2H.1

Laboratory Studies of Inhaled Simulated Downwind Components of Coal Combustion Emissions. JAKE MCDONALD, Matthew D. Reed, Matthew Campen, JeanClare Seagrave, Joe L. Mauderly, Lovelace Respiratory Research Institute.

A study of major components of coal combustion emissions encountered in downwind exposures was conducted. The target exposure atmosphere composition was set by consensus from a workshop of industry, government, and academic experts. Pulverized Powder river Basin (PRB) sub-bituminous coal was aerosolized and combusted in an electric \drop-tube\ furnace, emissions were cooled, a cyclone was used to establish an upper bound particle size, and the effluent was mixed with sulfate aerosol generated by a vaporization-condensation process. This stream was supplemented with sulfur dioxide and nitrogen oxides to achieve the target mixture. Animals were exposed 6 hr/day, 7 days/wk to the mixture generated from PRB coal, at dilutions containing 100, 300, or 1000 micro-gram particulate matter/m3, to the highest concentration with particles removed by filtration, or to clean air as controls. Evaluations of health effects included body and organ weights, histopathology, lung inflammation, resistance to bacterial respiratory infection, development and exacerbation of respiratory allergic responses, electrocardiogram, pre-atherosclerotic changes in blood vessels, and pre-cancer changes in DNA and chromosomes. Atmosphere composition, and initial biological findings, will be reported. This research is supported by funding from 16 government and industry sponsors, including the Environmental Protection Agency (CR831455-01-0), the Department of Energy National Energy Technology Laboratory (DE-FC26-05NT42304), the Electric Power Research Institute (EP-P17972/C8861), and Southern Company.

2H.2

Airborne Mycobacterium Tuberculosis Profile in A Hospital After An Outbreak of Tuberculosis. Pei-Shih Chen, TAI-WEI CHEN, Kaohsiung Medical University.

An outbreak of tuberculosis among eight medical personnel was happened in a hospital in Taiwan in mid-August of 2005. Therefore, the main purpose of this study was assessing the airborne Mycobacterium tuberculosis profiles in this hospital to identify the high risk area. In addition, the difference of airborne Mycobacterium tuberculosis concentration before and after ventilation improvement was also evaluated.

A total of 192 air samples were taken from negative pressure isolation wards, medical wards, waiting rooms and consulting rooms of medical department and pediatric department in the period of December 2005 to July 2006. The concentration of airborne M. tuberculosis was quantitatively determined by real time qPCR. In addition, cultivable airborne bacteria and fungus, temperature, and relative humidity were also measured.

All positive samples were in the wards of chest and infectious disease division in internal medicine department. The airborne M. tuberculosis concentration was in the range of 54 copy-cubic meter to 1109 copy-cubic meter. The highest concentration was found in the nursing station of chest division. After improvement of ventilation system, no M. tuberculosis was detected in the air. In addition, the airborne bacteria concentrations were also declining after the improvement. Our results showed that the improvement of air conditioning may reduce the risk of M. tuberculosis exposure. In addition, it was found a good correlation between M. tuberculosis and airborne bacteria.

In regard to the culturable bacteria and fungi concentration in the air, 122 samples were analyzed in the hospital. According to the Indoor Air Quality Recommended Values of Taiwan Environmental Protection Administration, the failure rate was 64 percent and 8 percent for bacteria and fungi, respectively. In addition, the airborne bacteria concentrations in the nursing station of chest division were all higher than the recommended values, even after the improvement of ventilation.

2H.3
Airborne Influenza and Avian Influenza Viruses from Long Term Transportation and Its Health Effect. Pei-Shih Chen, Qian Kun Lin, FENG-DA TSAI, Kaohsiung Medical University.

Due to desertification of northwestern China and Mongolia, the frequency and intensity of Eastern Asia dust storm has become higher and higher. This phenomenon has a great effect to Taiwan, the downstream region of Eastern Asia dust storm. Previous studies showed that airborne fungi might be transported by dust storm. Therefore, the main purpose of the present study is to investigate the concentration airborne influenza and avian influenza viruses during suspected dust storm events and on normal days. In addition, the correlations between influenza virus concentrations and hospitalized admissions were also studied.

Air samples were collected at Sin-Jhuang and Shi-Men during dust storm events and on normal days and then analyzed by Real-time qPCR. Our results showed that the positive rate and concentration of influenza virus at both sampling sites were higher during dust storm events than those on normal days. In addition, the associations between influenza A virus concentration and hospitalized admissions of influenza were prominent three weeks after the event ($r = 0.76$, $p = 0.0001$). In regard to the climate factors, the concentrations of influenza A virus have an negative correlation ($r = -0.41$, $p = 0.0006$) with temperature and a low correlation ($r = 0.30$, $p = 0.014$) with rainfall. Furthermore, the peaks of virus concentration were found earlier than the peaks of PM2.5' PM10. In conclusion, influenza viruses might possibly transported by airstreams for a long distance.

2H.4
Environmental Monitoring of Virus-containing aerosols around Children with Infections. CHUN-CHIEH TSENG, Chih-Shan Li, College of Public Health, National Taiwan University; Luan-Yin Chang, National Taiwan University Hospital.

Children are more vulnerable to viral infections than the general population. For understanding the mode of viral transmission, viral bioaerosols were collected by filtration method in the emergency room and the outpatient clinics of the pediatrics department at a medical center in Taipei. In this study, real-time quantitative polymerase chain reaction (real-time qPCR) was performed to detect influenza A virus (INFAV), human adenovirus (HAdV), and enterovirus. Among the 33 aerosol samples in the emergency room, the positive rate was 24% (8/33) for INFAV, 36% (12/33) for HAdV and 15% (5/33) for enterovirus; the results suggested that these viruses could be transmitted through droplets. In summary, this is the first report describing the filter/real-time qPCR can detect and quantify virus associated exposure in air. It suggests that this technique can provide further insight into hospital epidemiology and infection control, as well as viral transmissibility.

2H.5

Capturing the Exhaled Protein Aerosol: Evaluation of Rodent-Based Systems. OWEN MOSS, Earl Tewksbury, David Nash, The Hamner Institutes for Health Sciences.

The utilization of exhaled proteins as biomarkers for disease is a relatively recent advance in need of validation; validation with breath condensate from animal models of pulmonary disease. For pooled breath-samples from 50 mice or rats we previously showed that, by taking advantage of the small volume and short path-length of the central column, the operation of the Cannon Nose Only exposure system (Lab Products, Seaford, DE) can be modified to allow efficient collection of breath condensate. The modification consisted of utilizing zero-humidity air, and reversing the airflows in the system. By using this same modification, we have evaluated the application of another nose only exposure system; the Vaccine (Nose Only Exposure) Unit -- first working version (CH Technologies (USA) Inc., Westwood, NJ: -- In this system, the shortest path from the animal port to an exit resembles a narrow cylindrical channel.). For flow rates similar to the minute ventilation of mice, we measured penetration from the animal port for two cases: (1) an aerosol of 15 nm diameter spheres; and (2) air at 90 % RH and 36 degrees centigrade. Nanospheres were generated with a Graphite Aerosol Generator (GFG-1000, Palas, Karlsruhe, Germany), and detected with a Scanning Mobility Particle Sizer (SMPS 3936, TSI, St. Paul, MN). Condensate was collected with a three-stage cold trap. For breath collection the Vaccine Unit functioned similarly to the Cannon System: -- greater than 90% penetration of nanoparticles or water vapor. The impact of system configuration appears to be minor; as long as the dew point of the exhaled air is rapidly dropped to below the temperature of the system walls.

2H.6

A Web-Based Interactive Aerosol Program for Undergraduate Education-Aerosols in the Health Care Field. YU-MEI HSU, Chang-Yu Wu, Anne Donnelly, University of Florida; Paul Stephan, Santa Fe Community College; Pratim Biswas, Washington University in St. Louis.

Having adequate knowledge of the penetration, deposition and site of action of aerosols in the health care field must be ongoing since new medications and techniques of delivery are changing rapidly. To facilitate the teaching of this subject matter to community college students, University of Florida and Santa Fe Community College have collaborated together on a project to develop a web-based program. The goal is to increase students' retention and understanding of the physical properties of aerosols by active participation and visual modelling of content that is otherwise difficult to grasp.

Three types of aerosol generators commonly used in the health care field are included: MDI (Metered-Dose Inhaler), DPI (Dry Powder Inhaler) and SVN (Small-Volume Nebulizer). In addition to the principles, functions, advantages/disadvantages of each type of device, the program presents the advantages and disadvantages of administering medications via aerosols. The site of penetration and deposition, as well as methods for determining clinical relevance and assessment of patient outcomes and lung retention are included. The program is available for public access at http://aerosol_beta.ees.ufl.edu/.

In order to maximize the ease of use and interactivity of the learning environment, various web and scripting technologies are used to implement the user interfaces, including HTML and Flash. HTML was used to deliver normal static web pages. Macromedia Flash is a platform for easily developing interactive multimedia animation and audio presentations for the web and is used to create highly engaging and active content. To assess the effectiveness of the program, formative and summative evaluations will be conducted using on-line survey-techniques for community college students.

2H.7

Improvement of Particle-Mediated Gene Transfer Technology. CHIH-CHIEH CHEN, Sheng-Hsiu Huang, Wei-Shun Lin, College of Public Health, National Taiwan University; Yu-Mei Kuo, Chung Hwa College of Medical Technology.

The ways of gene transfer can be classified into three categories: biological method (such as virus-mediated transduction), chemical method (such as calcium-phosphate mediated, DEAE - dextran mediated, liposome-mediated method), and physical method (such as microinjection, electroporation, and biolistics (gene gun)). Among them, gene gun has many advantages: low harmfulness to cell, small amounts of DNA required, short reaction time, easy to operate, and applicable to both in vitro and in vivo transformation. The objective of this work was to enhance the uniformity and the coverage of the gene-laden gold particles, which, as illustrated below, resulted in better gene transfection efficiency.

In this research, the effect of gene gun configuration on the collection efficiency and uniformity of deposited particles was investigated. The operation parameters include: slot width (0.05, 0.1, 0.5, 5, 20 mm), slot height (0, 15, 25 mm), helium pressure (100, 150, 250, 400, 600 psi), transition cone (5, 15, 35, 65, 105, 155 mm), diameter of target filter (10, 15, 25, 30, 50 mm) and column height (25, 35, 45, 65, 95, 155 mm). The greatest transfection efficiency occurs when the gene gun is modified to have a slot width of 0.05 mm, slot height of 0.05 mm, transition cone of 65 mm and diameter of target filter of 50 mm. This new gene gun performs better than the original design. Collection efficiency, uniformity, and gene transfection are 5.2, 2.5 and 17.3 times higher than original gene gun.

2H.8

Use of a Non-Pathogenic Viral Model for Quantitative PCR Analysis of Artificially Produced Airborne Viruses.
DANIEL VERREAULT, Sylvain Moineau, Caroline Duchaine, Universit

Infectivity assessment of viral material has, for many years, been the main method in characterizing airborne viruses. However the outcome of this type of study is dependent upon the preservation of the virus infectivity, which can be influenced by many factors including surrounding environmental conditions as well as nebulization and sampling stresses. There is a need to independently measure the absolute number of viral agents to provide a basis for comparison. Hence, analytical techniques independent of viral culture should also be used to properly investigate samples of artificially and naturally produced viral aerosols. Advances in molecular technologies have led to the development of nucleic acid-based assays for the detection of viruses. Quantitative Polymerase Chain Reaction (qPCR), can be used for fast and quantitative analysis of viruses in various samples. In this study, a dual-labeled probe was used for qPCR analysis of virus-containing air samples collected from a nebulization chamber. The samples were collected at a rate of two liters of air per minute with two types of filters, polycarbonate and PTFE, mounted on 37 mm 3-piece cassettes. An aerodynamic particle sizer (APS) measured the particle median diameter as 0.8 micrometers. The viral model was phage phiX174, a 25 to 27 nanometer non-enveloped bacteriophage of Escherichia coli, with a nucleic acid composed of a circular single stranded DNA molecule. The simple structure and composition of this virus allowed the development of a simple single step qPCR protocol, which consisted of using a diluted aliquot of the sampled material without the need for DNA isolation. This latter unnecessary step was found to reduce efficiency in quantification of this virus. Results from this study show no statistical difference in DNA recovery from both polycarbonate and PTFE filters. We therefore suggest that, for equal qPCR results, filter choice should be based on culture.

2H.9

Characteristics of Atmospheric Bioaerosols by Fluorochrome. MIAO-CHING CHI, Chih-Shan Li,National Taiwan University.

Total concentration and viability of bioaerosols in the ambient atmosphere were monitored by using epifluorescence microscopy with fluorochrome (EFM/FL) with five fluorescent dyes (AO, DAPI, SYTO-13, PI, and YOPRO-1). The correlation of bioaerosols with meteorological factors and pollutants was simultaneously assessed. Results from EFM/FL were then compared with those using a commonly used culture method. The total microbial cell concentration measured by the non-culture-based methods averaged about 8 x 10^5 cells/m^3. However, culture method underestimated bioaerosol concentrations by the factor of 100 to 1000. The average viabilities were 0.66 by EFM/FL with PI staining, 0.35 with YOPRO-1 staining, and 0.0012 by the culture method. The viability by EFM/FL was much higher than the culturability. In summary, the total microbial cell concentration and viability were highly underestimated by the culture method. Moreover, based on culture and non-culture methods results, the total bioaerosol concentrations could be strongly correlated as a result of the temperature, rainfall, and UV light influence. However, there were weak correlations between bioaerosol concentrations and air pollutants. In conclusion, EFM/FL methods could effectively assess the total microbial cell concentration and viability of bioaerosols in atmospheric samples.

2I.1

Using a Human Airway Cast for Deposition Studies of Inhaled Medicine. YUE ZHOU, Clinton M. Irvin, Steven A. Belinsky, and Yung-Sung Cheng, Lovelace Respiratory Research Institute.

Inhalation drug delivery is considerably more complex than other drug delivery routes because drugs must be delivered to the specific target tissues in the lung appropriate to the diseases. To evaluate the deposition pattern of an inhalation medicine, a cascade impactor is generally used to measure the aerosol size distribution generated from medical devices. From the size distribution, the deposition pattern in different lung regions can be calculated. An appropriate device for the specific medicine can be selected utilizing the lung deposition information. However, many factors such as lung geometry and drug formulation may interfere in the drug deposition patterns in human. Hollow human airway replicas are an alternative means by which one may evaluate the deposition patterns of an inhaled medicine. In this study, a DNA methyltransferase inhibitor, 5-azacytidine, was nebulized by three different types of nebulizers: MicroMist, SideStream, and LC Plus. The particle size distribution was measured using a Next Generation Pharmaceutical Impactor (NGI) at a flow rate of 30 L/min. Three concentrations of the drug were tested to see the differences in the size distribution. The drug deposition patterns were calculated with the NCRP (Nation Council on Radiation Protection and Measurements) model. The LC Plus nebulizer was selected as the optimized device for further study, delivering the drug in a human lung replica. The replica includes the oral cavity, oropharynx, larynx, trachea, and four generations of bronchi. Three flow rates (15, 30, and 60 L/min) were tested to simulate human breathing patterns. The deposition efficiency at the oral region was compared with the deposition calculated by the NCRP model and obtained a good agreement. The NCRP model also can predict the deposition efficiencies in the tracheobronchial and pulmonary regions.

2I.2

Turbulence Modeling in the Human Nasal Cavity. KEVIN T. SHANLEY, Goodarz Ahmadi, Clarkson University.

The extreme complexity of the human nasal cavity makes finding an accurate Reynolds number difficult. Numerous experimental studies have identified the flow as being largely laminar with some regions of recirculation. The recirculation regions may not be properly represented with the standard laminar flow model. Deposition of nano-particles may be affected significantly by recirculation. This work makes a comparison of the different turbulence models for predicting the airflow in the nasal passage. MRI scans of an anonymous, adult male, human subject were used to construct a three-dimensional volume. Airflow was simulated for breathing rates corresponding with low to moderate activity (5 to 15 L/min). Comparisons are made between the standard k-epsilon model, enhanced k-epsilon model, and the Reynolds Stress model. A uniform concentration of particles ranging from 10 nm to 100 nm were injected at the nostril and tracked by a Lagrangian Discrete Phase Model. Comparisons are made between the deposition across models, as well as, with previously published results for laminar flow.

2I.3

Numerical Simulations of Inertial Particle Deposition in a Realistic Nasal Cavity. KEVIN SHANLEY, Parsa Zamankhan, Goodarz Ahmadi, Philip K. Hopke, Clarkson University; Young-Sung Cheng, Lovelace Respiratory Research Institute.

The nasal valves, anterior to the main airway, are believed to be an efficient collector of aerosols with aerodynamic diameter larger than 1-micron. This work focuses on developing a numerical model for predicting aerosol deposition in the human nasal cavity under low to moderate breathing conditions. MRI scans of a healthy adult male human were used to construct the three-dimensional volume of the nasal passage. The computational volume was discretized into 965,000 tetrahedral elements and 250,000 computational nodes and used in the computational model. The commercially available software FLUENT was used to perform computational fluid dynamics analysis and particle tracking. The Lagrangian particle tracking approach was used for analyzing the particle trajectories in the nasal passage. The predicted capture efficiencies are shown to correlate with the impaction parameter and have good agreement with published experimental results. An empirical expression for the capture efficiency is also proposed. The affects of the direction of gravitational acceleration is also studied.

2I.4

Deposition of Fiber and Spherical Aerosols in the Human Tracheobronchial Airway. YUNG SUNG CHENG, Yue Zhou, Wei-chung Su, Lovelace Respiratory Research Institute.

Inhalation exposure of fiber aerosol may have serious health consequences including lung cancers. The deposition pattern in the respiratory tract as a function of fiber dimensions is the information critical to understanding respiratory dosimetry and etiology. Controlled studies of fiber deposition in human volunteers are not available because of ethical concerns. The purpose of this study is to investigate the effects of fiber dimension and breathing rate on the deposition pattern in an oral/tracheobronchial airway cast with a defined geometry. Two types of fibers including a carbon fiber and a glass fiber were used for the deposition study. The fiber was generated with a small-scale powder disperser (Model 3433, TSI Inc., St Paul, MN). Regional fiber deposition pattern was measured at a constant inspiratory flow rate of 7.5,15, 30 and 43.5 L min-1. As a comparison we also did deposition experiments in the same cast using polystyrene latex (PSL) test particles tagged with fluorescent. Fiber depositions in different sections of the airway cast and the backup filter were extracted and prepared for optical microscopy and image analysis. From the counting data, deposition efficiency as a function of fiber length /diameter was calculated. Our experimental data of fiber deposition in the tracheobronchial region show large variability but generally agree with the numerical simulation results published by Zhang et al. (1996). The deposition efficiency can be expressed as a function of Stokes diameter, Reynolds number and branching angle. We also show that deposition efficiencies of spherical particles are higher than those of fibers at the same impaction parameter. This can be explained by the orientation of fibers, which tend to align with the flow direction. This information is useful in predicting the deposited dose of inhaled fiber particles. (This research was supported by the NIOSH under the Grant 1R01 OH03900).

2I.5

Improved Conversion Scheme for Eulerian Deposition Probability Rates. Mohammad I. Rahman, CARLOS F. LANGE, University of Alberta.

Eulerian models of aerosol lung deposition typically employ deposition probability functions derived from Lagrangian analysis. The Lagrangian deposition functions are either empirical or derived under steady state conditions. In these models, the deposition rate is calculated by first estimating the particles deposition per unit time for a whole lung generation, simply dividing the total deposited amount over a certain period by this time period. Then the total deposition rate is distributed, dividing it by the length of the generation.

The main advantage of Eulerian deposition models is treatment of the unsteady deposition. To capture the true effect of the breathing pattern and to predict the transient local deposition, deposition functions based on instantaneous deposition rate are required. But, at present, no such deposition function is available. Development of such analytical expressions involves complex mathematics and requires sophisticated experimental facilities for the development of empirical correlations, both of which are time consuming.

An attractive alternative is to develop a numerical technique to convert the generational deposition probabilities into an Eulerian frame of reference valid for each control volume within the domain. In this study, two such conversion schemes, one based on Generation Residence Time (GRT) and the on other on Control Volume Residence Time (CVRT), were investigated, and then used to estimate total and regional lung deposition under several clinically important cases. Both schemes showed excellent agreement with experimental aerosol deposition data in the human respiratory tract, with CVRT giving slightly better results.

2I.6

Prediction Of Particle Deposition In An Expanding Alveolar Model. JESSICA M. OAKES, Risa J. Robinson, Rochester Institute of Technology.

In order to fully understand particle deposition in the most distal airways of the lung, several parameters need to be considered; specifically the mixing between the tidal and residual air that occurs due to expansion and contraction of the alveolar walls. The mixing induced by the moving walls allow for the diffusive length scales to change with time (Tsuda et al., 2002)). When the lateral length scale and diffusive length scales are equal there is a sudden increase in entropy and therefore a decrease in the time it takes for a particle to diffuse (Butler and Tsuda, 1997)). Molecules that are breathed in, such as oxygen, have a high diffusivity, and therefore the time that is required to diffusive is small and insignificant. Particles such as aerosols have a much lower diffusivity, therefore the time required for the particles to diffusive from the tidal to the residual air is much higher. In order for the aerosol particles to deposit on alveolar walls, mixing must occur, which allows for the particles to travel to the alveolar surface.

Previous alveolar models have been created in order to predict particle deposition. Darquenne (2001) conducted research on a two dimensional static model, in which the only forces acting on the particle were gravitational and drag. The model did not take into consideration the mixing that occurs due to expansion and contraction. An expanding numerical model was created by Tsuda et al. (1995) which proved that expansion and contraction is significant in predicting particle deposition.

In the current study a computational fluid dynamic (CFD) model was created based off of Weibel's 23rd lung generation. The CFD model coupled the Navier – Stokes equation, a moving mesh application, and particle dynamics in order to visualize the fluid flow and predict particle deposition. The model was simulated with varying frequencies in order to represent a range of breathing cycles. Particle deposition was determined using two techniques; particle deposition due to diffusion acting alone in a static model and particle deposition due to mixing and diffusion. The data collected from the model was compared to analytical, numerical, and in vivo experimental data found in literature. Based on data collected from the models it was concluded that mixing in the acinus of the lungs is critical in determining particle deposition.

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Darquenne C. A realistic two-dimensional model of aerosol transport and deposition in the alveolar zone of the human lung. 32: 10: 1161-1174, 2001.
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2I.7

Inhalability of particles and fibers in the human lung. BAHMAN ASGHARIAN, CIIT at the Hamner Institutes for Health Sciences.

Particle inhalability is the fraction of particles in the inhaled air that enter the extrathoracic airways. Knowledge of airborne material inhalability is needed for accurate assessment of lung internal dose. Models of inhalability of particles and fibers for indoor environments were studied based on variables controlling movement of particles in the air. Non-dimensionalization of the transport equations under calm conditions (no wind) showed that inhalability depends on particle aerodynamic diameter and inhalation flow rate. A model of inhalability as a function of particle diameter and flow rate was constructed. Parameters in the model were estimated by fitting the model to available inhalability measurements for oral and nasal breathing. The inhalability model for spherical particles was extended to fibers by including the effects of fiber orientation and viscous drag. A diameter for fibers was obtained using the equation where is related to fiber Stokes diameters, and and are fiber minor axis and aspect ratio respectively. Fiber diameter can be replaced in the inhalability expression for spherical particle diameter to predict fiber inhalability. Fibers were predicted to have a lower inhalability than spherical particles of the same mass. The influence of breathing rate on inhalability for both fibers and spherical particles was more pronounced for oral breathing than for nasal breathing. While fibers have a lower tendency during inhalation to enter the extrathoracic airways and reach lung airways, the elongated shape of fibers leads to slower lung clearance. Therefore, fiber inhalability must be considered when studying their carcinogenic effects.

2I.8

3D Reconstruction of a Female Upper Respiratory using the Visible Human Data Set to Predict Cigarette Smoke Particle Deposition

JACKIE RUSSO, Risa Robinson, Dept. of Mechanical Engineering, Rochester Institute of Technolgy.

The goal of this research was to create a 3D lung model from 2D medical images to generate a more realistic geometry for CFD simulations. The lung geometry was created in 3D Doctor (Able Software Corp, 2006) based on the cryosectioned images from the Visible Female Dataset as part of the NIH Visible Human Project. The lung model consists of 4-5 generations of airways. The model morphometry was compared to several accepted lung morphometries from the literature and it was found that the Visible Female closely correlates with dimensions given by Horsfield and Cumming (1971). The lung model was attached to a larynx based on medical illustrations and to two separate scanned impression of an oral cavity. The first oral cavity represents normal breathing while the other represents the oral cavity during the inhalation of a cigarette. Commercial CFD software was used to simulate breathing during a realistic smoking cycle– puff, inhale bolus followed by clean air, which was compared to normal breathing.

Horsfield, K. and G. Cumming. Models of the Human Bronchial Tree. Journal of Applied Phsyiology. 31:207 -217, 1971.

2I.9

Puff Profile Simulator for Tobacco Smoke Particle Diameter and Mass Measurement.

JOHN McAUGHEY, British American Tobacco; Barrie Frost, Consultant; Kingsley Reavell, Colin Dailly, Cambustion.

This paper describes a system for cigarette testing measuring fresh TPM (tar particulate material) mass, median particle diameter, and particle number concentration, with any desired flow profile. This allows measurements at conditions representative of human smoking or for regulatory pre-defined machine smoking profiles. The data are collected at 10 Hz time resolution with cumulative number and TPM mass measurement in real time on a puff by puff basis.

The system is designed to be used with real-time aerosol instruments such as DMS-type fast electrical mobility spectrometers to provide continuous measurement of the aerosol inhaled from the cigarette during smoking. The flow through the cigarette is metered with an orifice-pressure-drop type flow sensor and controlled to follow a specified profile at 12.5 Hz. To follow highly dynamic puff profiles a feed-forward type controller is used. The complete smoking of a cigarette with a different profile for each puff can be reproduced.

The flow drawn through the cigarette is diluted with filtered air close to the filter holder to halt agglomeration processes. The system operates with a constant total diluted flow to minimise errors in the measurement of total mass emissions from the cigarette. A dilution ratio signal is provided to allow calculation of the undiluted concentrations if desired.

The system has been tested with standard machine profiles and those measured from human smokers. Control of cigarette flows down to approximately 1 ml/s is possible, with a dynamic range of at least 30:1. The typical error in the integrated volume of a puff is around 1%.

Puff by puff were measurements carried out on a series of 1- and 4-mg yielding products using a 35 ml puff of 2 s duration every 60 s, using an ISO puff profile, and normalised to 7 puffs. These data were compared on a puff by puff basis with gravimetric measurements.

Count median diameters (CMD) were measured puff by puff and ranged from 163 - 247 nm, depending on the puff number and yield of each puff. Individual puffs were measured from 0.18 to 1.05 mg TPM and correlated well with the equivalent gravimetric data ($r2 = 0.88$).

3B.1

Molecular Source Tracking of Bioaerosols in the Quarantined Katrina Flood Zone. MARI RODRIGUEZ-HERNANDEZ, Jeffrey Walker, Norm Pace, Mark Hernandez, University of Colorado Boulder.

The damage Hurricane Katrina caused to the city of New Orleans resulted in massive clean up efforts not seen since the September 2001 attacks. Remediation efforts included large scale pumping and aeration operations to reduce floodwater contaminant loads prior to their diversion into the Lake Pontchartrain canals. These remediation efforts resulted in enhanced aerosolization of microorganisms, which presented a potential inhalation hazard to emergency response personnel working in the vicinity.

The objectives of this study were to identify and enumerate airborne microorganisms associated with remediation efforts, determine whether the observed aerosol ecology was associated with proximal floodwaters, and to ascertain if microbes present in the air posed a potential health risk to emergency response personnel working in the immediate vicinity of water aerosolizing operations. To achieve these objectives, direct microscopy, broad spectrum PCR, and DNA sequencing analysis were conducted on air samples and adjacent water samples throughout flooded New Orleans. Widely-accepted phylogenetic analysis was used to quantitatively assess the relatedness between airborne and waterborne microbial communities. We report here that total bioaerosol loads near floodwater remediation operations were approximately 20 times greater than those observed in comparable outdoor environments. Phylogenetic observations suggest that there was no obvious relationship between the microbial ecology found in (local) composite New Orleans Parish air samples, and the ecology present in adjacent floodwaters. These results also suggest that the aerosol sequences observed in this study may be part of a large scale, inter-regional bioaerosol community. Potential pathogens identified were not associated with any respiratory illnesses, and would most likely only affect immunocompromised individuals. Regardless of airborne pathogen exposure assessment, these methods and observations contribute to a small, but growing genetic catalogue of airborne microorganisms in the outdoor environment.

3B.2

Airborne Aspergillus Particles in a Hospital: Effects of Construction and other Potential Factors. MARIAN D. GOEBES, Lynn Hildemann, Stanford University.

Aspergillus is a common genus of mold that can grow indoors, and that includes several species capable of causing fatal pulmonary infections in immunocompromised individuals. A longitudinal study investigating concentration fluctuations of airborne Aspergillus particles was conducted in a hospital undergoing renovations in one portion of the building. The remainder of the hospital continued to function as usual, including several specialty clinics serving immunocompromised patients.

Size-segregated samples of airborne particles were collected before, during, and after construction, using filters downstream of cyclones. Aspergillus particles were quantified with quantitative Polymerase Chain Reaction (qPCR), a DNA-based method. Results of the year-long study suggest that construction did not cause elevated concentrations of Aspergillus particles in the parts of the hospital that remained open, both because large concentrations of Aspergillus were generally not generated, and because the containment system used for the construction area appeared to be effective.

However, in one lounge of the hospital, concentration fluctuations greater than an order of magnitude that appeared unrelated to construction were observed. Intensive air sampling campaigns were conducted in late fall and late spring, coupled with observations of activities and conditions in this lounge, to investigate potential sources of Aspergillus particles, including diurnal variations in temperature and relative humidity of the lounge, the outdoor Aspergillus particulate concentrations, and foot traffic through the lounge. Correlations indicate that Aspergillus particulate concentrations are strongly influenced by foot traffic in this carpeted area. The behavior of Aspergillus particles relative to levels of particulate matter <= 5 um (PM5) was also examined.

3B.3
Effect of Protein Loading on Particle Size, Density and Shape. PATRICIA FRITZ, Lupita Montoya, Rensselaer Poytechnic Institute; Daniel Hershey, New York State Department of Environmental Conservation.

The allergenicity of common indoor allergens is often linked to source specific proteins, such as those originating from dust mite (e.g., Der p 1) and cat (e.g., Fel d 1). Allergenic proteins can be present in particles derived directly from the allergenic source, or can be carried on available non-specific particles such as house dust. In most cases, there is no commonly recognized concentration of these proteins, or particle size that can be interpreted as necessary for producing sensitization, or capable of eliciting an allergic response. Previously, we demonstrated that altering the volume and ratios of aqueous to solvent phases can influence shape, size, surface texture and protein loading of custom made polymeric microspheres. We characterized the morphological and aerodynamic size of those particles using scanning electron microsopy (SEM) in combination with an Aerodynamic Particle Sizer (APS) and a Dekati Electrical Low Pressure Impactor (ELPI). Our current efforts focus on the optimization and reproducibility of protein loadings of 15% or more when encapsulating ovalbumin in polymeric microspheres in the 0.5 to 5 micron size range. Recently we have expanded our work to try to achieve similar protein loadings through adsorption of ovalbumin on blank microspheres. Additionally, we have initiated studies to see if allergenic proteins from cat hair can be efficiently encapsulated or adsorbed using similar procedures. These particles with improved (higher) loadings of encapsulated or adsorbed ovalbumin, or cat hair protein will be analyzed using these three methods to monitor any alterations in morphology or aerodynamic size due to changes in protein content. Use of these microspheres in in-vivo models of allergic disease may be useful for identifying particle characteristics that are important for eliciting an immune response. This knowledge can lead to better control methods for indoor allergenic aerosols, particularly asthma triggers.

3B.4
Indoor air quality of four Southern High Plains dairy milking parlors in summer and winter. CHARLES W. PURDY, R. Nolan Clark, USDA-ARS; David C. Straus, Texas Tech University Health Sciences Center.

Milking parlor indoor air quality of 4 large dairies was sampled to investigate: 1) bacterial and fungal concentration/m^3 of air, 2) bioaerosol microbial types, and 3) respirable and non-respirable bioaerosol concentrations/m^3 of air. Equipment used were cascade biological samplers, a laser strategic aerosol monitor (SAM), and a weather station. Design & Methods: two milking parlor sampling sites were established for the equipment, one site on each end (front and back) of the milking parlor center alley with cows on both sides facing the alley. Cascade impactors were loaded in duplicate with each of 10 different media. Vacuum pumps displaced 28.3 L of air/min, and media were exposed from 30 seconds to 15 minutes depending on the medium used. Statistically the overall bioaerosol ANOVA model statement included the following parameters: one of 10 bioaerosol types, 2-stage or 6-stage impactors, winter and summer, parlor indoor aerosols compared to outdoor aerosol, AM and PM aerosols, and aerosols of 4 dairies. Conclusions: milking parlor indoor aerosols colony forming unit (CFU)/m^3 for all bacterial types were significantly increased compared to outdoor aerosols. Mesophilic fungi were significantly increased in outdoor aerosols compared to indoor aerosols; however, thermophilic fungi were significantly increased in indoor aerosols compared to outdoor aerosols. Six-stage total mean microbial aerosols among dairy parlors ranged from 2,124

3B.5
TBA

3B.6
Design and Development of an Electrostatic Sampler for Biological Aerosols with High Concentrating Rate.
GEDIMINAS MAINELIS, Tae Won Han, Rutgers University.

Integration of bioaerosol sampling with modern analysis techniques, such as PCR, requires samplers that can not only efficiently collect particles, but also to concentrate them in small amounts of fluids. In this research, we began development of a novel bioaerosol sampler, where a combination of electrostatic collection mechanism with superhydrophobic (\Lotus leaf\ type) collection surface allows for efficient particle collection, removal and concentration in small water droplets: 10 to 50 micro-L. This new sampling concept allows achieving very high sample concentration rates (up to 1 million) and could be applied to detect low concentrations of bioaerosols in various environments.
The prototype Electrostatic Precipitator with Superhydrophobic Surface had a shape of a closed half-pipe, where top surface served as a ground electrode, while 3 mm wide collecting electrode covered by a superhydrophobic substance was positioned in a groove of the flat bottom surface. Airborne particles drawn into the sampler were positively charged and then by the action of electrostatic field deposited onto the negatively charged electrode. The sampler was positioned at a ~20 degree angle, and the injected water droplets rolled-off of electrode's surface removing deposited particles. Our tests have shown that at a sampling flow rate of 10 L/min we achieved retention efficiency of about 90% for 3 micro-meter PSL particles. By using 20 and 40 micro-L water droplets, we achieved concentration rates as high as 100,000 as indicated by counting of removed particles by microscopy. Majority of the particles are removed by the first applied droplet, and few particles are removed by subsequent droplets. Tests with other particles also yielded high concentration rates, which points to the suitability of this new method for measuring low concentrations of bioaerosols. The sampler's performance is being improved further by adjusting the sampling flowrates, strength of ion source and collection voltage.

4B.1

Generation of Hydroxyl Radicals from Ambient Particulate Matter in a Surrogate Lung Fluid. EDGAR VIDRIO, Chin Phuah, Ann M. Dillner, Cort Anastasio, University of California - Davis.

While epidemiological research links exposure to particulate matter (PM) to several adverse health effects, including cardiovascular and pulmonary disease, the mechanisms for these effects are still poorly understood. The generation of reactive oxygen species, such as hydroxyl radical (OH), from inhaled particles is one of the many hypotheses for PM toxicity. Although there are several studies that have measured the generation of OH from PM, very few have done so in a quantitative manner in actual or surrogate biological fluids. Furthermore, there is little data illustrating how OH generation from PM samples varies as a function of time of year. Therefore, the goal of our work here was to quantitatively measure OH formation in a surrogate lung fluid (SLF) from $PM_{2.5}$ collected over the course of a year. To do this we collected three consecutive 24 hour $PM_{2.5}$ samples in Davis once each month. Samples were extracted in our SLF solution and the amount of OH generated was quantified using a benzoate chemical probe. Deferoxamine (DSF), a chelating agent, was added to a portion of our samples to remove transition metal reactivity in order to assess the fraction of OH produced via metal mediated pathways. Overall, if we express the amount of OH produced in each sample normalized by volume of air sampled (e.g., nmol OH per m^3 air), the amounts vary greatly day by day and show no consistent seasonal variation. However, when the amount of OH produced in our samples is normalized by particulate mass (e.g., nmol OH per micro-gram PM), we see a clear seasonal variation, with a maximum in the summer and minimum in the winter. In addition, metals play a key role in OH formation from our particles: on average, the addition of DSF reduced the OH reactivity of our $PM_{2.5}$ samples by 93%.

4B.2

Removal Efficiency and Disinfection Capacity of Iodine-Treated Filter for Virus Aerosols. JIN-HWA LEE, Chang-Yu Wu, Katherine M. Wysocki, Christiana N. Lee, University of Florida; Joseph Wander, Brian Heimbuch, Air Force Research Laboratory, Tyndall Air Force Base.

The iodine-treated filter, which combines mechanical filtration and the disinfection capacity of iodine, was tested for protection against airborne pathogens. The removal efficiency of the test filters was assessed by challenging it with MS2 bacteriophage. The experiments were conducted at three environmental conditions: room temperature (23 +/- 2 Celsius) & low RH (35 +/- 5 %), high temperature (40 +/- 2 Celsius) & low RH, and room temperature & medium RH (55 +/- 5 %). After removal efficiency experiment, the filter was vortexed to extract the collected MS2 from the filter.

The pressure drag of the tested filters was 352 Pascal/(meter/second) with a negligible variation during the entire experiment. In comparison, the pressure drag of a glass fiber filter was 38,625 Pascal/(meter/second). Both iodine-treated and untreated filter exhibited a similar removal efficiency at room temperature and low RH, 94 +/- 3 % and 92+/-2 %, respectively. At high temperature and low RH, the removal efficiency of the iodine-treated filter presented a higher value (99.98+/-0.04 %), while that of untreated filter (93+/-4 %) was similar to the results of room temperature and low RH. The iodine vapor released from the iodine-treated filter at high temperature may affect the infectivity of MS2, though the filter has similar removal efficiency to the untreated filter.

No significant difference between the survival fraction (CE/CC, CE: Extracted MS2, CC: Collected MS2) of collected MS2 on the iodine-treated and untreated filter at the same environmental condition was observed: $2.2*10^{-2}$ +/-$8.0*10^{-3}$ vs. $4.0*10^{-2}$+/-$3.0*10^{-2}$ at room temp. & low RH, and $7.8*10^{-1}$+/-$7.7*10^{-1}$ vs. $8.7*10^{-1}$+/-$4.4*10^{-1}$ at high temp. & low RH. According to the t-test, the difference between the average of survival fraction between room and high temperature was not significant (p-value was 0.08). The insignificant effect of iodine on the infectivity of MS2 can be explained by the shielding effect of aggregated MS2 particles collected on the filter.

4B.3

Collection of influenza virus aerosols: comparison of sampler efficiencies with molecular and infectivity assays.

PATRICIA FABIAN, James McDevitt, Harvard School of Public Health; Donald Milton, University of Massachusetts Lowell.

Apprehension regarding an influenza pandemic is on the rise due to concern regarding high rates of morbidity and mortality that could occur if a new highly virulent strain of influenza spreads throughout the world. Methods to evaluate transmission of influenza via aerosols are limited and largely un-validated. Using a benchtop aerosol generation chamber we collected air samples using 2.0 um Teflon filters, gelatin filters, the SKC Biosampler and the Polyurethane Foam (PUF) Compact Cascade Impactor (CCI) fitted with a single, 0.16 um 50% cut diameter stage. Samples were analyzed for total influenza A virus nucleic acid using reverse transcriptase-quantitative polymerase chain reaction (RT-qPCR) and infectivity was quantified using a cell culture based fluorescent focus reduction assay. When compared to the SKC Biosampler, total virus recovery, measured by PCR, from the gelatin filter, CCI and Teflon filter was 69%, 38%, and 66%, respectively (all differences were significant at the 0.05 level). Differences between the Teflon and gelatin filters were not statistically significant and both were significantly greater than the CCI results. When compared to the SKC Biosampler, infectious virus particles assayed from the gelatin filter, CCI impactor, and Teflon filter were 10%, 7% and 24%, respectively (all differences were statistically significant at the 0.05 level). Analysis of the ratio of the PCR results to the infectivity assay results for the SKC Biosampler, gelatin filter, CCI and Teflon were 0.34%, 0.06%, 0.09%, and 0.10%, respectively. These results suggest that recovery of viruses from filters and other dry impaction substrates is problematic in terms of virus removal from the surfaces and virus survival. Collection of influenza aerosols directly into liquid media favors virus recovery and continued infectivity. Despite these advantages, the SKC Biosampler is not an ideal sampler due to relatively low flow rates and dilution of samples into large impinger fluid volumes.

4B.4

Detection of Airborne Influenza And Avian Influenza Virus.

Pei-Shih Chen, Qian Kun Lin, FENG-DA TSAI, Kaohsiung Medical University.

To our knowledge, there was no study to quantify airborne influenza and avian influenza virus. Therefore, the purpose of our study is to establish a method to quick quantifying the airborne influenza and avian influenza virus in the air. Then, field validation was also held at an air quality monitoring station and a live-bird market.

Air samples were sampling with Teflon filter within a 37 milli-meter cassette and analyzed by real-time qPCR (ABI PRISM 7500 Sequence Detection System). In addition, sampling stress and storage effect were also evaluated. Furthermore, 48 samples were collected at a live-bird market and 12 samples were collected at Sin-Jhuang air quality monitoring station during February 2006 to September 2006.

Our results showed that the R^2 value of standard curves were 0.988, 0.995 and 0.998 for influenza A, influenza B and influenza H5 virus, respectively. In regard to the detection limits, they were 0.78 copy/m^3,0.58 copy/m^3 and 1.1 copy/m^3 for influenza A, influenza B and influenza H5 virus, respectively. For sampling stress, close phase of three piece cassette was batter than open phase. In regard to storage effect, it was 94% within three days at 4 degrees C of sampled virus. For the isolated RNA, it can be conserved at least three months without any degradation at -80 degrees C.

For field validation, the positive rate of air samples at air monitoring station was 67%. The virus concentration was in the range of 4~439 copy/m^3. In live-bird market, the positive rate for chicken stall was 42% and the virus concentration was in the range of $4.36x10^2$~$1.97x10^4$ copy/m^3. For duck stall, the positive rate was 33% and the virus concentration ranged from $8.10x10^2$ to $2.83x10^4$ copy/m^3. These results showed that this quantifying method was successfully developed and validated in the field.

4B.5

Acute Injury to Rat Airway Epithelium by Exposure to Flame-Generated Soot Particles Doped with 1-Nitronaphthalene. BENJAMIN KUMFER, Lindsay Davison, Evan Wallis, Michelle Fanucchi, Ian Kennedy, University of California - Davis.

Particles emitted from anthropogenic sources, such as diesel engines, are often found to contain on the surface organic species, including PAHs, oxy-PAHs, and nitro-PAHs, that may contribute to the adverse health effects associated with ambient PM. The large number of organic species found in ambient PM makes it difficult to assess the toxicity of these components individually. Alternatively, using pure organic materials without carrier particles is not desirable for in vivo exposure studies, since this does not mimic the natural exposure route. To overcome these problems, a method was developed for the synthesis of flame-generated soot particles doped with specific organics for toxicity studies. Soot particles, which are initially clean of PAHs, are generated from an acetylene diffusion flame. The post-flame aerosol is subsequently mixed with a heated gas stream containing saturated PAH vapor and then cooled to promote condensation of the PAH onto soot particles. This system was evaluated using 1-nitronaphthalene (1-NN), a substance found in ambient PM and a known toxin. Good control over the amount of condensed 1-NN was achieved by varying the temperature of the saturated PAH stream. Particles of variable 1-NN loading were instilled into rat airways using a dry powder insufflator. The injury to epithelium was determined by high-resolution histopathology and by measurement of the release of cytokines associated with oxidative stress. Results show an increase in injury with 1-NN loading. The injury induced by flame-generated soot was also compared to that by commercial carbon black. Carbon black particles were found to be more efficiently cleared from the airways than were soot particles, suggesting that the clearance mechanism is dependent upon particle size, morphology and possibly surface composition.

4B.6

Comparative Composition and Inhalation Toxicity of Urban versus Rural Samples of Resuspended Paved Roadway Material. JAKE MCDONALD, JeanClare Seagrave, Matthew Campen, Joe Mauderly, Lovelace Respiratory Research Institute.

On June 30, 2005 the U.S. EPA released a Staff Paper with a recommendation to regulate PM10- PM2.5, and to focus the regulation on urban areas because of a perception that urban dust will be more of a health concern than rural dust. Unfortunately the data on composition (and toxicity) of dust in these specific size fractions is extremely sparse, and much of the suggestions that dust in more urban areas is more toxic than non-urban areas is based on speculation. We have conducted a study to characterize the composition of resuspended dust in several areas throughout the U.S., to define the chemical and physical characteristics of dust in the coarse and fine fractions by region, including contrasts in cities that are defined as rural and urban dominated. Samples were collected from street surfaces in NY, NJ, GA, AL, NM, TX, KS, and CA. Initial aerosol experiments showed clear differences in the composition of urban versus rural samples. A strategy to composite samples according to urban versus rural was developed, and two separate exposure atmospheres were employed after aerosolization with a Wright Dust Feeder. Dust traversed through a PM2.5 cyclone and into a rodent nose-only inhalation exposure system where pulmonary toxicity in rodents was assessed. Samples were collected for analysis of particle size, metal content, organic species and total organic carbon, endotoxin, protein, and carbohydrate. Composition and differential health response after inhalation will be reported. Funding from the National Environmental Respiratory Center, with contributions from multiple federal and non-federal sponsors.

11E.1
Development of Sampling and Analysis Methods to Monitor Nanoparticles in the Workplace Environment. GARY CASUCCIO, Traci Lersch, Keith Rickabaugh, RJ Lee Group, Inc.; Randall Ogle, John Jankovic, Oak Ridge National Laboratory.

The recent thrust in research related to nanotechnology has created opportunities to improved materials, devices, and systems that can exploit the physical, chemical, and biological properties at the nanoscale level (1 to 100 nanometers). While nanotechnology is still in the developing stages, nanoparticles are already being used in a number of industries including electronic, magnetic and optoelectronic, biomedical, pharmaceutical, cosmetic, energy, catalytic and materials applications.

Although the field of nanotechnology is developing rapidly, there is concern regarding the potential toxicity of nanoparticles, and little is known regarding worker exposure to particles in this size range in the workplace environment. This issue is compounded by the fact that nanoparticles, from both natural occurring and anthropogenic sources, are ubiquitous in the ambient environment and engineered nanoparticles will vary in physical and chemical properties from industry to industry. Furthermore, methods to monitor nanoparticles in the workplace and references to acceptable dose levels have not established. The combination of these factors has created a unique challenge for health and safety professionals with respect to monitoring the workplace environment.

This presentation will discuss the development of sampling and analysis methods to monitor worker exposure.

11E.2
Increases of Iron Concentrations of Human Airway Epithelial Cells in Vitro by Exposure to Magnetic Nanoparticles Coated with Organic Aerosol and Inorganic Acid. MYOSEON JANG, The University of North Carolina at Chapel Hill; Andrew J. Ghio, Environmental Protection Agency.

BACKGROUND. Applications of iron oxide magnetic nanoparticle (MNP) are diverse including magnetic recording media, magnetic filters for the removal of selected impurities from various types of fluids, and numerous biomedical uses for hyperthermia, drug delivery, and nuclear magnetic resonance contrast agents. However, little is known about the health effects of iron oxide MNPs. The toxicity of airborn MNPs mainly depends upon coating materials and dose amounts. We hypothesize that atmospheric inorganic acids and organics can interact wtih airborn MNP and accelerate the dissolution of MNP and potentially increases the adverse biological effects.
APPROACH. The study began with an appropriate device design and the dose model to deliver MNP onto the target area of human airway epithelial BEAS-2B cells in vitro. MNPs were nebulized into the gas-phase of indoor Teflon film chambers and directly coated with seconadry organic aerosol (SOA) created from ozonolysis of alpha-pinene. The resulting airborn matter was targeted on in vitro human airway epithelial cells through the exposure device. Each experimental set for the exposure study comprised of background air, MNP, SOA, SOA/MNP, inorganic acid/MNP, and inorganic acid/MNP/SOA and was compared to the base control cells that remained in the incubator for the duration of exposure experiments. Cells were grown to confluence on inserts, an air-liquid interface introduced, and exposed. Twenty-four hours following the exposure, supernatant was collected to determine cell iron concentrations using colorimetric analysis and various biological effects.
RESULTS. The solubility of MNP is accelerated in the presence of sulfuric acid, increasing ferric and ferrous ions in aerosols. The SOA products also accelerate the dissolution of iron oxide by chelating metal ions. The human airway epithelial BEAS-2B cells in vitro exposing to sulfuric acid or SOA products increase all biological effects (IL-8, ferritin, acetaldehyde, and DMT1 RNA) being tested, except ferritin RNA. This study indicates that the interaction of MNP with sulfuric acid or SOA can produce unpleasant health effects through increases ionic iron species in airborne MNP matter.

11E.3

A Study on Magnetic Passive Aerosol Sampler for Measuring Aerosol Particle Penetration through Protective Ensembles. Zhong-Min Wang

Current testing for particle penetration through protective ensembles is mainly based on active filtration principles, which may overestimate the particle penetration due to additional driving force. In contrast, passive sampling has the potential to be a simple, small size, light weight, and inexpensive device for aerosol sampling. However, most passive devices are not suitable for the testing because of low collection efficiency and the requirement for long sampling times.

A novel prototype magnetic passive aerosol sampler (MPAS) has been developed for measuring particle penetration through protective ensembles. The MPAS consists of a 25 mm diameter sampler body, a piece of Teflon (or PVC) film, and magnet(s). The magnet could be a single magnet or a number of mini disc magnets (multi domain). For the latter, the magnets were arranged with an alternative N and S pole pattern. Iron oxide nanoparticles were generated using an atomizer as the challenge aerosol. Passing through a diffusion dryer, the aerosol was then sent to a testing chamber where the MPAS and an active sampler were located. The active sampler was a 25 mm PVC filter cassette operated at 200 ml/min. After each test, the active sampler and MPAS were analyzed using a microbalance. Compared to a conventional passive sampler, the MPAS was able to collect more particles due to the magnetic force. Although the collection efficiency of the MPAS was approximately 100 times higher than that of a conventional passive sampler, it obtained only about 0.8 percent of the collection efficiency of the active sampler. With sampling times of 2, 4, and 6 hours, particles collected by the MPAS were approximately 5, 10, and 15 micrograms, respectively. The multi domain pattern greatly improved the uniformity of particle deposition and magnetic force was able to drop off within a few mm from the magnets' surface.

11E.4

Measurement of Airborne Nanoparticle Exposures Associated with the Use of Fume Hoods. SU-JUNG TSAI, Earl Ada, Michael J. Ellenbecker, University of Massachusetts Lowell.

Manual handling of nanoparticles is a fundamental task of most nanomaterial research; such handling may expose workers to ultrafine or nanoparticles. The chemical laboratory hood, also called the fume hood, is commonly used in university and research laboratories as the primary local exhaust ventilation (LEV) system. Such hoods rely on the proper face velocity for optimum performance. As air flows around the worker toward the hood, counterrotating eddies occur on the downstream side of the worker and the reverse flow can pull the airborne nanoparticles back into the worker's breathing zone. The end of the reverse flow zone reaches at least two body widths downstream of the worker and implies that a hand-held contaminant source cannot escape the influence of the recirculating flow.

Experiments were performed to measure airborne particle concentration while handling nanoparticles in two fume hoods located in different buildings under a range of hood operating conditions. A TSI Fast Mobility Particle Sizer (FMPS) was used to measure airborne particle concentration from 5 nm to 560 nm in 32 size channels. Nanoalumina was selected as the primary material. Air samples were also collected on titanium dioxide-filmed TEM grids placed on polycarbonate membrane filters and particles were characterized by transmission electron microscopy (TEM) and scanning electron microscopy (SEM). Handling tasks included transferring particles from beaker to beaker by spatula and by pouring. Measurement locations were the room background, the researcher's breathing zone and upstream and downstream from the handling location. Airborne particle concentrations measured at breathing zone locations were analyzed to characterize exposure level. Statistics were used to test the significance of differences between data.

Measurements at the researcher's breathing zone using Hood 2 found elevated airborne particle number concentrations during both particle handling and post handling. The complete results will be fully discussed in our presentation.

11E.5

Generation of Agglomerates of Nanoparticles for use in Biological Studies. DAVID G. NASH, Owen R. Moss, Brian A. Wong, The Hamner Institutes for Health Sciences.

Because of their high diffusivity, nanoparticles released into the atmosphere will likely begin to agglomerate. The state of agglomeration upon inhalation and the potential to deagglomerate back into nanoparticles may affect the toxicity of the inhaled material. In order to investigate this, a system was set up to generate aggregates from agglomerates. Primary particles, composed of zinc, were generated using zinc rods in a spark generator (Palas GFG -1000, Karlsrhue, Germany). These agglomerates from the spark generator were passed through a room temperature aging chamber or through a tube furnace (Carbolite HST, Derbyshire, UK). Agglomerate size was measured with a scanning mobility particle sizer (SMPS model 3936, TSI Inc., Shoreview, MN). When furnace temperature was set near the zinc coalescence temperature, instead of decreasing in size, agglomerate size increased up to 30%; a percentage increase duplicated with the room temperature aging chamber. Starting with an aerosol of primary zinc particles, equal concentrations of agglomerate and aggregrate aerosol were produced.

11E.6

Occupational Monitoring of Carbonaceous Nanomaterials. M. EILEEN BIRCH, Douglas E. Evans, Bon-Ki Ku, National Institute for Occupational Safety and Health.

Carbon nanotubes and nanofibers (CNTs/CNFs) are one of the most mass-produced engineered nanomaterials. The annual global production of CNTs is over 100,000 tons; CNF production and use are increasing at a similar pace. High volume production presents an exposure concern for workers who handle these materials, which may be especially toxic if inhaled because of their composition (metal catalysts) and fibrous structure. Field investigations to evaluate potential exposures to CNTs/CNFs are important because the toxicological properties of these materials are not yet understood, and the manufacturing processes are rapidly changing. Studies were conducted at two facilities that produce CNFs or composite materials thereof. Among other measurements, air and surfaces samples collected in different areas were monitored for total carbon (TC) by NIOSH Method 5040 [1]. Nearby office areas also were monitored to check for possible contamination outside the process areas. In addition, air samples for analysis by transmission electron microscopy (TEM) were collected, and multiple, direct-reading instruments were used for air monitoring. At one facility, TC concentrations in the processing areas were 2 to 64 times higher than those in an office area. Surface TC loadings were about 3 to 30 times higher. Several TEM samples evidenced fibers or entangled fiber bundles. Particle number concentrations in 11 process areas were well below outdoor background. Slight increases relative to laboratory background occurred during weighing/mixing CNFs and cutting a composite material with a wet saw. Particle mass concentrations for the 11 processes exhibited the same general trend as number concentrations. The major finding was with the wet saw, where the mass concentration increased to about three times laboratory background. Preliminary TC results for a second facility also indicate air contamination. TC concentrations in six processing areas were 3 to 155 times higher than that found in an office area.

Disclaimer: The findings and conclusions in this abstract have not been formally disseminated by the National Institute for Occupational Safety and Health and should not be construed to represent any agency determination or policy.

[1] Birch, M.E., Monitoring diesel particulate exhaust in the workplace, Chapter Q, NIOSH Manual of Analytical Methods, DHHS(NIOSH) Publication No. 2003-154 (2003).

11E.7

Modeling of Workplace Nanoparticle Exposure. CHRISTOF ASBACH, Heinz Kaminski, U. Rating, Heinz Fissan, Thomas A.J. Kuhlbusch, Institute of Energy and Environmental Technology (IUTA)

Inhaled nanoparticles are currently being discussed to induce adverse health effects. Particles in this size range can either originate from unintended anthropogenic or natural formation processes or can be intentionally produced engineered nanoparticles. Exposure to engineered nanoparticles in e.g. workplaces has recently raised increased interest as these particles may have health relevant properties beyond their mobility due to particle size. Monitoring of nanoparticle exposure at workplaces in the nanotechnology industry is thus an important issue for assessing the safety of workers.
For an expedient investigation of possible workplace exposure as well as save workplace design it is essential to understand the behaviour and dispersion of particles within a given workplace. Precise modeling of particle dispersion and physical reactions can therefore help to improve work place design, identify hot spots within the room, and give guidance for the definition of suited measurement locations. Furthermore, such simulations can provide a three dimensionally resolved picture of the exposure scenario. Therefore exposure can also be inferred from the model based on the posture of the worker, e.g. whether she/he is sitting or standing.
In this work, three exemplary, realistic workplaces have been simulated using the commercial computational fluid dynamics (CFD) code FLUENT, along with the Fine Particle Model (FPM). The modeled scenarios comprise a welding workplace, a large hall with several pipes and a reactor with (nano-) particles trickling from a conveyor belt, and a hall with a leak in a slightly pressurized transport pipe of freshly formed nanoparticles. Besides convective transport of the particles and dilution with background air (assumed to be particle free), the considered physical processes also comprised sedimentation and coagulation.
Results from the different simulated scenarios will be presented along with recommendations for representative and conclusive modelling of workplace exposure to nanoparticles.

This work has been supported by the government of North-Rhine Westphalia and the European Union under grant number 005-0406-0004.

11F.1

Physical and Chemical Characteristics of Aerosol Mists in Fertilizer Manufacturing Facilities. YU-MEI HSU, Chang-Yu Wu, Dale A. Lundgren, University of Florida; Brian Birky, Florida Institute of Phosphate Research.

Strong inorganic acid mists containing sulfuric acid have been reported to correlate well with lung and laryngeal cancers in humans. Phosphate fertilizer manufacturing facilities are listed as one of many occupational exposures to strong acid. To better protect workers from potential exposure, a field campaign was carried out to determine the physical and chemical characteristics of mist aerosols in fertilizer manufacturing facilities.

The sampling was carried out at 8 phosphate fertilizer plants using the UW-cascade impactor to obtain size fractionated information. The sampling time was 24 hours and 3 samples were obtained at each location. Ion chromatography was used to analyze water soluble species, including sulfate, phosphate, fluoride, chloride, nitrate, sodium, potassium, magnesium, calcium and ammonium. The sampling results indicate that the highest sulfuric acid mist concentration was obtained at the sulfuric acid pump tank area and the highest phosphoric acid mist concentration was obtained at the belt/rotating table filter floor. Acid mists at these areas were dominant in the coarse mode when high concentrations were identified. The major species found at the plants were phosphate, sulfate, fluoride, ammonium and calcium. An aerosol thermodynamic model was used to estimate the acidity of aerosols with sulfuric acid concentration higher than 200 micro-gram/m3. The calculation indicates the mode size of hydrogen concentration in the ambient condition was 1.8-3.8 micro-meter for 5 samples and 3.8-10 micro-meter for 2 samples. In the high relative humidity environment, i.e. the human respiratory system ($< 95\%$), the aerosol can reach its equilibrium size within 0.014 seconds, which is longer than the traveling time of an aerosol in the upper respiratory system. Particles with these sizes mainly deposit in the upper respiratory tract and the results agree with the relation between strong inorganic acid mists containing sulfuric acid and laryngeal cancer.

11F.2

Time-Dependent Release of Iron from Soot Particles by Acid Extraction and the Reduction of Fe3+ by Elemental Carbon.
STEPHEN DRAKE, Bing Guo, Texas A&M University.

Elemental carbon reduces Fe^{3+} to Fe^{2+} in aqueous solutions. This process has potential implications in the adverse health effects of fine particle air pollution, because both elemental carbon and iron are major components in atmospheric particulate matter. In this study we measured the time-dependent release of iron from laboratory flame soot particles that contained low concentrations of iron, and the reduction of Fe^{3+} to Fe^{2+} in an acid extraction process. The concentration of Fe^{3+} and Fe^{2+} ions in the extraction solutions was measured by a spectrophotometric method. The original valence state of iron in the soot particles was measured by Mossbauer spectroscopy. The results showed that while Fe^{3+} was the dominant valence state in the dry soot particles, significant fraction of iron was reduced to Fe^{2+} in the aqueous solution. Further investigation is needed to assess the significance of this phenomenon in the biological effects of Fe-containing soot particles.

11F.3

Tracking personal exposure to diesel exhaust at a trucking industry freight terminal using organic tracer analysis by thermal desorption GCMS.
REBECCA J SHEESLEY, James J Schauer, University of Wisconsin, Madison; Thomas J Smith, Francine Laden, Drew Blicharz, Harvard School of Public Health; Eric Garshick, VA Boston Healthcare System, Channing Laboratory, Brigham and Women's Hospital and Harvard Medical School; Jeff DeMinter, Mark Meiritz, University of Wisconsin-Madison, Wisconsin State Lab of Hygiene.

Personal exposure samples were collected in St. Louis, MO as part of a larger epidemiologic project aimed at assessing carbonaceous fine particulate matter (PM) exposure at trucking terminals. The mixture of personal exposure, ambient worksite and ambient urban background samples provides an unique opportunity to track the work-related exposure to carbonaceous fine PM in a trucking terminal. A comparison of the samples provides information on the origin of the personal exposure to elemental and organic carbon: urban background, work site or personal activity. To accurately assess the impact of PM emission sources, particularly motor vehicle exhaust, elemental and organic carbon by thermal optical transmittance and nonpolar organic tracer analysis by thermal desorption gas chromatography/mass spectrometry (TD GCMS) were conducted on all of the PM samples.

This data set provides an excellent base for the discussion of important questions: How well does an area sample (local urban or indoor) represent personal exposure and does this vary by source? Do elemental carbon and hopanes track the same motor vehicle source within a diesel-impacted environment? For primarily on-site workers, this data suggests that the worksite sample can be used to estimate personal exposure to motor vehicle exhaust. This does not appear to be true for the truck drivers, as the urban background and yard (terminal background) samples do not accurately depict their exposure to motor vehicle exhaust; the drivers tend to have a much higher exposure than the ambient samples and the correlation for specific compounds is poor. Also, an overall assessment of the personal exposure, work site area and local background samples indicates that hopanes and elemental carbon do not necessarily depict the same source. Thus, elemental carbon measurement would not be sufficient to depict the lube oil/organic carbon component of the diesel source in freight terminals or other high impact areas.

11F.4

Characterization of welding fume particles generated from a robotic welding system. BEAN T. CHEN, Sam Stone, Diane Schwegler-Berry, Amy Frazer, Michelle Donlin, Jared Cumpston, Aliakbar A. Afshari, David G. Frazer, Vincent Castranova, James M. Antonini, National Institute for Occupational Safety and Health.

Epidemiological studies suggest that the long-term inhalation of welding fumes may lead to lung disease, neurotoxicity, and cancer. To study health effects of welding fume exposure, a computer controlled, robotic welding system was developed at NIOSH to allow for continuous welding for animal exposure. Gas metal arc welding was performed using a stainless steel electrode. A flexible trunk was attached to the robotic arm of the welder and was used to collect and transport fume from the vicinity of the arc to the animal exposure chamber. During welding, fume mass concentrations were continuously monitored with a real-time aerosol monitor and gravimetrically measured with Teflon filters. Fresh fume particles attained concentrations as high as 150 mg/m^3 which could be diluted with air to maintain a desired exposure concentration in the chamber. At a mean concentration of 40 mg/m^3, the aerosol samples were taken using polycarbonate filters for scanning electron microscopy and grids for transmission electron microscopy to assess particle morphology and elemental composition. In order to estimate the deposited dose in the pulmonary region of exposed animals, the particle size distribution was measured with both a Micro-Orifice Uniform Deposit Impactor (MOUDI) and a Scanning Mobility Particle Sizer (SMPS). Results from MOUDI indicate the mass median aerodynamic diameter was approximately 0.24 um with a geometric standard deviation of 1.39. Although this median diameter has a value similar to that obtained from SMPS, there were discrepancies between the two distributions in both mass and number. Results show that welding fume particles having the same electrical mobility appear to exhibit very different aerodynamic behaviors because of their highly-aggregated morphologies and electric charging capacities. These findings may apply to other ultrafine particles such as diesel exhaust and carbon nanotube particles and should be considered when interpreting their size distributions.

11F.5

Stimulation of Rat Alveolar Macrophages by Water-Soluble Components of PM2.5 Aerosols. Amy Prasch, MARTIN SHAFER, Jocelyn Hemming, James Schauer, University of Wisconsin-Madison; Michael Hannigan, University of Colorado.

Daily PM2.5 samples were collected for one year in the Denver metro area on pre-cleaned Teflon filters. Filters were sectioned for chemical characterization, including high-resolution ICP-MS analysis of both water soluble and total forms of major and trace inorganic species (over 40 elements). In addition major ions (sulfate, nitrate, chloride, ammonia) and carbon and nitrogen were also analyzed. To assess the potential toxicity of water-soluble components of the PM2.5 samples, bioassays using a rat alveolar macrophage cell line were developed and applied to a subset of the samples. Macrophages are exposed to aqueous filter leaches and subsequently assessed for viability and production of reactive oxygen species (ROS) as an indicator of macrophage stimulation. The novel macrophage bioassay exhibited high sensitivity (100 microgram PM samples are workable) and excellent short and long-term precision. Importantly, because the macrophages are maintained in a well-defined media, devoid of complex organic ligands, the bioassay is compatible with further trace element speciation protocols. The method is rapid (2-hour exposures), automated (96-well plate reader), and suitable for implementation in the context of large scale air monitoring and health effects studies. Results from the Denver study show that variations in the magnitude of the ROS response observed between samples were only partially explained by differences in the total mass loading. This suggests that the chemical composition of the PM2.5 is also important in mediating this response and may be an important factor in explaining how PM2.5 exposure leads to adverse health effects. We are currently exploring statistical relationships between ROS response and the comprehensive elemental dataset.

12B.1
Effects on manufactured nanoparticles on lung and vascular cells. JOHN VERANTH, N. Shane Cutler, Cassandra Deering, Agnes Ostafin, Garold Yost, University of Utah.

Recent publications by our laboratory related to the effects of manufactured nanoparticles on lung epithelial cells and on vascular endothelial cells will be integrated and summarized. Fluorescent labled nanoparticles are shown to be taken up by various cell types leading to concern about the potential biological effects of other nanomateials as well. Nanoparticles from metal oxides appear to have low potency for the induction of proinflammatory signaling compared to soil-derived dusts. In addition the metal oxide particles have limited ability to induce formation of reactive oxygen species in the tested cell cultures. Use of various pathway-specific inhibitors provides insights into the cell signaling pathways mediating biological responses. The in vitro lung and vascular models provide an easily manipulated biological system for studying particle-induced toxicities, but details of the cell culture conditions can affect observed results.

12B.2
Size Distribution and Characteristics of Airborne Unrefined Carbon Nanotube Particles. JUDY Q. XIONG, Maire S.A. Heikkinen, Beverly S. Cohen, New York University School of Medicine.

Carbon nanotubes (CNTs) are among the most dynamic and fast-growing nanomaterials due to their novel properties. With a compound annual global production growth rate of well above 60%, the potential of human exposure to this new type material in the workplace as well as in the general environment are rising, and their impacts on human health are of largely concern.

A method has been developed in our laboratory for sampling, quantifying and characterizing airborne CNT particles utilizing a 13-stage Electrical Low Pressure Impactor (ELPI) combined with image analysis by Atomic Force Microscopy (AFM). The method is capable of identifying agglomerated nanoparticles in the presence of other airborne particles, and measuring size-resolved number concentrations.

The technology has been applied for sampling and characterizing airborne unrefined CNT samples (raw material) of various types including single-walled (SWNT), double-walled (DWNT) and multi-walled (MWNT) nanotubes. The experimental data showed that the particle sizes generated from all types of CNT raw materials were widely distributed across all 13 stages of the ELPI including the filter stage ranging from 7 nm to 10 um in diameter. The particle size distributions varied with the type of CNTs and with the methods by which they were manufactured. AFM results also showed that the CNTs tend to agglomerate rather than exist as single particles, physically. As deposition efficiency and sites of inhaled particles within the respiratory system largely depends on particle size, the deposition pattern of agglomerated nanoparticles should be similar to those larger equivalent sized non-agglomerated particles. Nevertheless, entrained particles depositing on/in the deep lung surfaces of the bronchioles or alveoli will contact pulmonary surfactants in the surface hypophase and the agglomerated CNT are likely to (ultimately) be de-agglomerated. Therefore, to investigate human exposure to airborne CNTs, the full size range of inhalable particles must be taken into account.

12B.3
Measured Airborne Nanoparticle Exposures at an NSF Nanoscale Science and Engineering Center. SU-JUNG TSAI, Kwangseog Ahn, Earl Ada, Michael J. Ellenbecker, University of Massachusetts Lowell.

The NSF Center for High-Rate Nanomanufacturing (CHN) is a collaboration of the University of Massachusetts Lowell, Northeastern University, and the University of New Hampshire which has a unique purpose to integrate occupational and environmental health and safety into its mission. As a part of this effort we have monitored nanoparticle air concentrations and size distributions in various research laboratories at CHN and Massachusetts Institute of Technology.
A TSI Fast Mobility Particle Spectrometer (FMPS) was used to measure airborne particle concentration from 5 nm to 560 nm diameter in 32 size channels. We have monitored particle exposure at workplaces for 7 process types and 20 operations to date. Measurements were taken at background locations, source locations, and researchers' breathing zones. Monitored processes include electrospinning, compounding, carbon nanotube furnace, fullerene reaction, twin screw extruding, silica handling and carbon black handling. Monitored nanoparticles include nanoclay, nanoalumina, carbon black, fullerenes and carbon nanotubes. Some processes were characterized by collecting aerosol particles for further analysis by transmission electron microscopy (TEM) or scanning electron microscope (SEM).
The change in breathing zone concentration before, within and after an operation varies with process type and operating conditions. Significant increases in particle number concentration measured 8 centimeters (3 inches) from a particle release source were detected on most processes. One of the processes, twin screw extruder (TSE), is the standard industrial equipment for compounding nanocomposites. We have monitored the compounding process using polymer beads with nanoalumina particles. For the synthesis of carbon nanotubes (CNTs), the measurement on the CNT furnace found high particle number concentrations in the exhaust air during synthesis of single-walled CNT by chemical vapor deposition (CVD).
In this presentation, monitoring data from most processes evaluated will be presented.

12B.4
The fate of airborne nanoparticles from a leak in a manufacturing process into a working environment.
NICHOLAS STANLEY, David Y.H. Pui, Thomas Kuehn, University of Minnesota; Christof Asbach, Thomas Kuhlbusch, Heinz Fissan, Institute of Energy and Environmental Technology.

Nanoparticle toxicology has become a major issue in recent years as the potential for human exposure has risen. A leak in nanoparticle production equipment can cause large quantities of nanoparticles to be emitted into a work environment. These nanoparticles can cause adverse health affects, and toxicologists have proposed using nanoparticle surface area as a health relevant measure to assess worker exposure. However particle properties can change as these particles traverse from the leak and undergo physical and chemical reactions. The particle properties need to be examined by looking at changes in chemical composition, particle morphology, and number and surface area concentrations.

Nanoparticles of different materials were injected through an experimentally simulated leak into an ASHRAE 52.2 - 1999 classified wind tunnel. Measurements were taken with various instruments to determine the fate of the injected nanoparticles. Lung deposited surface area was measured using an NSAM; an SMPS measured the size distribution. Particle morphology and chemical composition were determined using TEM or SEM/EDX analysis. Particle size, material, and concentration were altered, as well as other parameters. By adjusting the experimental parameters (such as particle material and pressure drop across the leak) the effect of various conditions on the fate of nanoparticles could be studied. Measurements however could only be taken at discrete locations throughout the wind tunnel, so a numerical simulation were used to show a more in depth look at the fate of these nanoparticles.

The background of this project and the experimental set up and conditions will be presented along with initial results from experiments and modeling.

This project is sponsored by NSF G2006-Star-F2 (Fate/Transport). The financial support is gratefully acknowledged.

12B.5

Evaluating the potential for release of carbon nanotubes and subsequent occupational exposure during processing of a nanocomposite. AMIT GUPTA, Mark L. Clark, Battelle Toxicology Northwest; Daniel J. Gaspar, Pacific Northwest National Laboratory; Michael G. Yost, University of Washington; Gwen M. Gross, Paul E. Rempes, The Boeing CompanyL; John C. Martin, Jr., Washington Technology Center, Seattle, WA.

Evaluating the potential impacts of nanotechnology on human health and the environment requires an understanding of the potential for nanoparticle exposure during manufacturing operations. Routine manufacturing processing steps for nanocomposite materials (materials consisting of a nanoparticles or nanotubes in a bulk, typically polymer, matrix) such as sanding, grinding, water-jet cutting etc., have the potential to liberate harmful components of a composite material. Little is known about the potential for the release of nanoparticles when common operations are performed on nanocomposites and there is a chance the nanomaterial will be liberated, thereby creating the potential for occupational exposure or environmental release of waste containing free (unbound) nanoparticles or nanotubes. This study is focused on the potential to generate respirable nanoparticles when sanding a structural nanocomposite material.

In this initial study we determined the number, concentration, size distribution, and morphology (including agglomeration) generated by a sanding process on carbon fiber:MWNT-modified epoxy resin composite panels. The MWNT's (50-70 nm diameter) were dispersed into the epoxy resin binder after surface modification to ensure good encapsulation by the epoxy. The sanding experiments were carried out in a glove box customized to support simultaneous real-time monitoring of particle size distribution, number and concentration (using both an optical particle counter and a condensation particle counter) and collection of filter samples for ex situ characterization. Particle size, morphology and degree of agglomeration were evaluated using both scanning and transmission electron microscopy. During sanding of a MWNT-containing material, real-time monitoring instrument (Scanning Mobility Particle Sizer) detected the presence of loose and unbound nanoparticles whereas, they were not seen during sanding of a standard carbon-carbon composite material (without MWNT). The TEM images showed the presence of carbon nanotubes projecting from the edges of larger particles. Preliminary attempts to determine the chemistry of the nanoparticles were unsuccessful using Raman and NIR spectroscopy. Future studies are planned to identify the chemistry of the generated nanoparticles.

12B.6

Murine Pulmonary Pathology and Systemic Immune Function Following Inhalation of Multiwalled Carbon Nanotubes (MWCNTs). LEAH A. MITCHELL, Andrew Gigliotti, Jacob D. McDonald, Lovelace Respiratory Research Institute; Jun Gao, Scott W. Burchiel, University of New Mexico.

The purpose of the following studies was to create a novel inhalation exposure system for Multiwalled Carbon Nanotubes (MWCNTs) and to determine if acute doses of inhaled MWCNT cause significant pulmonary damage and/or systemic immune function alterations. C57Bl/6 adult male mice were exposed to control air or 300 micro-g/m3 and higher particle concentrations caused systemic immunosuppression. None of the doses administered for 7 days were adequate, and did not cause immune function alterations compared to control animals. Immunosuppressed animals were determined to be suppressed in their T-dependent antibody response to sheep erythrocytes as well as T cell proliferative ability in presence of mitogen, Concanavalin A (Con A). Furthermore, assessment of nonspecific Natural Killer (NK) cell activity showed that animals exposed to 1000 micro-g/m3 had decreased NK cell function. Bronchial Alveolar Lavagate and Histopathological analysis of lungs from exposed animals showed little more than macrophage engulfing black particulate and did not indicate pulmonary inflammation, fibrosis, or granuloma formation as has been suggested by others. Real time RT PCR was conducted on RNA collected from spleen and lung. Splenic mRNA expression of interleukin-10 (IL-10) and NAD(P)H quinone oxidoreductase 1(NQO1) was increased in 1000 micro-g/m3 exposed splenocytes but was unaltered in RNA isolated from exposed lung. These results taken together support the hypothesis that MWCNT, when delivered in vivo by inhalation, have a systemic suppressive effect on the immune system. This suppression may be a result of systemic oxidative stress and the production of IL-10, a cytokine that regulates cell mediated immunity.

13B.1

Relationship between redox activity and chemical speciation of size-fractionated particulate matter. CONSTANTINOS SIOUTAS, Leonidas Ntziachristos, University of Southern California,; John R Froines, Arthur K Cho, UCLA.

Background

Although the mechanisms of airborne particulate matter (PM) related health effects remain incompletely understood, one emerging hypothesis is that these adverse effects derive from oxidative stress, initiated by the formation of reactive oxygen species (ROS) within affected cells. Typically, ROS are formed in cells through the reduction of oxygen by biological reducing agents, with the catalytic assistance of electron transfer enzymes and redox active chemical species such as redox active organic chemicals and metals. This study aims at relating the chemical composition of ambient size-fractionated fine particles to their redox activity, determined by the dithiothreitol (DTT) assay.

Results

Size-fractionated (i.e. <0.15; <2.5 and 2.5 - 10 micro meters in diameter) ambient PM samples were collected from four different locations in the period from June 2003 to July 2005, and were chemically analyzed for elemental and organic carbon, ions, elements and trace metals and polycyclic aromatic hydrocarbons. The redox activity of the samples was evaluated by means of the dithiothreitol activity assay and was related to their chemical speciation by means of correlation analysis. Our analysis indicated a higher redox activity on a per PM mass basis for ultrafine (<0.15 micro meters) particles compared to those of larger sizes. The PM redox activity was highly correlated with the organic carbon (OC) content of PM as well as the mass fractions of species such as polycyclic aromatic hydrocarbons (PAH), and selected metals.

The results of this work demonstrate the utility of the DTT assay for quantitatively assessing the redox potential of airborne particulate matter from a wide range of sources. Studies to characterize the redox activity of PM from various sources throughout the Los Angeles basin are currently underway.

13B.2

Correlation of atmospheric ultrafine particle ferrous iron and mitochondrial toxicity. ANNE M. JOHANSEN, Stephanie L. Bryner, Eric L. Bullock, Justin M. Johnston, Carin Thomas, Josie K. Wells, Central Washington University.

Atmospheric ultrafine particles (UFPs, <0.1 micro-meter diameter) have been shown to induce oxidative stress in murine macrophages and bronchial epithelial cells and to disrupt mitochondrial membrane ultrastructure. To further understand the mechanisms that control UFP toxicity, ambient UFPs were collected in rural Washington State and exposed to bovine heart mitochondria. Reactive oxygen species production, lipid peroxidation and electron transport chain function were monitored throughout the experiments and results were compared with UFP ferrous iron concentrations as determined spectrophotometrically. Other analyses of UFP surface chemical composition include time of flight secondary ion mass spectroscopy (TOFSIMS) and x-ray photoelectron spectroscopy (XPS). Results indicate that mitochondrial electron transport chain inhibition correlates with ferrous iron concentrations in UFPs.

13B.3

Personal Exposures and Cardiopulmonary Responses of Children Riding Diesel Powered School Buses, A Pilot Study (Phase II). Xing Sheng, Sheela V Surisetty, Xiaodong Zhou, Bozhao Tan, Emily MacWilliams, Ryan LeBouf, Stephanie Schuckers, Alan Rossner, Andrea R. Ferro, PETER A. JAQUES, Clarkson University.

Children that ride the bus to school are continuously exposed to exhaust particles within the cab. Exposures can be highest while on the bus, and can persist during periods of idling. Time on buses in the morning and afternoon may range from several minutes to more than an hour. Acute exposures to diesel exhaust particles (DEP) may result in cardiovascular and respiratory symptoms. Children residing in close proximity to roadways have shown corresponding acute responses, such as pulmonary inflammation, exacerbations of asthma, and changes in pulmonary function. Inflammatory biomarkers, such as oxides of nitrogen can be elevated in asthmatic children exposed to DEP, and normal variability in heart rate may be compromised as a function of respiratory induced sinus arrhythmia. For example, asthmatic children have been shown to have a seasonal variation in HRV (Kazuma et al., 200, 2001). In this study, 20 healthy third and forth graders carried a hand held condensation particle counter (CPC) and Dustrak on the bus, or while walking to school, to the classroom and back home as a measure of continuous personal exposures. A LifeShirt, which measures continuous electrocardiogram (ECG), respiration, and accelerometry, was worn throughout the day. Five times, exhaled breath condensate (EBC) and exhaled nitric oxide (eNO) was collected as biomarkers of pulmonary inflammation: immediately before and after both commutes between school and home, and immediately before lunch. The bus route was tracked with a global positioning system. Pick-up and drop-off times reflect in-cab spikes of ultrafine particle concentrations of 100,000 particles/cc with slow decays to between 10,000 and 20,000, reflecting influence of DEP infiltration and its persistence corresponding to the frequency of pickups. Exposures to DEP and cardiopulmonary outcomes on a continuous and integrated basis will be compared and presented.

13B.4

Applying the thermal optical transmittance (TOT) method for estimating elemental carbon particle concentrations in biological samples. Rajiv Saxena, Jawaharlal Nehru University; Ian Gilmour, MICHAEL HAYS, U. S. Environmental Protection Agency.

Inhalation of submicrometer soot particles - also referred to as elemental [EC] or black carbon [BC] - poses serious human health risks. Yet, there is scant quantitative information about soot deposition and retention in lung tissue and its subsequent impact on health. To address this challenge, a novel bio-analytical technique for quantifying soot carbon deposits in biological samples was developed. This study investigates the technique's ability to isolate exogenous diesel engine particle EC from lung epithelial cell, alveolar macrophage, and tissue cultures using a series of chemical and physical pretreatment steps, and to subsequently measure the isolated particle EC concentration using thermal optical transmittance (TOT). We demonstrate how the sample pre-treatment steps developed permitted us to disregard the artifacts normally associated with the TOT laser-based char correction. We also focus on how the TOT response to different biological and particle matter sample matrices influenced method development. Results from applying the new technique showed that (i) diesel engine and control particle EC mass uptake by cultured lung epithelial cell lines and alveolar macrophages can be reproducibly estimated; (ii) biological uptake of particle EC is dose and time dependent; (iii) macrophages consume diesel engine and control particle EC with equal efficiency; (iv) and LA4 cells ingest substantially more diesel engine particle EC than control particles. The method's potential to evolve as a valuable research and diagnostic tool in health studies of fine particulate matter air pollution will be illustrated.

13B.5

Reduction of Fe^{3+} by Elemental Carbon and Its Implication in the Health Effects of Aerosols. BING GUO, Stephen Drake, Texas A&M University, College Station; Airat Khasanov, John Stevens, University of North Carolina, Asheville.

Fe^{3+} can be reduced to Fe^{2+} by elemental carbon in an aqueous solution. Atmospheric aerosols contain both Fe^{3+} and elemental carbon. When the particles are uptaken by a cell, the Fe^{3+} may become bioavailable and be reduced to Fe^{2+} by the elemental carbon. The Fe^{2+} can then inflict oxidative stress through the Fenton reaction. To assess the significance of this reaction in the health effects of aerosols, we measured the oxidation state of iron in laboratory-generated flame aerosols and NIST standard reference materials, using Mossbauer spectroscopy and a spectrophotometry method combined with acid extraction. In Fe-containing soot particles generated from a laboratory flame, the iron was mostly Fe^{3+}, with some metallic iron, as shown by the Mossbauer results. However, the iron extracted from the soot and the NIST SRMs all had a significant Fe^{2+} fraction. These results suggest that the reduction of Fe^{3+} to Fe^{2+} by elemental carbon is potentially important in the health effects of aerosols that contain both elements, and further research is needed to investigate this effect.

13B.6

The relationship between particle active surface area, number and respirable mass concentration in an automotive foundry and engine machining facility. WILLIAM A. HEITBRINK, University of Iowa; Douglas E. Evans, ;Bon Ki Ku, National Institute for Occupational Safety and Health; Andrew D. Maynard, Woodrow Wilson International Center for Scholars; Thomas M. Peters, University of Iowa; Thomas J. Slavin, International Truck and Engine.

Concentration mapping performed at a co-located automotive engine plant and foundry resulted in 891 simultaneous measurements of particle number, active surface area, and respirable mass concentrations. Aerosol concentrations were measured with a 15-channel optical particle counter (OPC) used to estimate respirable mass concentration, a condensation particle counter (CPC) used to obtain number concentration, and an instrument which used diffusion charging to measure the active surface area concentration. At selected locations, particle size distributions were characterized with the optical particle counter and an electrical low pressure impactor. Resulting data were analyzed to evaluate whether particle number concentration and respirable mass concentrations were predictive of surface area concentration. Statistical analyses demonstrated that active surface area concentration was essentially independent of respirable mass concentration. However, active surface area concentration was correlated with ultrafine particle number concentration. Correlation was stronger during the winter ($R2 = 0.6$ for both plants) than in the summer ($R2= 0.38$ and 0.36 for the foundry and engine plant respectively). The larger value of R2 was attributed to aerosol generated by direct-fire gas fired heaters used during winter. Generally, particles from the gas heaters were much smaller (number mode between 0.007 and 0.023 micrometers) than the aerosol generated by routine foundry and engine plant operations (number mode between 0.023 and 0.05 micrometers). Optically derived surface areas, for particles larger than 0.3 micrometers, were estimated from optical particle counter number measurements and converted into corresponding surface areas. During summer measurements, the ratio of optical surface area to active surface area had a geometric mean of 2.37 indicating that active surface area is not predicative of surface area derived with OPCs. Overall, active surface area concentration is a concentration metric that is distinct from particle number concentration and respirable mass concentration.

14B.1
Recent Advances in Mathematical Modeling of Lung Deposition of Inhaled Particles.
CHONG KIM, USEPA National Health and Environmental Effects Research Laboratory; Jung-Il Choi, North Carolina State University.

Dose of inhaled particles is an important factor for determining toxic effects of inhaled pollutant particles on one hand and efficacy of drug aerosols on the other hand. Over the last decades many mathematical models have been proposed with varying designs of lung morphology and computational scheme. Most models use Weibel's symmetric lung morphology for its simplicity, but asymmetric lung morphology and multi-lobe models are also used for more realistic and versatile modeling. Under steady state transport conditions deposition is calculated by sequential filtration method. Dynamic transport methods, however, is used to solve a set of time-variant transport equations allowing for investigating effects of varying inhalation patterns. Both deterministic and stochastic approaches have been used in model design. Stochastic approach is particularly useful for investigating effects of random variation of lung morphology and airflow pathways. Although mathematical models provide a convenient means of estimating the dose at varying inhalation conditions, all models use simplified lung morphology and idealistic flow conditions and as such, no mathematical models are considered complete. Models need continuing validation and adjustments and modifications as new experimental data become available. Recently, we have developed a versatile model capable of handling a variety of inhalation situations; different lung morphology (single path vs. multi-path), inhalation wave patterns, oro-nasal simultaneous breathing, multi-modal polydisperse aerosols, single vs. multiple breaths inhalation and whole vs. partial volume aerosol. The results show excellent agreement with experimental data available. The present model study will be discussed in comparison with other models that have been widely used. This is an abstract of a proposed presentation and does not necessarily reflect EPA policy.

14B.2
Airflow and Particle Deposition in the Central Airways of the Human Lung.
KAMBIZ NAZRIDOUST, Bahman Asgharian, CIIT at the Hamner Institutes for Health Sciences

Detailed solutions of airflow and particle transport are needed for accurate assessment of the deposition of airborne pollutants in the lung. While a number of studies have recently been conducted on this topic, the significance of lung physiology that presents itself through airflow boundary conditions has often been overlooked. In this work, airflow and particle deposition in the central airways of the human lung were studied. Nine common airways of the human lung were included, consisting of the trachea, main, lobar, and segmental bronchi connected as a branching network of cylindrical tubes with dimensions based on morphometric measurements. Airflow fields in this geometry were solved numerically for a 2-second inhalation under three different boundary conditions: (a) prescribed flow entering the trachea (inlet) with atmospheric pressure at the exit to distal airways (outlets), (b) atmospheric inlet pressure with prescribed outlet flows, and (c) variable pressure at the outlets induced by attaching expanding lobes to the distal end of each segmental bronchus. To evaluate particle deposition patterns, spherical particles of sizes from 1nm to 10μm were injected at the inlet to the trachea. A Lagrangian particle tracking method was used that included particle inertia, gravitational settling, and Brownian motion. The resulting airflow and deposition patterns were different among all cases, which indicated the importance of selecting the proper boundary conditions. These results could assist in identifying preferred deposition sites in the respiratory tract and thereby helping to set standards for minimizing exposure to environmental pollutants and also aiding in improved efficiency of drug delivery for inhalation therapy.

14B.3

The Comparison of Fiber Deposition in the Human Nasal Airway. WEI-CHUNG SU, Yung Sung Cheng, Lovelace Respiratory Research Institute.

Many occupational lung diseases are associated with exposure to aerosolized fibers in the workplace. The nasal airway is a critical route for fiber aerosol to enter the human respiratory tract. The efficiency of fiber deposition in the nasal airway could directly indicate the fraction of the inhaled fiber transported to the lower airway. In this research, a large number of fiber deposition experiments were conducted to compare the deposition characteristics of different fiber materials in the human nasal airway. Carbon, glass, and TiO_2 fibers were used as test materials. Deposition studies were carried out by delivering aerosolized fibers into a human nasal airway replica at constant human inspiratory flow rates ranging from rest state (15 l/min) to moderate exercise (43.5 l/min). The results showed that the deposition efficiency of the carbon fiber increases as the fiber impaction parameter increases. Many carbon fibers were found deposited in the anterior region of the nasal airway. In contrast, very few glass or TiO_2 fibers were found deposited in the nasal airway, and most the fibers were able to pass through the entire nasal airway. These results imply that the inhaled glass and TiO_2 fibers could enter the human lower airway relatively easily compared to carbon fiber.

14B.4

Transport and Deposition of Ellipsoidal Fiber in Human Tracheobronchial Tree. LIN TIAN, Goodarz Ahmadi, Philip K. Hopke, Clarkson University; Yung-Sung Cheng, Lovelace Respiratory Research Institute.

Elongated fibers are hazardous to human health due to the vulnerability of removing it from the respiratory system once inhaled. The high occurrence of bronchial carcinoma and lung cancer in certain occupational environment is linked to human exposure to these substances. Due to the anisotropy of fiber geometry, very limited work has been conducted to study its dynamical behavior in human airway passages. In this study, Lagrangian simulation of ellipsoidal fiber transport and deposition in human tracheobronchial tree is presented. The computational model accounts for the hydrodynamic drag and torque, shear induced lift, gravitational sedimentation and turbulence diffusion. The coupled translational and rotational motions of the fiber are resolved in the model formulation. The computational model provides a detailed description of the fiber's rotational characteristics during its motion. The influences of the fiber's diameter, aspect ratio, fiber inertia, and the intensity of shear field on fiber motion are analyzed. The airflow is assumed quasi-steady during inhalation process under light, moderate and intensive breathing conditions. The transport and deposition mechanisms of elongated particles in human lung are studied. The deposition patterns of ellipsoidal fibers in the human tracheobronchial tree are compared with the spherical particles', and their differences are discussed.

14B.5

Development of a two-phase drift flux model for the deposition of fine respiratory aerosols with comparisons to experimental results. P. WORTH LONGEST, Virginia Commonwealth University; Michael J. Oldham, University of California, Irvine (currently Philip Morris USA).

The transport and deposition of fine aerosols in the upper respiratory tract is governed by convective, diffusive, and inertial transport mechanisms. However, continuous two-phase models of submicron respiratory aerosols typically neglect particle inertia effects. The objective of this study is to develop and test a continuous two-phase model for simulating the regional and local deposition of dilute fine aerosols in an idealized bifurcation geometry. To evaluate the developed transport model, novel in vitro deposition results for 400 nm particles have been determined in a double bifurcation geometry of respiratory generations G3-G5. In addition, previously reported local deposition characteristics for 1 micrometer aerosols have also been considered. Computational two-phase models that have been evaluated include a standard chemical species (CS) mass fraction approximation, the drift flux (DF) approach to account for finite particle inertia, and a novel extension of the drift flux model to correct for near-wall particle velocity. The velocity correction model (DF-VC) applies a sub-grid near-wall Lagrangian solution to determine particle velocity at initial contact with the wall. Localized experimental results for the deposition of 400 nm particles indicated elevated deposition contours ranging from 1-5% of total deposition at the first bifurcation and 0.1-1% at the second. Of the computational models tested, the DF-VC method provided the best match to experimental deposition values on a regional and highly localized basis. Specifically, the DF-VC model matched regional experimental deposition results to within 10% for both 400 nm and 1 micrometer particles. Considering the local deposition of fine aerosols, the DF-VC model matched the experimentally determined elevated contours at the first and second bifurcations for both 400 nm and 1 micrometer particles. In conclusion, a drift flux particle transport model with near-wall velocity corrections appears to provide a highly effective solution for the deposition of fine respiratory aerosols.

14B.6

Micro- and Nano- Particle Deposition in Human Tracheobronchial Airways. ZHE ZHANG, Clement Kleinstreuer, North Carolina State University.

In total and regional lung deposition models, the particle deposition in each airway generation is typically computed with analytical equations which were developed for simple geometries, e.g., straight circular tubes or bent tubes. Clearly, the use of analytical formulas based on simple tube models for predicting deposition in local bronchial airway segments has to be carefully examined considering in light of the actual complex geometric features, realistic inlet conditions, and air-particle flow characteristics. In this study, inhalation and deposition of both micro- and nano-sized particles are numerically simulated for a human tracheobronchial airway model, starting from the trachea to generation G15 employing 3-D bifurcating airway geometries. Specifically, the conducting zone, in terms of G0-G15 is subdivided into five blocks, or levels, which are approximated by \triple-bifurcation units\ (TBUs). Thus, air-particle outflow conditions of the oral/nasal airways are adjusted as inlet conditions for G0-G3, which at their outlets are again adjusted to become inlet conditions for G3-G6, and so on.
Using a commercial finite-volume software with user-supplied programs and an in-house, parallelized particle trajectory code as solvers, validated solution approaches, i.e., Euler-Euler (for nano-particles) and Euler-Lagrange (for micro-particles), are employed with a low-Reynolds-number k-omega model for laminarto-turbulent airflow transitions. Validated computational results are obtained in terms of particle distributions and deposition patterns, deposition fractions, efficiencies as well as deposition enhancement factors. Both the essential (averaged) and variable (local) features of each indicator are analyzed \in series\ and \in parallel\ under different inspiratory flow conditions and compared to results obtained with analytical deposition formulas. Effects of branch orientation are discussed as well, and the deposition parameters are correlated with airway geometric features, particle characteristics and local flow rates.

Finally, the computer model predictions of total deposition in the human tracheobronchial airways are compared with: (i) the new correlation equations; (ii) available experimental measurements; and (iii) other mathematical modeling results. This study may provide useful information for both health assessments of inhaled toxic particulate matter as well as optimal drug aerosol delivery via inhalation.