. The airborne size distribution during this deposition was measured by two aerodynamic particle sizers (APS, TSI Inc, Model 3321) and these measurements were used to estimate the size distribution of particles on the floor. Two volunteers then walked in the room at a rate of 100 steps per minute for 30 minutes while airborne particle concentrations were measured by two APS units and filter samples. Particle loss rates by deposition and ventilation were also measured. The re-deposition of resuspended particles to surfaces was quantified by deposition coupons on the walls and floor. Fluorescent techniques were used to quantify particle mass on air filters and deposition coupons. Real-time APS concentration data and measured particle loss rates were used in a mass-balance model (which includes a decaying particle source from resuspension) to calculate the fraction of particles resuspended per step and the decay rate of particles available for resuspension in the size range 0.5-10 microns.
The fluorescence measurements suggested that most of the resuspended particle mass re-deposited to the room floor. APS measurements suggested that 2.3 percent of the total particle mass was resuspended in 30 minutes; this estimate was independent of the fluorescence measurements. The fraction of particles in the footprint area that were resuspended with each footstep was in the range $2x10^{-5}$-$4x10^{-5}$ per step and nearly independent of particle size. The particle mass on the floor available for resuspension was calculated to decrease 2-10 percent per minute (depending on particle size) during the 30 minutes of walking.

8B.2

A Model for Resuspension of Particles due to Human Walking including Electrostatic Effects. XINYU ZHANG, Jing Qian, Goodarz Ahmadi, Andrea Ferro, Clarkson University.

A model for resuspension of particles with electrostatic effect due to human walking was developed. The foot stepping down and up process was treated as the motion of an effective circular disk toward or away from a stationary surface. The airflow generated from this squeezing film was assumed laminar and the corresponding gas velocity was evaluated. The squeezing flow outside the foot range was evaluated based on radial wall jet theory. The surface roughness was included in the analysis. For particle detachment, the adhesion force, the electrostatic force and drag forces were taken into account. The particle cloud deposition, diffusion and transport were included in the analysis. The PM concentrations for different particle sizes due to human walking were evaluated. The effect of various factors affecting the resuspension process was discussed. The model predictions were compared with the experimental data. The results show that shoe bottom roughness, foot size as well as foot stepping down and up velocities and frequencies can affect the PM concentrations.

8B.3

Measurement of Ultrafine Particles Generated by Indoor Combustion and Electric Appliances. FANG WANG, Harbin Institute of Technology, Harbin, China; Lance Wallace, Cynthia Howard-Reed, National Institute of Standards and Technology.

Several studies have reported the concentration of ultrafine particles indoors due to sources such as combustion and electric appliances. These previous studies, however, have only measured ultrafine concentrations for particles as small as 10 nm. The advancement of particle measurement technology now makes it possible to measure particles as small as 2 nm. As a result, the National Institute of Standards and Technology is conducting a study to measure the source strengths of several indoor combustion and electric appliances to include counts of particles from 2 nm to 64 nm. Experiments were conducted in an unoccupied manufactured house equipped to semi-continuously measure air change rates, carbon monoxide levels, gas/ electricity usage, environmental conditions (e.g., indoor/ outdoor pressure differences, temperature, relative humidity, etc.), and local weather conditions. Ultrafine particles were measured in multiple locations every 2.5 min to 5 min with a scanning mobility particle sizer equipped with a nano-differential mobility analyzer. Ultrafine particle sources included a gas stove, hair dryer, electric toaster, and electric heater . Size distributions were measured in two rooms, a source room (kitchen) and a receptor room (master bedroom). Preliminary results for the gas stove show the peak concentration occurring at a particle size of approximately 5 nm to 8 nm and total concentrations to be about 10 times greater than reported in previous studies of particles greater than 10 nm. These results suggest that ultrafine number concentrations previously reported for combustion appliances, and perhaps electric appliances, may be significantly underestimated.

8B.4

Secondary organic aerosol from ozone-initiated reactions with terpene-rich household products. BEVERLY K. COLEMAN, William W Nazaroff, University of California, Berkeley; Melissa M. Lunden, Hugo Destaillats, Lawrence Berkeley National Laboratory.

Household cleaning products can contain high levels of terpenes that may be oxidized indoors by ozone transported from outside, resulting in formation of secondary organic aerosol (SOA). Characterizing the particles formed from these reactions is necessary to understand the possible health effects of these aerosols. An analysis was performed on SOA data from a series of small chamber experiments where ozone and terpene-rich household product vapors were reacted at conditions similar to those for typical product use indoors. Experimental details are presented in Destaillats et al. (Environmental Science & Technology 40, 4421, 2006). Cleaning product vapor and later ozone were introduced into a 198 L chamber at steady levels. Consistently, at the time of ozone introduction, a nucleation event occurred that exhibited behavior similar to atmospheric nucleation events.

SOA was measured with a scanning mobility particle sizer (SMPS, 10 to 400 nm) in every experiment and with an optical particle counter (OPC, 0.1 to 2.0 micro-meter) in a subset of experiments. In order to fully characterize the aerosol size distribution, we aligned the OPC and SMPS measurements in the overlapping size range of the two instruments. Effective bin bounds for OPC measurements change according to the composition of the aerosol, and this change is related to the refractive index of the aerosol. A model was developed to determine a representative refractive index for the cleaning product aerosol. The results from experiments where the entire distribution could be measured were used to infer information for the experiments where only part of the distribution was measured. The number and mass distribution as a function of time for each experimental condition was determined using the measured and modeled data. The effects of environmental conditions, such as ozone level, product formulation, air exchange rate, relative humidity, and preexisting particles, on particle distribution characteristics were explored.

8B.5

SOA formation and growth from ozononlysis of terpene in indoor environments. XI CHEN and Philip K. Hopke, CClarkson University.

It has been suggested that secondary organic aerosol (SOA) can form in indoor air from infiltrated ozone and indoor reactive volatile organic compounds. In order to provide the basis for a particle nucleation and growth model to estimate SOA formation at various combinations of alpha-pinene and ozone concentrations for typical ventilated indoor environments, an experimental study of particle formation was conducted. In addition the production of reactive oxygen species (ROS) was also examined. Experiments were conducted using a 2.4 m3 stainless steel chamber with steady-state conditions. This study describes kinetics of the SOA and ROS formation initiated from ozonolysis of terpene and contributes to the understanding of indoor SOA formation mechanisms. In addition to the basic study of SOA formation, the influence of major inorganic chemical species such as ammonia and NOx present in indoor air on particle formation and growth was also studied.