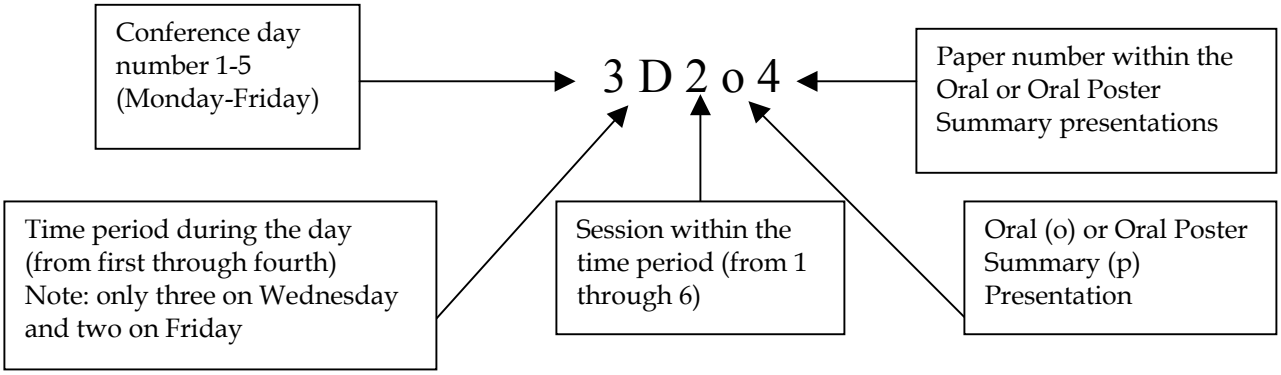
Indoor Air 2002

ABSTRACTS

Hal Levin, Editor
Gina Bendy, Assistant Editor

How to use this document

This volume contains abstracts for all the papers included in the Proceedings of Indoor Air 2002. To find a particular paper or session, it is useful to understand the paper identification system. The fictitious example below should help you find the abstracts for papers of interest.



Session Numbers and Titles

Session Number	*Session Title*	*Begins on page*
	Monday, July 1, 2002, 8:00 –9:30 am	
1A1	Plenary Lectures: Connections, Linkages	1
	Monday, July 1, 2002, 10:00 – 11:50 am	
1B1	Bioaerosols: I - Identification Methodology	1
1B2	Asthma and Respiratory Health I	3
1B3	Outdoor Pollutant Impacts on IAQ	6
1B4	Volatile Organic Compounds I	8
1B5	Indoor Air Flow and Air Distribution	10
1B6	Ventilation System Hygiene I - Emissions	12
	Monday, July 1, 2002, 1:00 – 2:50 pm	
1C1	Bioaerosols II - Sampling Methodology	14
1C2	Asthma and Respiratory Health II – Children	16
1C3	Particles and Dust I	18
1C4	Volatile Organic Compounds II	20
1C5	Radon	22
1C6	Ventilation System Hygiene II - Duct Cleaning and Assessment of Cleanliness	24
	Monday, July 1, 2002, 3:10 – 5:00 pm	
1D1	Bioaerosols III - Decontamination Approaches	26
1D2	Productivity and Economics	28
1D3	Particles and Dust II	30
1D4	Volatile Organic Compounds III: Soil gas as a source	32
1D5	Floor Coverings - Carpets vs. Hard Surfaces	34
1D6	Thermal & Energy Performance of Buildings and Building Systems	37
	Tuesday, July 2, 2002, 8:00 – 9:30 am	
2A1	Plenary Lectures: Environmental Tobacco Smoke, Comfort	39
	Tuesday, July 2, 2002, 10:00 – 11:50 am	
2B1	Bioaerosols IV - Prevention and Control Policy	40
2B2	Children's Environmental Health I - Exposure Assessment	41
2B3	Environmental Tobacco Smoke I	43
2B4	Emissions I - Field Investigations	45
2B5	Perceived Indoor Environmental Quality	47
2B6	Controlling Indoor Climate with HVAC systems	49
	Tuesday, July 2, 2002, 1:00 – 2:50 pm	
2C1	Bioaerosols V - Prevention and Control Treatments	51
2C2	Children's Environmental Health II - Exposures to Bioaerosols	54
2C3	Environmental Tobacco Smoke II	56
2C4	Emissions II - Laboratory Measurements	58
2C5	Health Effects of Pollutant Mixtures	60
2C6	Air Cleaning I	62

Session Number	*Begins Session Title*	*on page*
	Tuesday, July 2, 2002, 3:10 – 5:00 pm	
2D1	Bioaerosols VI - Prevention and Control by Drying or Ventilation	65
2D2	Children's Environmental Health III - School Policy	67
2D3	Natural and Hybrid Ventilation	68
2D4	Emissions III - Methods and Small Chamber Measurements	71
2D5	Research, Broad National Programs, Overviews	73
2D6	Air Cleaning II	75
	Wednesday, July 3, 9:30 – 11:00 am	
3A1	Plenary Lectures: Microbes, Asthma	77
	Wednesday, July 3, 11:20 am – 1:10 pm	
3B1	Bioaerosols VII - Health Effects in Moldy Buildings	78
3B2	Building Cleaning	80
3B3	Instruments and Methods	82
3B4	Emissions IV - Physical & Chemical Processes	84
3B5	IAQ Modeling	86
3B6	Building Ventilation	89
	Wednesday, July 3, 2:10 – 4:00 pm	
3C1	Children's Environmental Health IV - Health Effects of Bioaerosol Exposures	91
3C2	Sick Building Syndrome I - Building Factors	93
3C3	Indoor Air Chemistry and Pollutant-Surface Interactions	95
3C4	Emissions V - Control	98
3C5	Guidelines, Government programs, Policy	100
3C6	Modeling Studies of Thermal Comfort	102
	Thursday, July 4, 2002, 8:00 – 9:30 am	
4A1	Plenary Lectures: Sustainability, Global Impacts of IAQ	105
	Thursday, July 4, 2002, 10:00 – 11:50 am	
4B1	Bioaerosols VIII - Understanding & Controlling Building Moisture	106
4B2	Sick Building Syndrome II - Chemical Exposures	107
4B3	Semi-volatile Organic Compounds	109
4B4	Pollutant Transport and Mixing I	111
4B5	Novel Air Distribution	113
	Thursday, July 4, 2002, 1:00 – 2:50 pm	
4C1	Bioaerosols IX - Exposures in Workplaces	115
4C2	Sick Building Syndrome III	118
4C3	IAQ Surveys	120
4C4	Pollutant Transport and Mixing II	122
4C5	World Bank Symposium - Indoor Air Quality and Health in Developing Countries I	124
4C6	Thermal Comfort	126

Session Number	*Begins Session Title*	*on page*
	Thursday, July 4, 2002, 3:10 – 5:00 pm	
4D1	Bioaerosols X - Exposures in Residences	129
4D2	Special Indoor Environments	131
4D3	Pesticides	134
4D4	Life Cycle Perspectives: Health and Risk	136
4D5	World Bank Symposium - Indoor Air Quality and Health in Developing Countries II	138
4D6	Thermal Comfort and Perceived IEQ: Impacts of Ventilation System Type	141
	Friday, July 5, 2002, 8:00 – 9:50 am	
5A1	Bioaerosol: Featured Papers	144
5A2	Health: Featured Papers	144
5A3	Pollutants: Featured Papers	145
5A4	Thermal Comfort: Featured Papers	147
	Friday, July 5, 2002, 10:30 am – 12:30 pm	
5B1	Distinguished Lectures	148

Indoor Air 2002 Organizing Committee

Hal Levin, President
Lawrence Berkeley National Laboratory, and
Building Ecology Research Group, Santa Cruz

Joan M. Daisey, (1941-2000) Vice President
Lawrence Berkeley National Laboratory

William J. Fisk, Vice President
Lawrence Berkeley National Laboratory

William W Nazaroff, Vice President
University of California, Berkeley

Richard G. Sextro
Lawrence Berkeley National Laboratory

Kirk R. Smith
University of California, Berkeley

Jed M. Waldman
California Department of Health Services

Eugena Bendy, Conference Secretariat

1A1o1 Connections: particles, sensory offending filters, the "sink" effect and nasal pungency thresholds
CJ Weschler

Outdoor and indoor environments are profitably viewed as highly connected parts of a whole. Pull a thread outdoors and one or more threads moves indoors; indoor threads can, in turn, affect still other outdoor threads. Physical and chemical phenomena connect both settings. As an example of such connections, this paper examines different processes that correlate with an organic compound's saturation vapor pressure. This includes equilibrium partitioning to outdoor particles and indoor surfaces, as well as activation of trigeminal nerve receptors.

1A1o2 Linkages between outdoor and indoor air quality issues: pollutants and research problems crossing the threshold
J Mauderly

This paper reviews relationships between indoor and outdoor air quality research. Outdoor air quality has attracted greater regulatory and health research attention than indoor air quality, but the fields share many issues and pollutants. People spend more time indoors than outdoors, and pollutants cross the threshold in both directions. Recognition of indoor exposures to air pollutants of outdoor origin has grown during the past three decades, but there has been no comparable consideration of outdoor exposures to pollutants of indoor origin. Apportionment of total exposure to pollutants of both origins can improve our understanding of exposure-health relationships. It is plausible that the full range of health effects thought to be caused by outdoor air pollution is also caused by indoor pollution. Little attention has been paid in outdoor pollution research to understanding the effects of highly complex pollutant mixtures, which will also be important for indoor air pollution research.

1B1o1 Is your *Stachybotrys chartarum* a genuine *S. chartarum*?
D-W Li, R Haugland, S Vesper, and CS Yang

The fungus *Stachybotrys chartarum* is the type species of the genus *Stachybotrys*. Certain strains of the species are known to produce trichothecene mycotoxins. It is a cellulolytic saprophyte with worldwide distribution and frequently discovered in water-damaged buildings. Evidences of the detrimental effects on human health due to respiratory exposure to this fungus have been reported. However, morphological and mycotoxin profile studies showed that this species is not well delineated. This presentation reviews and summarizes data and evidences regarding the taxonomic status of the epithet *S. chartarum*.

1B1o2 The production and characterization of monoclonal antibodies to the fungus *Aspergillus* versicolor
D Schmechel, JP Simpson and DM Lewis

Fungal exposure measurements in indoor environments require accurate and precise monitoring methods. Such techniques may be based on monoclonal antibodies (MABS) and enzyme-linked immunosorbent assays (ELISA) and here we report the production of MABS to *Aspergillus* versicolor. Balb/c mice were immunized with the particulate fraction of homogenized spores and 46 MABS (35 IgM, 9 IgG3, 2 IgG1) were produced and tested for cross-reactivity against 55 fungal species. None of the MABS was found to be species-specific for A. versicolor. Several MABS strongly cross-reacted with most *Aspergillus* and *Penicillium species* except *A. fumigatus*, *P. islandicum*, *P. purpurogenum* and *P. variabile*. Several MABS also strongly cross-reacted with *Paecilomyces variotii* and *Eurotium amstelodami*, *E. rubrum*, and several *Cladosporium* and *Stachybotrys* species. The implications of our results for the production of species-specific MABS against fungi and the interpretation of diagnostic allergy tests are discussed.

1B1o3 Fungicidic and mitochondriotoxic bacilli frequent in water damaged buildings
M Andersson, R Mikkola, C Apetroaie, D Hoornstra, T Nieminen and M Salkinoja-Salonen

Bacillus colonies antagonistic to fungi were isolated from indoor materials from microbially damaged public buildings, including a hospital. Fungicidic colonies were identified as Bacillus cereus (14 strains) and B. amyloliquefaciens (18 strains). The strains were tested for toxicity towards mammalian cells using boar spermatozoa. The strains emitted heat stable substances that inhibited sperm motility and depolarized the mitochondria. Dusts and building materials contained 102-104 cfu g^{-1} and 103 -106 cfu g^{-1}, respectively, of mitochondriotoxic and fungisidic *Bacilli*. The substances emitted by the 14 *B. cereus* strains depolarized mitochondria and hyperpolarized the plasma membrane, similarly as cereulide, a known mitochondriotoxic depsipeptide emitted by B. cereus. MALDI TOF mass spectrograms of these toxins were identical to cereulide. The toxic agent(s) emitted by the 18 B. amyloliquefacies strains differed from cereulide by depolarizing both the mitochondria and the plasma membrane. Fungicidic mitochondriotoxic Bacilli may represent a health hazard in mouldy buildings

1B1o4 Method for measuring the size distribution of airborne rhinovirus
ML Russell, R Goth-Goldstein, MG Apte and WJ Fisk

About 50% of viral-induced respiratory illnesses are caused by the human rhinovirus (HRV). Measurements of the concentrations and sizes of bioaerosols are critical for research on building characteristics, aerosol transport, and mitigation measures. We developed a quantitative reverse transcription-coupled polymerase chain reaction (RT-PCR) assay for HRV and verified that this assay detects HRV in nasal lavage samples. A quantitation standard was used to determine a detection limit of 5 fg of HRV RNA with a linear range over 1000-fold. To measure the size distribution of HRV aerosols, volunteers with a head cold spent two hours in a ventilated research chamber. Airborne particles from the chamber were collected using an Andersen Six-Stage Cascade Impactor. Each stage of the impactor was analyzed by quantitative RT-PCR for HRV. For the first two volunteers with confirmed HRV infection, but with mild symptoms, we were unable to detect HRV on any stage of the impactor.

1B1p1 Storage stability of viable mould spores and endotoxin in house dust samples
A Koch, KJ Heilemann and W Bischof

To assess indoor pollution exposure, due to mould spores and endotoxin, it is often necessary to analyse stored samples. But present knowledge about disintegration of biological agents during storage is insufficient. Dust sample aliquots were distributed randomly over a range of storage temperatures. Mould spore concentrations were analysed over a period of two years and endotoxin over one year. Mould spores: A disintegration of 10 % of the initial concentration of mould spores was found at a storage temperature of 4 C and a storage time of two weeks. *Cladosporium* seems to be the storage time limiting component of the house dust samples. Lower storage temperatures have the advantage that the disintegration rates are lower than at 4 C. Endotoxin: The concentration in house dust is constant over a storage period of one year at room temperature and at –20 C.

1B1p2 PCR detection and diversity of *Streptomycetes* in water-damaged buildings
H Rintala, M Suutari and A Nevalainen

Streptomycetes are actinobacteria that are common in soil, but also found in buildings indicating moisture conditions favorable for both fungal and bacterial growth. In addition, *Streptomycetes* are potential causes of adverse health effects on human. Current detection methods are based on cultivation, which is time-consuming and detects only viable microbes. A Polymerase chain reaction (PCR) based method for the specific detection of *Streptomycetes* was developed. DNA isolated from two moisture damaged building materials served as a template for PCR amplification with two *Streptomyces*-specific primer pairs targeting the 16S rRNA gene. The PCR amplification products were sequenced and the sequences were analyzed. Both primer pairs were specific for *Streptomycetes* and several different sequence types were detected in both materials suggesting the presence of several species. The results of this work confirm the presence of streptomycetes in moisture-damaged buildings and provide a more quick and accurate method for their determination.

1B1p3 Characterisation of the microbial community in indoor environments: a chemical-analytical approach
A Sebastian and L Larsson

Gas chromatography/ion trap-tandem mass spectrometry (GC/MS/MS) was used to determine 3-hydroxy fatty acids with 10-18 carbon atoms, branched-chain fatty acids with 15 and 17 carbon atoms, muramic acid, and ergosterol in samples of settled house dust. These substances serve as chemical markers of Gram-negative bacterial lipopolysaccharide, Gram-positive bacteria, bacterial peptidoglycan, and fungal biomass, respectively. A hydrolysate of 13C-labelled algal cells was used as an internal standard for first three markers. These analyses required two dust samples, one for 3-OH fatty acids, non-hydroxylated fatty acids and muramic acid, and another for ergosterol. The method can be useful for quantifying and characterising microbial communities in environmental samples.

1B1p4 Using PCR to detect indoor fungi
BT Chen, J Keswani, G Zhou, and T Ong

This research attempts to develop a molecular bioassay that uses a Polymerase Chain Reaction (PCR) technique for detecting fungi commonly found in an indoor environment. During sample preparation, the method of bead-beating was identified as the most effective way for spore breakage and fungal DNA release. In the process of assay development, a fungal primer set, FF2/FR1, was designed and tested with DNA from human, rats, mice, bacteria, pollens and six fungal species. The results based on the crude extracts indicated that the primer set successfully amplified the fungal DNA without any cross-amplification with non-fungal DNA. In addition, higher amplification efficiencies were achieved using 20% nutrient media, rather than water, as the process solution. This PCR assay has a sensitivity of detecting low levels of fungi (2 fungal spores per reaction).

1B1p5 Comparison of genetic methods to optical methods in the identification and assessment of mold in the built environment - comparison of TAQMAN™ and microscopic analysis of *Cladosporium* spores retrieved from Zefon Air-o-Cell™ traces

D Kahane, D Sime, M McGinnis, S Vesper and RA Haugland

Recent advances in the isolation of genetic sequences of relevant water intrusion fungi by the EPA, combined with the development of probes and primers have allowed for the unequivocal quantitative and qualitative identification of fungi in selected matrices. In this pilot study, quantitative PCR was performed on previously analyzed Zefon traces to validate methods of extraction of deposited spores, and to compare relative quantitative agreement between the two methods of analysis. The pilot study employed the comparison of *Cladosporium* obtained from field generated Zefon samples. Thirty-two samples ranging in concentration from 128 to 104,000 spores per cubic meter were analyzed and compared for general agreement. General agreement was confirmed for the majority of samples analyzed. In all cases *Cladosporium* was detected by molecular methods. Where lack of agreement occurred, it appears that heavily loaded samples may yield lower optical spore trap concentrations as compared to molecular methods.

1B1p6 Environmental assay to measure cat flea (*Ctenophalides felis*) antigens in dust samples using polyclonal anitbodies

R Codina, R Diwadkar, R Lockey

Fleas are present indoors, causing allergic sensitization. The purpose of this study is to standardize an ELISA-inhibition assay to measure flea antigens in dust. Two rabbits were immunized with a flea extract, and the rabbit-antiserum and 30 dust samples from homes utilized to standardize the assay. The following parameters were studied: 1) specificity of the antiserum by ELISA-inhibition using the flea extract as a solid phase and other common extracts (cockroach, oak, a mold, cat, dog, mouse, and rat) as fluid phases; 2) sensitivity; 3) within- and between-run variations. Specificity studies indicate that the antiserum partially binds to other common extracts, but at high concentrations never achieved in house dust. The sensitivity of the assay is 100 ng/ml. Within-run and between-run variations are 13.7% and 30.5%, respectively. Flea antigens were present in 26 of 30 (86.6%) dust samples. A technique to measure flea antigens is available for environmental control studies.

1B1p7 Detection method of airborne *Mycobacterium tuberculosis* complex DNA in environment

C Vadrot, V Bex, A Mouilleseaux, R Bessard, AC Joly, F Squinazi, and JC Darbord

The incidence of tuberculosis among homeless people is 10 to 50 times higher than in the general population. To evaluate airborne environmental Mycobacterium tuberculosis in risk indoor areas, a non-invasive useful method was developed to study the spread of *Mycobacterium tuberculosis* particles in bioaerosols expelled from human respiratory tract. A semi-quantitative approach, based on a Polymerase Chain Reaction (PCR), was coupled with air sampling methods. The modified PCR method described allows to detect less than 95 CFU/m^3 in impinger air samples and less than 140 colony forming unit (CFU)/cm^2 in sedimentation samples. As an "in use" example, environmental samples were collected during one month in bus carrying homeless people, but *Mycobacterium tuberculosis* was not detected in collected samples, probably because the method was tested with a slight number of people.

1B1p8 GC-MS of microorganisms in the indoor environment: sampling strategies and structure-bioactivity relationships

L Larsson, B Szponar , A Sebastian, and D Milton

We present a strategy for applying gas chromatography- mass spectrometry (GC-MS) analysis to characterize the microbiology of indoor environments. Air-borne dust in the breathing zone collected both by sedimentation on horizontally placed plexiglass plates and by pumping air through polycarbonate filters showed similar patterns of ergosterol (fungal biomass marker) and 3-hydroxy fatty acids (3-OH FAs, endotoxin markers) thus indicating closely related microbial communities. The same markers were also detected in damp carpets regardless whether or not bacteria were revealed by culture. Convincing correlations have been demonstrated between marker contents, culture, and endotoxin potency of dust. Chemical marker analysis by GC-MS is a useful tool for characterizing the microbial community in indoor environments and has the advantage that it detects not only the minority of the microorganisms that is cultivable but also non-cultivable cells.

1B2o1 Work-related asthma symptoms correlate with environmental measures in a healthcare facility

JM Cox-Ganser, CY Rao and K Kreiss

In a healthcare facility with two hospitals (A and B), 6 non-latex asthma cases were diagnosed between 1998 and 2000 on hospital A's top floor, which had water incursions during this period. Hospital A had more work-related lower respiratory symptoms, with higher levels on the top floors. Univariate models showed positive associations between lower respiratory

symptoms and a number of air, and chair and floor dust analytes including; endotoxin, ultrafine particles, culturable fungi, spore counts, EPS-*Pen/Asp*, fungal glucans, latex allergen, and cat allergen. In multiple regression models work-related asthma symptoms were associated with subjective assessment for signs of water incursion, ultrafine particles in air, culturable *Penicillium*/*Aspergillus* in chair dust, and EPS-*Pen/Asp* in floor dust. This study contributes to the growing knowledge base in the field of indoor environmental research by showing that there were relationships between work-related asthma symptoms and our indices of exposure to biologicals and particles.

1B2o2 Are there any differences in indoor environment of asthmatics and non-asthmatics persons? A case/control study performed in Sweden and Estonia
M Frisk, A Raukas-Kivioja, H Andersson, H-M Loit , M Meren and G Stridh

Increased prevalence of asthma may be due to changes in our environment. This study included asthmatics (n=98) and non-asthmatics controls (n=97), matched by age, gender and type of accommodation. The aim was to investigate indoor environment regarding to risk factors for respiratory symptoms. Measurements of temperature, relative humidity, carbon dioxide, formaldehyde, nitrogen dioxide and dust mites were performed at house calls. Generally there was no difference between the Swedish groups. There was however, a significant higher level at the controls for internal moisture supply. In the Estonian investigation there was a tendency that the cases' home environment had higher levels of formaldehyde and dust mites. There was a significant higher level of relative humidity at the cases, compared with the controls. The highest level of nitrogen dioxide was found in Estonia. For individual asthmatics, both in Sweden and Estonia, we identified risk factors at levels that can increase respiratory symptoms.

1B2o3 Building-related risk factors and work-related lower respiratory symptoms in 80 office buildings
MJ Mendell, GM Naco, TG Wilcox, and WK Sieber

We assessed building-related risk factors for lower respiratory symptoms in office workers. The National Institute for Occupational Safety and Health in 1993 collected data during indoor environmental health investigations of workplaces. We used multivariate logistic regression analyses to assess relationships between lower respiratory symptoms in office workers and risk factors plausibly related to microbiologic contamination. Among 2,435 occupants in 80 office buildings, frequent, work-related multiple lower respiratory symptoms were strongly associated, in multivariate models, with two risk factors for microbiologic contamination: poor pan drainage under cooling coils and debris in outside air intake. Associations tended to be stronger among those with a history of physician-diagnosed asthma. These findings suggest that adverse lower respiratory health effects from indoor work environments, although unusual, may occur in relation to poorly designed or maintained ventilation systems, particularly among previously diagnosed asthmatics. These findings require confirmation in more representative buildings.

1B2o4 Lung function and symptoms in damp and mouldy buildings
NE Ebbehøj, AL Svensson, HW Meyer, and O Valbjørn

Irritative and respiratory symptoms are reported from people working or living in damp and mouldy buildings, but signs of pulmonary involvement have not yet been found. We studied 522 teachers working in 15 primary schools with various degrees of dampness and mould growth. Symptoms, spirometry, CO-diffusion, and bronchial challenge was compared to classification of dampness and mould growth in or outside classrooms. No symptoms, no results from spirometry, or any diffusion changes were related to any exposure measures, but the bronchial responsiveness was greater in dry schools and the frequency of cough larger in dry and mechanically ventilated schools. Exposure to damp and mouldy buildings at school level seems not to influence irritative or lung symptoms or lung function. A higher bronchial reactivity in dry buildings and a higher frequency of cough in mechanically ventilated buildings indicates a possible bronchiolar irritation, which might be related to dust rather than moulds.

1B2o5 Indoor air quality, dust mite allergens and asthma
SG Howieson, A Lawson, C McSharry, G Morris and E McKenzie

This controlled trial evaluated allergen and water vapour control measures on the level of house dust mite (HDM) *Der pI* allergen and indoor absolute humidity, concurrently with changes in lung function measured by am/pm peak flow and questionnaire indices of clinical well being in 54 subjects who completed the protocol. Allergen control involved protein de-naturing by steam cleaning and exposure was minimised by mattress encapsulation using microweave envelopes. Mechanical heat recovery ventilation units (MHRV) increased air change rates and lowered internal water vapour pressures during the winter months. Mean *Der pI* reservoirs in carpets and beds were reduced by over 94% and 86%, while the MHRV units reduced water vapour pressures in the active group by an average of 12%. Lung function measurement and health questionnaire data confirmed a significant clinical improvement in the active group compared with the control.

1B2p1 Acute respiratory effects of indoor pollutants in two general population samples living in a rural and in an urban area of Italy
M Simoni, L Carrozzi, S Baldacci, A Scognamiglio, A Angino, F Pistelli, F Di Pede andG Viegi

To investigate the effects of indoor pollution on acute respiratory symptoms, 421 houses in Po Delta rural and in Pisa urban areas were monitored for nitrogen dioxide (NO_2) and particulate matter <2.5µm ($PM_{2.5}$). Exposure indices were computed as products of pollutant concentration and exposure time. Mean levels resulted significantly higher in winter than in summer; $PM_{2.5}$ was significantly higher in presence of tobacco smoke, regardless of the area. In winter, acute respiratory illnesses were related to NO_2 and $PM_{2.5}$ in adults (O.R.=1.50, 95%CI 0.96-2.33; O.R.=1.70, 1.10-2.65, respectively); bronchitic/asthmatic symptoms only to $PM_{2.5}$ (O.R.=1,31, 1.10-1.55). In spite of slightly lower indoor level in the urban than in the rural area (NO_2=15 vs 22 ppb; $PM_{2.5}$=67 vs 76 µg/m^3), a significant 'urban' effect on the presence of acute symptoms was found: complex inter-relationships between indoor and outdoor pollution may explain this result.

1B2p2 Assessment of exposures to airborne toxic chemicals and the development or exacerbation of asthma in the general population
BE Barry, MP Chang, SB Bloom, NE Moss, and CB Bates

Numerous questions exist regarding possible connections between exposures to airborne toxic chemicals at levels likely to occur in the general population and the development or exacerbation of asthma. The goal of this project was to evaluate existing scientific knowledge concerning airborne toxic chemicals and asthma based on comprehensive searches of the medical and scientific literature since the 1960s. This evaluation included the 188 hazardous air pollutants listed in the 1990 Clean Air Act Amendments, other similar toxic chemicals, and certain mixtures. Using an online service to search multiple bibliographic databases simultaneously, the searches yielded journal articles, articles and abstracts from scientific meetings, and government reports. Selected studies were critically reviewed to determine the extent and quality of the scientific evidence for relationships between airborne toxic chemicals and asthma. The results of this evaluation provided valuable information for determining future research directions for this important public health issue.

1B2p3 Airway hypersensitivity related to incorrect polishing procedures
JV Bakke, A Askeland, O Bjørseth, N Iversen, B Martens and TB Aasen

Six employees were referred with airway hypersensitivity after exposure to cleaning and polishing procedures in a small hospital. The symptoms emerged gradually after introduction of so-called dry cleaning methods in 1992 and were attributed to the use of an ultra-high-speed polishing machine. The effects were confirmed by questionnaires and objective examinations. The polishing machine was equipped with a vacuum cleaner without HEPA-filter. The total dust pollution was reduced by this vacuum cleaner but the employees experienced continued aggravation and developed work-related hypersensitivity of the airways. Our studies showed that exposure to irritants and possible chemical sensitising agents had been extremely high due to incorrect and excessive polishing activity. The vacuum cleaner contributed to the pollution by distributing high concentrations of respirable particles into the indoor air carrying irritant, corrosive and possibly sensitising emissions. These exposures constitutes biologically plausible explanations for the observed effects.

1B2p4 Indoor air quality and health problems associated with damp floor coverings in an office building
A Tuomainen, M Seuri and A Sieppi

In an office of about 130 employees eight new cases of asthma were found during four years. In addition, the workers complained respiratory, conjunctival and nasal symptoms. Emissions indicating the degradation of plastic floor coverings (e.g. 2-ethyl-1-hexanol, 1-butanol) were found in the indoor air samples. In two working rooms, the plastic floor coverings, adhesives and the levelling layers were carefully removed. It was observed that the volatiles had been diffused into the concrete slabs. To eliminate the volatiles, the surface of the concrete was warmed up to remove the diffused VOCs from these areas. Thereafter, new low emitting surface materials were installed in these workrooms.

1B2p5 Quantified absorbable dusting powder (ADP) allergen aerosol generated from powdered natural rubber latex (NRL) gloves compromises pulmonary function in NRL sensitized individuals
MC Swanson, S Quirce, M Fernandez-Nieto, M de las Heras, J Cuesta and J Sastre

Lung function in many natural rubber latex (NRL) sensitized individuals is compromised by inhalation of NRL aeroallergens on absorbable dusting powder (ADP). We conducted quantified environmental challenge (QEC) studies on 30 asthmatic individuals who were exposed to NRL allergens at work and we monitored symptoms, pulmonary function and exposure duration up to 114 cumulative minutes. Latex aeroallergens were captured with a volumetric air sampler and polytetrafluoroethylene filters. The aeroallergens were then quantified by a competitive IgE immunoassay using sera from latex-sensitive individuals. Nineteen of the thirty individuals demonstrated an asthmatic response during the QEC. The

duration of exposures sufficient to elicit asthmatic responses (20%↓ FEV_1, forced expiratory volume / second) varied from 3 to 114 cumulative minutes at 3, 5, 15, 30 and 60 minute incremental exposures. Time weighted average NRL aeroallergen concentrations during QEC with subjects having asthmatic responses ranged from 199 to 1107 ng/m^3.

1B3o1 The use of light scattering data to estimate the contribution of indoor- and outdoor-generated particles to indoor air
R Allen, T Larson, and L-J S Liu

This paper applies a mass balance model to real-time light scattering data, collected at 85 residences in Seattle from October 1999 to May 2001, to estimate the contribution of indoor- and outdoor-generated particles to indoor air. The subject time-activity-location data are used to estimate personal exposure to indoor and outdoor particles. The particle infiltration efficiency averages 0.53±0.25 and differs significantly across dwelling types and by season. Despite having higher outdoor particle concentrations and spending more time outdoors, the pediatric subjects, as compared to elderly subjects, have no higher exposure to ambient particles.

1B3o2 Predicting indoor $PM_{2.5}$ of outdoor origin: testing a transient size-resolved model using intensive measurements from a residence
ML Fischer, MM Lunden, TL Thatcher, RG Sextro, and NJ Brown

We report tests of a model for indoor $PM_{2.5}$ of outdoor origin that incorporates physical mechanisms for time dependent transport, and size dependent penetration and deposition. This work was performed using information obtained from an intensive study of a house near Fresno, CA, USA. During the multi-week study covering two seasons, we measured particles in both indoor and outdoor air, with high temporal, chemical, and size resolution, and other variables that also affect transport and fate. Results suggest that 1) the model captures a significant fraction of the variation in meteorologically forced air infiltration rate, 2) the predicted indoor/outdoor $PM_{2.5}$ ratio is not consistent with the measured ratio unless a large (unphysical) deposition rate > 2 hr^{-1} is assumed, and 3) the differences between model and measurement in indoor $PM_{2.5}$ are likely due to loss of volatile ammonium-nitrate aerosol. We conclude that nitrate particle volitization must be included in the model formulation.

1B3o3 Prescribed burns in Colorado: impacts of mitigation measures on indoor air particulate matter
D Henderson, J Milford and S Miller

Wildfires and prescribed burns are receiving increasing attention as sources of fine particulate matter (PM). This study measures residential indoor and outdoor $PM_{2.5}$ concentrations that occur during a prescribed burn. This pilot-scale study solicited participant pairs of residences impacted by smoke from prescribed burns and monitored the $PM_{2.5}$ inside and outside of the houses. The effect of using an air cleaner on indoor $PM_{2.5}$ was measured. Appropriately sized air cleaners were provided to one of the two residences; occupants of both residences were asked to keep windows shut and minimize opening of exterior doors. Outside $PM_{2.5}$ concentrations were 22–38 mg/m^3 during the fire and 2.1– 3.0 µg/m^3 after the fire. During the fire, $PM_{2.5}$ was 2.2 µg/m^3 inside the house with the air cleaner compared to 22 µg/m^3 inside the other house. After the fire, background indoor levels were 3.5-6.9 µg/m^3. Indoor $PM_{2.5}$ decreased by 83% with the air cleaner operating.

1B3o4 Impact of the urban pollution on the indoor environment - experimental study on a mechanical ventilated dwelling
S Kirchner, AM Laurent, B Collignan, Y Le Moullec, O Ramalho, JG Villenave and JP Flori

This study aims to assess the transfer of outdoor air pollution into an unoccupied dwelling in Paris area with heavy traffic during winter and summer periods. CO, SO_2, NO, NO_2, O_3, BTEX, $PM_{2.5}$, black smoke index were monitored simultaneously indoors and outdoors. The indoor/outdoor relationships have been studied regarding ventilation strategies and indoor surface impact. Results show that a reduction of the average daily concentrations of NO (7-30%), SO_2 (33-41%), O_3 (80%), $PM_{2.5}$ (20%) and black smoke (20%) is observed indoors in reference to outdoors. The inert gas CO is integrally transferred. NO_2 shows no apparent difference between outdoor and indoor daily concentrations but the I/O ratio can be significantly above one in summer (high reactivity between NO and O_3). In the presence of sorbing material, indoor concentrations of SO_2, O_3 and NO_2 show a reduction of 75%, 90 % and 30% (in winter only for NO_2) compared to outdoors.

1B3o5 Accidental transportation releases of toxic chemicals in urban, residential and rural areas and protection by indoor environments
DJ Moschandreas and A Sierocki

Occupants of structures downwind of an accidental release of dense gas are likely to experience a larger exposure than a release of neutrally buoyant gas. This paper assesses the risk from accidents of transportation of chemical with instantaneous

release of dense gases and the potential protection that indoor structures provide to their occupants from such catastrophic releases. The accidental release of ammonia, chlorine, hydrogen chloride, hydrogen fluoride, hydrogen sulfide, ethylene dioxide, phosgene and sulfur dioxide is simulated. They are transported as liquefied pressurized gases and are extremely hazardous substances. The Exposure to Dense Gas from Accidental Releases (EDGAR) algorithm developed and used in this study simulates the dispersion of dense gas using the SLAB model and its impact on the indoor environment using a conventional indoor air mass balance model. Four of the eight gases should not be transported under nighttime conditions, and phosgene should be transported in less than 2000 lbs. quantities during daytime.

1B3p1 Factors affecting the concentration of outdoor particles indoors: existing data and data needs
TE McKone, TL Thatcher, WJ Fisk, RG Sextro, MD Sohn, WW Delp, and WJ Riley

Accurate characterization of particle concentrations indoors is critical to exposure assessments. It is estimated that indoor particle concentrations depend strongly on outdoor concentrations. For health scientists, knowledge of the factors that control the relationship of indoor particle concentrations to outdoor levels is particularly important. In this paper, we identify and evaluate sources of data for those factors that affect the transport to and concentration of outdoor particles indoors. To achieve this goal, we (i) identify and assemble relevant information on how particle behavior during air leakage, HVAC operation, and particle filtration effects indoor particle concentration; (ii) review and evaluate the assembled information to distinguish data that are directly relevant to specific estimates of particle transport from those that are only indirectly useful; and (iii) provide a synthesis of the currently available information on building air-leakage parameters and their effect on indoor particle matter concentrations.

1B3p2 Indoor and outdoor particle measurements in a street canyon in Copenhagen
P Wåhlin, F Palmgren, A Afshari, L Gunnarsen OJ Nielsen, M Bilde and J Kildesø

Particle number concentrations and size distributions were measured in the living room of an unoccupied apartment located in a street canyon in central Copenhagen, in the street, and at a nearby urban background station. A simple dispersion model was used to calculate the particle concentrations outside a window facing the street from where most of the ventilation air was supplied. The penetration efficiencies and the deposition rates were estimated using the concentration rate balance, ignoring indoor sources. The analysis indicates that the deposition rate of particles in the apartment is negligible for PM_{10} and for particles in the size range 100 - 700 nm. In the size range below 100 nm the deposition rate increases with decreasing particle diameter to a value of approximately 1 h^{-1} at 10 nm. The penetration efficiency shows a maximum of 60% at 100 nm. The penetration rate for PM_{10} was found to be 43%.

1B3p3 IAQ characterization in urban areas: indoor to outdoor correlation
N El-Hougeiri and M El-Fadel

This study investigates indoor and outdoor air quality at public locations. Indoor and outdoor air samples were collected and analyzed for the presence of TVOC, PM, CO, NO_2, and selected priority metals (Ca, Pb, Zn, Fe, Mn, Cu, and Br). Correlation between indoor and outdoor air quality were developed and compared for various constituents. Whereas priority metals concentrations were mostly below recommended standards, the concentrations of other constituents were affected by indoor and outdoor sources. The indoor-to-standard ratios for locations with indoor sources of pollution ranged between 1.5 and 3.5 compared to 0.6 to 2.78 for locations where the contribution of indoor sources is minimal. The effects of outdoor sources was reflected in terms of distance to the main road with an indoor-to-standard ratio of 1.02 to 11.8 for locations along the main road compared to 0.5 to 6.6 for locations at least one block away from the main road.

1B3p4 The impact of a ventilation system on air with different chemical composition: a study of the influence of ozone
J Fick, L Pommer, B Andersson andC Nilsson

Reactions among pollutants in the intake air can increase the concentrations of irritating and hazardous products in the indoor air and may lead to an increase of the sick building syn-drome (SBS). A short description of an experimental set-up that enables the studies of the impact of different settings of a full scale ventilation system on air with different ambient compositions is presented. Preliminary sampling using Tenax TA show that some reaction rates are increased in the experimental set-up, which could indicate that heterogenous reac-tions occur.

1B3p5 Characterisation of filter performance in relation to outdoor air quality
M Jamriska, L Morawska and T Nathanson

Airborne particle size distribution depends on the type of source from which the particles originate - filtration efficiency in turn, is dependent on particle size. Thus, in order to optimise filtration efficiency, it is important to gain knowledge on both: the size distribution of particles in the air to be filtered and the relationship between filtration efficiency and particle size. In

addition, assessment needs to be made about the expected concentration level of particles around the building envelope and its time variation. This information is necessary for selecting the most suitable type of filters for the characteristics of particles that dominate in outdoor air. The aims of this project were to: (i) establish typical scenarios in relation to outdoor air concentration and size distribution, and (ii) to assess filtration performance of tested air filters in ultra fine, submicrometer and $PM_{2.5}$ size ranges.

1B4o1 Residential VOC concentrations in a probability-based sample of households with children
JL Adgate, M Bollenbeck, LE Eberly, C Stroebel, ED Pellizzari, and K Sexton

As part of the MNCPES (Minnesota Children's Pesticide Exposure Study) we measured indoor volatile organic chemical (VOC) concentrations in a probability-based sample of 284 households with children. Six-day average concentrations for 10 common VOCs were obtained in both urban and non-urban residences. Households with smokers had significantly higher concentrations of benzene and styrene compared to non-smoking households. Households with an attached garage had significantly higher levels of benzene, chloroform, styrene, and m/p- and o-xylene than households without an attached garage. Non-urban residences had significantly higher concentrations of 1,1,1,-trichloroethane, styrene, and toluene compared to urban households, while urban households had significantly higher tetrachloroethylene concentrations than non-urban households. The weighted population results estimate the mean and variability in VOC concentrations for more than 45,000 households with children.

1B4o2 German environmental survey of children and teenagers 2000 (GerES IV): a representative population study including indoor pollutants
D Ullrich, C Gleue, C Krause, C Lusansky, R Nagel, C Schulz, and B Seifert

The German Environmental Surveys (GerES) are an integral part of an Environment and Health Surveillance System which includes measuring and documenting changes in the environment and in environmental health. GerES I - III which were conducted from 1985 on have mainly focussed on adults. Since children must be considered as a high-risk group with regard to adverse health effects caused by environmental factors, GerES IV will concentrate on children and adolescents (0 to 17 years). A pilot study for GerES IV has been started in February 2001 to be completed in March 2002. The study population of the pilot study includes about 560 children/teenagers with a sub collective of 112 for personal, indoor and outdoor air analysis. This presentation describes the study design and the field work and gives preliminary results for benzene, toluene and formaldehyde.

1B4o3 Exposure to volatile organic compounds and carbon monoxide of adult population in Milan (EXPOLIS study)
P Carrer, D Cavallo, S Fustinoni, Y Bruinen de Bruin, F Vercelli, F Visigalli and M Maroni

Exposure to CO, TVOCs, benzene, toluene and xylenes of 50 Milan office workers was studied during 48 consecutive hours (EXPOLIS study). Urine samples for the determination of benzene, toluene and xylenes concentrations were collected at the end of the monitored period. VOC indoor levels resulted higher than the outdoor levels due to the presence of indoor sources. VOC urine concentrations confirmed that active smoking is an important source of benzene exposure in office workers, and also passive smoking seems to be of some importance. Subjects were exposed to higher CO levels in indoor environments when they were exposed to ETS and/or gas cooking than without these factors, in particular in public environments (mean value more than 3 ppm). Subjects were exposed to high CO levels during commuting, in particular in cars (5.79 ppm).

1B4o4 Personal monitoring of benzene in Perth, Western Australia: results of a pilot trial
A Horton and F Murray

As part of a larger study co-ordinated in four cities by the Western Australian Department of Environmental Protection to characterise non- industrial personal exposure to Benzene, Toluene, Ethylbenzene and Xylene (BTEX), a pilot trial was conducted in Perth, Western Australia. The objectives of the pilot trial were to assess the use of passive samplers in the measurement of BTEX at a range of concentrations over 24 hours, evaluate the ease of use of a self administered questionnaire and a time/ activity diary, and to trial the logistics of conducting a personal exposure study. The results of the pilot trial indicated the questionnaire and diary effectively revealed potential lifestyle and behavioural factors that influence personal exposure to benzene. The BTEX samplers also proved effective in measuring a range of benzene concentrations, and did not limit the behaviours or activities of the participants whilst being worn.

1B4o5 Indoor-outdoor-personal exposure relationships of volatile organic compounds (VOCs) in Mexico City
PI Serrano-Trespalacios, JD Spengler and L Ryan

This study was designed to reveal the relationship between central-sites concentrations and personal exposures in Mexico City. Over a one-year period, 90 volunteers from 30 families living close to one of five central monitoring stations were measured

for personal exposures to volatile organic compounds (VOCs). Simultaneous indoor, outdoor home and central-site measurements were also taken. Dual packed thermal desorption tubes and acidified 2,4-dinitrophenylhydrazone cartridges were used for sampling VOCs and these were analyzed by GC/MS and HPLC respectively. Mean ambient concentrations of carbon tetrachloride, trichloroethene and tetrachloroethene were similar to personal exposures. Outdoor and indoor home concentrations of benzene, MTBE, xylenes, styrene and carbon tetrachloride were comparable and in turn they were about half of the mean personal exposures. Indoor concentrations of 1,3-butadiene, 1,1,1-trichloroethane, formaldehdye and carbon tetrachloride were comparable to personal exposures. For certain compounds, such as chloroform, 1,4-dichlorobenzene, formaldehyde and acetaldehyde, personal exposures were several times higher than ambient measurements.

1B4p1 Building related factors and inhabitants exposure to indoor air volatile organic compounds in the EXPOLIS-Helsinki study
T Tirkkonen, K Saarela, K Villberg, J Jurvelin and M Jantunen

The EXPOLIS study was a representative population based study of adult air pollution exposures in five European cities. Personal exposure to 30 different volatile organic compounds (VOCs) and their concentrations at home and at work was measured. In Helsinki, Finland, the sample population consisted of 201 randomly selected participants. Home indoor air VOCs of the participants were measured by active sampling on Tenax TA adsorbent and subsequent GC-FID/MSD analysis. Questionnaires and time activity diaries were used to collect information about participant's personal activities, commuting behavior, residence and workplace, e.t.c. Using basic statistical methods correlation between the target indoor air VOC concentrations and reported building related factors such as building age, building type and surface materials were analyzed. The analysis showed some indicative correlation between the subjects.

1B4p2 Volatile organic compounds and formaldehyde in bedrooms: results of a survey in Vienna, Austria
H-P Hutter, H Moshammer, P Wallner, B Damberger, P Tappler and M Kundi

Despite increasing public concern about indoor air pollution in Austria there are no systematic investigations of typical exposure to VOCs (volatile organic compounds) in households. Air samples were taken in bedrooms of 160 randomly selected households in five districts. Formaldehyde was measured by photometry, VOCs by adsorption on charcoal and solvent extraction. To determine individual volatile compounds GC/MS was used. Formaldehyde levels ranged from 0.007 to 0.092 ppm. All but six samples were below 0.05 ppm. Total VOC levels ranged from 11 to 6045 $\mu g/m^3$. Out of the samples 131 were below 300 $\mu g/m^3$ and 5 exceeded 1000 $\mu g/m^3$. Aliphatic compounds were the most prominent (14% of total VOC), followed by aldehydes (12%) and aromates (8%).

1B4p3 TVOC, formaldehyde and ammonia levels in two new blocks of flats
M Tuomainen and J Pirinen

Two new blocks of flats have been built for people with respiratory diseases. A number of points were taken into particular account during the design and construction of the buildings. For example, the project designers and builders were given training in prevention of problems with indoor air, only building materials that had been tested and found to have low emissions were used, and a supply/exhaust ventilation system and a central vacuum-cleaning system were installed. Total volatile organic compound (TVOC) levels and concentrations of formaldehyde and ammonia were measured in one apartment on each of the six floors of both buildings before occupants moved in and after seven months of occupancy. TVOC values had decreased after seven months to the target level of < 200 $\mu g/m^3$. Ammonia and formaldehyde values were at their respective target levels (<30 $\mu g/m^3$) immediately after the buildings were ready for occupancy in building A and in building B after seven months of occupancy

1B4p4 On the formaldehyde and VOCs concentration difference among houses in apartment house just after the construction
K Ikeda, M Shiotsu and S Sato

Measurement of formaldehyde and VOCs concentration 88 apartment houses for single persons which was build in September 2001 were conducted. We investigate the concentration difference among the houses.

1B4p5 IAQ assessment in two indoor swimming pools: swimmers' exposure to aerosols, VOC and carbonyl compounds
P Yli-Pirilä, T Raunemaa, A Hirvonen, P Pasanen, J Nuutinen and M Hyttinen

Swimmers' exposure to aerosols, VOCs and carbonyl compounds was assessed in two indoor swimming pools representing old and the latest technology. Swimming pools studied had different air and water quality attributes adjacent to the swimmers' inhalation space on the water surface. The aerosol concentrations were rather high ranging between 7600-9700 $1/cm^3$ with the

size distribution centered at 80-100 nm. The size distribution in the older pool was remarkably wide (30-400 nm), but was extremely narrow at the new pool. The distance of the pools from main traffic routes seemed to affect the aerosol size distribution. Trihalomethanes were the most abundant VOCs found in air samples, and they were present in the pool water at both of the pools. The concentrations of THMs in air were similar to the earlier studies.

1B4p6 A fugacity-based indoor residential pesticide fate model
DH Bennett, E J Furtaw, Jr. and TE McKone

Dermal and non-dietary pathways are potentially significant exposure pathways to pesticides used in residences. Exposure pathways include dermal contact with residues on surfaces, ingestion from hand- and object-to-mouth activities, and absorption of pesticides into food. A limited amount of data has been collected on pesticide concentrations in various residential compartments following an application. But models are needed to interpret this data and make predictions about other pesticides based on chemical properties. In this paper, we propose a mass-balance compartment model based on fugacity principles. We include air (both gas phase and aerosols), carpet, smooth flooring, and walls as model compartments. Pesticide concentrations on furniture and toys, and in food, are being added to the model as data becomes available. We determine the compartmental fugacity capacity and mass transfer-rate coefficient for wallboard as an example. We also present the framework and equations needed for a dynamic mass-balance model.

1B5o1 Assessing multi-zone airflow simulation software
DM Lorenzetti

Several standard multizone modeling programs, in order to improve their computational efficiency, make a number of simplifying assumptions. This paper examines how those assumptions reduce the solution times and memory use of the programs, but at the cost of restricting the models they can express. Applications where these restrictions may adversely affect the program's usefulness include: (1) natural ventilation, when buoyancy effects dominate mechanically-driven flow; (2) duct system design, when losses in T-junctions affect the system performance; and (3) control system design, when the dynamic transport of pollutants plays a significant role in the simulated system.

1B5o2 Computation of airflow in a displacement ventilation/chilled ceiling environment
L Jalil, AH Taki and DL Loveday

Displacement ventilation combined with a chilled ceiling system have been investigated by (Kofoed, 1994), (Almadari and Eagles, 1996), (Fitzner, 1996), (Taki et al., 1996), (Loveday, et al 1998) and (Rees, 2001). However, characterisation tests in such a combination system revealed that the use of a chilled ceiling with displacement ventilation could have a detrimental effect upon the displacement flow. This paper presents an assessment of the ability to model airflow and temperature distributions in such combination environments with a standard Computational Fluid Dynamics (CFD) code. Modelling is carried out over a range of typical office conditions for a range of heat loads and ceiling surface temperatures. It was found that the CFD code could be used to successfully predict the airflow in these environments by showing good agreement with those of earlier studies. The implications for the future design of displacement ventilation and chilled ceiling environment are discussed.

1B5o3 Study of indoor air quality air flow pattern in a room with floor heating
J Heng and Y Li

The airflow pattern, temperature field and indoor air quality in the room with floor heating are investigated in this paper. A numerical model predicting the air movement and heat transfer in this kind of room is built. The ventilation efficiency is adopted to indicate indoor air quality. The numerical simulation is used to calculate room air distribution at different locations of ventilation system Applied to tracer-gas techniques to the experiment program, a concentration decay of CO_2 is used to calculate ventilation efficiency. The result indicated that the floor heating method could produce approximately uniform air temperature along the perpendicular direction and the indoor air quality might be dominantly influenced by arrangement of inlet/outlet diffusers.

1B5o4 An examination of the influence of various effects on room air flow
Y Sun and TF Smith

The objective of this study is to examine the influence of various effects on the room air-flow and -temperature distributions. A computational fluid dynamics methodology combined with infrared thermography is used in this study. Simulations are conducted for different indoor and outdoor conditions to account for heating and cooling of the room. The effects of time varying velocity and temperature of the supply air on the response of the room are also examined. The results show that the diffuser characteristics play an important role in determining the room air flow patterns. For a certain discharge angle, due to

the Coanda effect, the air jets flow along the ceiling. The radiant exchange between the exterior window and interior surfaces causes a significant change in the window temperature. For the conditions considered, the room has a slow response to the supply air temperature change.

1B5p1 Tracer gas techniques for measurement of ventilation in multi-zone buildings - a review
H Stymne, M Sandberg and CA Boman2

There is a need for reliable and easy to use measurement techniques that can provide information about the ventilation and air distribution within buildings, in order to verify performance or trace possible reasons for insufficient air quality. Ventilation air is often unevenly distributed in a building. Recent development of tracer gas methods offer robust techniques, that can cope with such cases in all types of buildings, whether mechanically or naturally ventilated. The paper presents a review of available single tracer gas techniques with special emphasis on new developments for their use in incompletely mixed multi-zone objects. The described methods involve the "decay", "step-up", "homogeneous emission", "inlet pulse" and "homogeneous pulse" techniques.

1B5p2 The evaluation of multi-zone air flow pattern and ventilation rates with tracer gas methods in apartment house
DW Yoon, JY Sohn, SD Kim and HS Kim

The air change rates of ventilation system and inter-zone airflow rates were investigated at the apartment house. The fully developed ventilation systems are designed to supply outside air at each room and gas range hoods are installed with makeup air to remove pollutants effectively from cooking processes. The airflow patterns and air balance could be changed due to the different operating conditions of the ventilation systems. Detailed testing of multi-zone airflow and ventilation rates were conducted using two different types of tracer gas method. The results of measurement and airflow pattern were compared with those of the design strategies. Air changes per hour were ranged from 0.38~1.33[h^{-1}] at individual rooms. In the dining room and kitchen area, air change rates are varied from 4.69~10.59[h^{-1}] with various operating conditions of range hoods.

1B5p3 Influence of furniture layout and ventilation design on air quality and thermal comfort
KWD Cheong, E Djunaedy, KW Tham, SC Sekhar, NH Wong and MB Ullah

This paper describes the development of design charts to determine the influence of diffuser's layout on the air quality and thermal comfort conditions based on three diffuser's layouts and two office's layouts over a range of air change rates. Layout A, with a ceiling supply diffusers and a wall extract grille, was studied as the base case. The measurements of air velocity, temperature and pollutant were conducted in an environmental test facility. Computational Fluid Dynamics simulations were carried out to predict the air velocity, temperature and pollutant profiles. These simulated results were validated against the empirical measurements to ensure that the subsequent simulations for Layouts B and C were accurate. Air quality and thermal comfort parameters, such as pollutant removal efficiency, predicted mean vote and predicted percentage of dissatisfied, were computed for all layouts over a range of air change rates and presented in the form of design charts.

1B5p4 Experimental and numerical studies on air diffusion in a single office
S Grignaffini and A Vallati

In this paper the behavior of air flow generated from a set of multiple jets placed in an office with a surface area of 10 m^2 has been studied. The obtained results, through a preliminary numeric study, has been compared with those experimentally studied utilizing an experimental apparatus prepared in the laboratory of the Department of Technical Physics at "La Sapienza" University of Rome. Through such study, it was possible to assess the value of air velocity so as to verify the comfort conditions for the occupants at all points of the room. In particular, on a set of longitudinal and transverse planes to the injection axis, the values numerically extracted with those experimentally measured were compared, so as to verify the effective distribution of air in the occupied zone. The quality of obtained results authorizes to expand the use of the numerical approach during the planning of aeraulic plants designed to achieve high levels of environmental comfort.

1B5p5 The simulation of ventilation of entrance atrium in the Moravian library
J Katolicky, P Julinek and M Jicha

In the paper, based on MS Thesis by Julinek, 2001, the authors describe CFD modelling of the natural and mixed convection of air inside the entrance atrium of the Moravian library in Brno, Czech Republic. The eight-floor high atrium is formed with eight galleries, which are linked together with staircase, on one side and with glass wall on the other side. Inside the atrium, combination of natural and forced ventilation is used. The goal was to determine temperature and airflow fields, which are caused by interaction between air supply of fresh air and natural convection inside the entrance atrium. The problem was solved using a set of equations for incompressible, unsteady turbulent 3D flow with heat transfer and RNG k-ε model of turbulence. The set of equations was solved using the control volume method and CFD code Star-CD.

1B5p6 The impact of tracer gas mixing on airflow rate measurements in large commercial fan systems
FJ Offermann, JP Robertson, and TWebster

We characterized the mixing of tracer gas in three fan systems under two airflow rate conditions. The systems were configured for 100% outside air and SF_6 gas was injected at a constant rate into the supply air stream. The tracer gas concentrations were measured using a GC/ECD. The downstream tracer gas mixing was evaluated by collecting samples from a 12 point sampling grid. Errors were calculated as the difference between the local and the average concentration divided by the average concentration. The maximum errors associated with central point sampling ranged from 0% to 14% and averaged 5.5%, while the errors associated with the 12 single point sampling locations ranged from 3% to 27% and averaged 11.2 %. Averaging of two sequential single samples did not significantly reduce errors. High and low flow rate data suggest that tracer gas mixing times of less than 6 seconds may result in higher errors.

1B5p7 Development of a measurement method for air current by the use of balloons for gravity free
T Mori, T Konishi, S Ikenaga, M Enai and H Hayama

Designing an effective air-conditioning system for a large space requires precious planning by numerical simulation, and modification of the utilization of systems based on the measurement result. Recently, numerical analyses, such as CFD, have frequently been used in the planning of a thermal and air environment for a large space. Although simulation results are often used for planning, there have been few case in which the results of actual measurement of air currents inside a large space after completion of construction. One reason for this is the difficulty of measuring air currents in a large space. In this report, presents a simple method for visualizing air currents and for estimating distribution of air movements are presented.

1B5p8 Isothermal airflow in a gymnasium studied by numerical and full-scale experimental methods
X Ma, X Li, D Li, and C Dou

The computational fluid dynamics (CFD) and measurement technique were used to simulate and analyze the indoor airflow field in isothermal air-conditioned space of a gymnasium. Some different airflow patterns according to different supply air were simulated by numerical methods. The authors set up the full-scale experimental study of the airflow pattern of the same gymnasium. Measurement data and analysis of air distribution were presented in which the airflow is isothermal. Based on comparison with measured and simulated data, the airflow pattern of the sports hall is analyzed, and the results show that the numerical simulation in gymnasium and the similar large space buildings is qualitative correct because of the complicated boundary condition.

1B6o1 The impact of air pollution from used ventilation filters on human comfort and health
G Clausen, O Alm and PO Fanger

The comfort and health of 30 women was studied during 4 hours' exposure in an experimental room with either a used or a new filter present in the ventilation system. All other environmental parameters were kept constant. The presence of the used filter in the ventilation system had a significant adverse impact on several perceptions and symptoms, both immediately upon entering the office and throughout the exposure period. None of the perceptions or symptoms were better when the used filter was in the system.

1B6o2 Sensory source strength of used ventilation filters
G Clausen, O Alm and PO Fanger

A two-years old filter was placed in a ventilation system recirculating the air in an experimental space. Via glass tubes supplied with a small fan it was possible to extract air upstream and downstream of the filter to an adjacent room. A panel could thus perform sensory assessments of the air from the experimental space after facial exposure, without entering the space. Alternatively, the panel could enter the space and evaluate the air quality after full exposure to the air. The sensory pollution load of the filter determined from full exposure was approximately 7 times lower than when determined after facial exposure. Even with the lower values of the sensory pollution load found in the present study, model predictions of the perceived air quality in a typical office show that used filters may still be important sources of indoor air pollution.

1B6o3 Operation time of the ventilation system as a cause of microbial contamination of the infiltration filter
H Kokotti, L Kujanpää, R Halonen, T Keskikuru and M Reiman

Two identical ventilation systems having glass fiber bag filters as fine filters (EU7) without pre-filters located in the same building, were monitored for three and four months during winter and spring. One ventilation system (A) operated continuously at full capacity during days and nights and the other (B) operated periodically during days from 6 a.m. to 9 p.m.

The relative humidity and temperature were measured continuously in outdoor air and in fine-filter bags. Air, surface and filter material samples were taken to evaluate the extent of microbial contamination with viable fungi and bacteria. The conditions of filter units were dryer and warmer in the system B than in the system A. Filter and air of the system A with higher relative humidity were less contaminated by microbes and the contamination was more evenly spread in the filter than in the system B.

1B6o4 Oil residues on HVAC components
V Asikainen, M Björkroth, R Holopainen and P Pasanen

This paper is the review article of earlier published studies. A sampling and analysis method has been developed for oil residues on HVAC-components. Sampling was made by filter contact method and analysis was carried out by infrared spectroscopy. Amount of oil residues varied considerably both on used sheet metal and manufactured HVAC-components. The mean amounts of oil residues on surfaces of components varied between <10 mg/m² to 700 mg/m². A significant ($P<0.0005$) linear correlation was found between odour intensity and cumulative amount of oil residues. Cleaning of oil residues from the duct surfaces with typical cleaning methods is also very difficult. Because of that HVAC-components should be manufactured so that the inner surfaces of components are free of oil residues. In Finland, the cleanliness classification of HVAC-components is partly based on the oil residues. For example, for spiral seamed HVAC-ducts the recommended limit value is set to be 50 mg/m².

1B6o5 Macro- and micro-evaluation of air intake - a demonstration of the need for more optimal tools
F Frydenlund, EN Haugen, C Ahlén, I Bryn, H Davidsen, SO Hanssen and GT Møgedal

This paper describes systematic parallel studies of hygiene and microbiological status of air intakes and ventilation systems. Our approach was to perform separate microbiological and hygienic studies and to find a common evaluation for the results from both methods. The aim was to identify potential risk ventilation systems for indoor air contamination. From these 30 ventilation systems, 24 were potential risk systems identified from the hygienic method and 12 from the microbiological method. We found a clear relation between the microbiologic and the hygienic conditions. A good hygienic factor compares to a good microbial factor; i.e., dry and clean intakes are less likely to be microbially contaminated. Bad hygienic factors were seen both with and without microbiological contamination, but the method seems to identify potential problems, which could be confirmed by a microbiological study. Ventilation systems, without such confirmation, may avoid future problems if they improve satisfactorily the hygienic factor.

1B6p1 VOC emissions from dusty air filters
M Hyttinen, P Pasanen, and P Kalliokoski

Emissions from dust collected on pre- and main ventilation filters were examined by using thermodesorption technique (TCT-GC-MS). The elemental composition of the dust samples was determined with a CHN elemental and a thermal-optical carbon analyzer. Desorption experiments were made at 70 C and 150 C. Aromatic hydrocarbons were the main emission products at 70 C. Some emissions of aldehydes were also detected. At 150 C, main emitted compounds included carboxylic acids, alcohols, aldehydes, terpenes, phthalates, and aromatic hydrocarbons. Filter samples were collected in late winter, and, therefore contained a lot of fresh particles derived from traffic, combustion, and power production. In earlier studies, the intensity of odors from filters was found to be strongest in the winter. Thus, aromatic compounds may contribute to the odor formation. Contents of carbon and elemental nitrogen were 7-40% and 1-2%, respectively. The carbon content was highest in the dust, which was collected from a pre-filter.

1B6p2 Measurement of sensory load from ventilation systems by trained and untrained panels
M Björkroth and E Kukkonen

A new cleanliness labelling system of air-handling components was introduced in Finland 2001. It is largely based on the results of the international AIRLESS research project and the Finnish Clean Ventilation Systems (PTIV) project. In these projects all experiments were carried out using a trained sensory panel, but this method was considered to be too expensive for simple labeling tests. This paper describes experiments carried out by Helsinki University of Technology in order to study the overall accuracy and comparability of both trained and untrained both panels, to determine the required size of the untrained panel, and to determine the limit value (mean vote) corresponding to an acceptable air quality. Based on the results, an acceptable accuracy is achieved by using an untrained panel of 15 persons. The risk connected with the use of such a small, untrained panel was calculated to be 10 % and it is equal to both parties.

1B6p3 Selection of lubricant for manufacture of HVAC components
V Asikainen, M Hyttinen, R Lappalainen and P Pasanen

To minimise emissions from HVAC systems to supply air clean and low emission HVAC components should be used. This supports use of manufacturing techniques, which utilise low emission lubricants or lubricants that leave only minor amount of residues on the surface. In this study the lubrication, evaporation and odour emission properties of fourteen lubricants were studied. Lubrication properties were studied by pin-on disk method. Evaporation of the volatile compounds from the lubricants on sheet metal was followed for 91 weeks. Odour emissions of four lubricants were analysed by olfactometer with untrained panel of 41-49 members. The remarkable variations were found between the properties of lubricants. The evaporated fraction of the lubricants varied from 0 to 90%. Friction coefficients varied four-fold and threshold values of odour showed eight-fold differences between lubricants. According to the different properties of lubricants, the selection of lubricant is important to improve hygiene of the components.

1B6p4 Microbial measurements at ventilation systems supply vents
M Hinker

The number of cfu (colony forming units) in the air at outlets of ventilation systems has been compared to the incoming fresh air. In a first step 75 outlets of ventilation systems in 12 different companies were checked by taking 4 parallel samples with two different culture media, at the same time taking samples from the corresponding fresh air. At one of the 75 sampling places significantly elevated numbers of fungi were detected, with one penicillium species dominating. Consequently this sampling place was checked regularly for a period of 14 months to get information about fungal contamination over a longer period. In conclusion our results provide further evidence that microbial measurements of ventilation-air could be used as an indicator for the hygienic conditions of mechanical ventilation systems.

1B6p5 In-situ testing of ventilation air intake louvers subjected to snow
O Kristiansen, SO Hanssen and J Stang

The ventilation air intake is the first line of defence against an unfavourable outdoor climate. Previous studies have shown that it often is a neglected component which can result in unwanted intrusion of rain and snow. In Norway and other areas with similar climatic conditions, snow is a major problem. In order to study the performance of louvers available on the market with respect to snow penetration, we have tested 10 louvers of 4 types in an in-situ test rig. Each louver was fitted into an opening of 0.6 m x 0.6 m, and the air speed through the gross area was 1.7 m/s. The penetrated snow was collected in bag type air filters downstream of each louver. Increase in pressure drop between the front of the louver and downstream of the snow collection filter was used as a measure on snow penetration in order to rank the louvers. A louver with a complex flow profile and an electric heating cable performed significantly better than ordinary louvers

1C1o1 Airborne microorganism collection by a new electrostatic precipitator
K Willeke, S Lee, G Mainelis, A Adhikari, T Reponen, SA Grinshpun, SH Cho, H Wang and M Trunov

Many aerobiological measurements and the protection of governmental/military establishments from bioterrorism require the development of new bioaerosol collectors that can be operated efficiently at low power. We have developed and evaluated a new bioaerosol sampler in which the microorganisms are collected by electrostatic means. An ionizer charges the incoming microorganisms, if they carry insufficient charge for efficient collection in the device. The microorganisms are collected on two square agar plates placed along the flow axis. Laboratory experiments have shown that bacterial cells and spores are generally collected more efficiently than inert particles. We attribute this difference to the natural negative charge contained in the cell membranes of microorganisms. The results of field measurements parallel those obtained through laboratory experiments.

1C1o2 Airborne allergen exposure: measurements with a novel ion charging device
NJ Custis, JA Woodfolk, JW Vaughan, and TAE Platts-Mills

Current techniques for measuring allergen exposure involve assaying samples of dust from reservoirs in the home. However, it is clear that airborne allergen is more relevant to lung exposure, thus there is a need for a technique of measuring airborne allergen that can be applied easily to homes. Using a device that positively charges airborne particles we measured airborne allergens in homes with or without animals. This device has two major advantages; i.) it creates airflow silently and ii.) it collects allergen on negatively charged plates, which are easily wiped with filter papers to provide an accurate measurement of allergen collected. Quantities of cat allergen airborne imply that patients in a house with a cat can inhale up to 100 ng/day. By contrast, mite allergen was only detectable during disturbance and the calculated quantity inhaled was ~1-5% of the quantity of cat allergen.

1C1o3 ORM (optimal removing of moisture from water damaged building constructions) - MVOCs
O-A Braathen, N Schmidbauer, C Lunder, P Blom and J Mattsson

The Norwegian ORM project was focussed on establishing optimal procedures for removing moisture from damaged constructions with as low possibility for microbiological activity as possible. Different floor coverings were water damaged and contaminated with a mixture of spores and then dried in different ways. During the drying process, the emissions of MVOCs were measured and the moulds were studied. In this paper, results of the measurements of MVOC-emissions from a parquet sample dried in a natural way, are presented. The measurements showed different emission profiles during the 85 days drying process for volatile and semi-volatile MVOC-compounds. The emission of semi-volatile MVOCs was detectable for much longer periods than the emission of volatile compounds. The results of the study show that MVOC-investigations can be used as a non-destructive way to indicate the presence of active moulds inside building constructions and thus help the practitioners to choose the best remediation strategy.

1C1o4 Gas chromatography-mass spectrometry/solid phase micro-extraction: a new technique for the identification of MVOCs from moldy building materials
L Wady, A Bunte, C Pehrson and L Larsson

Gas chromatography-mass spectrometry/solid phase microextraction (GC-MS/SPME) was applied to identify microbial volatile organic compounds (MVOCs). Aqueous reference mixtures of commonly reported MVOCs were studied. Building materials (gypsum board papers, mineral wool, and masonite) and cultivated molds (*Aspergillus penicillioides*, *Stachybotrys chartarum*, and *Chaetomium globosum*) were investigated using both electron impact and chemical ionization. Three different SPME fibers (65 mm PDMS-DVB, 75 mm Carboxen-PDMS, and 70 mm Carbowax-DVB stableflex) designed for automated injection were used. The 70 mm Carbowax-DVB stableflex fiber showed better performance than the other fibers. Several MVOCs were identified in the building materials and the fungal spp. Interestingly, methyl benzoate was identified in both *S. chartarum* and *A. penicillioides* cultures and in the mould-infested materials. SPME combined with GC-MS is a useful method to determine MVOCs emitted from moldy building materials.

1C1o5 Air and surface sampling measurements of fungal contaminants in indoor environments
P Cruz Perez, JL Henry, AK Klima-Comba and LD Stetzenbach

Research was conducted to evaluate surface sampling in conjunction with air sampling for the detection of fungi in indoor environments. Residential units in a condominium complex with reported water intrusion problems were selected for sampling. Air sampling for culturable fungi was conducted with an Andersen impactor sampler supplied with malt extract agar amended with chloramphenicol (MEAC). Surface samples consisted of carpet dust and swabs. To improve the isolation of *Stachybotrys spp*., surface samples were cultured using a cellulose-based agar, and replicate MEAC plates were incubated at 45 C for the isolation of *Aspergillus fumigatus*. Tape impression samples were also collected and viewed with light microscopy. The results of this study demonstrated that air sampling alone did not always indicate the presence of a fungal contamination problem and that the use of surface sampling in conjunction with air sampling enhances the detection of fungal contaminants in indoor environments.

1C1p1 The dustfall collector - a simple way to measure exposure to microorganisms
H Würtz

A new developed dustfall collector has been investigated which collects airborne dust by sedimentation. The dustfall collector was placed at least 1.5 m above the floor. It was made of cardboard and the collecting surface was covered with aluminium foil; a chicken wire covered the box. After 140 days the dust was collected using the VacuMark sampler. Bioaerosols were sampled three times during a school day with one week intervals using IOM samplers. Airborne total particulate mater (TPM) was sampled on closed faced Millipore cassettes. Floor dust was sampled at the end of a school day using an HVS-3-sampler. Dust collected by the three sampling methods was weighed and analysed for culturable fungi.

1C1p2 Microbial VOC (MVOCs) in buildings, their properties and potential use
K Wilkins

The scope and occurrence of MVOC, their physiological effects and possible relevance for symptoms in occupants in moisture damaged buildings is reviewed. The general conclusion is that MVOC have not been demonstrated to cause the observed symptoms. Physiological effects have been demonstrated in a cell bioassay, however. The potential use of MVOC to detect microbial growth is discussed. Practical difficulties in the analysis and interpretation of MVOC measurements are described. A relationship between MVOC concentration and microbial growth (biomass or affected area) is unavailable and is probably unattainable.

1C1p3 Volatile metabolites from microorganisms grown on building materials
A-S Claeson, J-O Levin, G Blomquist and A-L Sunesson

Microorganisms are able to produce a variety of volatile organic compounds. Microbially produced substances are one possible explanation of odour problems and negative health effects in buildings affected by microbial growth. In this study emissions of volatile compounds from mixed cultures of five fungi grown on three different humid building materials were investigated. Six different sampling methods were used, to be able to collect both non-reactive volatile organic compounds and reactive compounds such as volatile amines, aldehydes and carboxylic acids. Analysis was performed using gas chromatography, high-pressure liquid chromatography and ion chromatography. Mass spectrometry was used for identification of compounds. The main microbially produced metabolites found on pinewood were ketones and alcohols. Compounds such as nitromethane and dimethoxymethane were found on particleboard. On all materials the emission of aldehydes decreased during microbial growth. No amines or carboxylic acids were identified.

1C1p4 Bioaerosols - where should one measure them in a room ?
MGLC Loomans, PM Bluyssen and CCM Ringlever-Klaassen

Bioaerosol measurements are performed to assess the exposure to micro-organisms in a room. Literature however reveals little consensus on the procedure with which measurements are made. Comparison of individual results therefore remains difficult. This paper tries to initiate the development of a procedure for performing bioaerosol measurements. As a first step the measurement location in a room is considered. Through bioaerosol measurement and CFD modeling knowledge is gained on the bioaerosol contaminant distribution in a room and the parameters that play an important role. From these results an onset is given for a procedure to determine the measurement location. The indoor air flow pattern and the (possible) source location are the main parameters in this context. The procedure is set up more broadly and includes for example a questionnaire. It is the intention to elaborate on the development of this procedure in future projects.

1C1p5 Microbial flora and concentrations on material surface determined by the dilution and direct plating
M Reiman, L Kujanpää and R Kujanpää

Microbial growth of the building is a common cause of indoor air complaints. In a hospital building, workers suffered from symptoms suggesting mold exposure. Twenty parallel surface samples were taken for direct and dilution plating from vertical wall surfaces in patient rooms with no mold damages in order to evaluate the influence of possible microbial source in adjacent bathrooms. By dilution plating, 7 samples out of 20 showed no microbial growth, but by direct plating, microbes were detected in all the samples. Many fungal species or genera were more frequently found, and fungal spore estimates were higher by direct plating than by dilution plating. Direct plating confirmed the migration of spores from severely damaged bathrooms to patient rooms more sensitively than dilution plating. Direct plating from surfaces is useful tool for making retrospectively a long-term estimate of the concentration of airborne microbes and the migration of microbes from nearby sources.

1C1p6 A field comparison of methods for enumerating airborne fungal bioaerosols
KS Lee, W Black, M Brauer, G Stephens, K Teschke, J Hsieh and K Bartlett

A field comparison of three microbial samplers, the Andersen N6 single stage (N6), the Surface Air System 90 (SAS) and the Reuter Centrifugal Sampler (RCS), using malt extract agar (MEA) media, was conducted at 50 sites in public buildings in British Columbia, Canada. There were significant differences between sampling devices. Overall geometric mean concentrations were ranked in the following order for indoor: RCS>N6>SAS and for outdoor: N6=RCS>SAS. Naturally ventilated buildings also had higher concentrations of fungal aerosols compared to mechanically ventilated buildings. The results from this study indicate that concentration data are dependent on the methods used for assessment, and introduce additional variability in exposure assessment studies.

1C2o1 Housing characteristics and children's respiratory health
JD Spengler, J Jaakkola, H Parise, V Kislitsin, N Lebedeva, S Kuzmin, A Kosheleva, B Katsnelson and L Privalova

A health and housing questionnaire was administered to the parents of 5,951 elementary school children as part of an air pollution cross-sectional study in nine Russian cities. Information about the child's respiratory and medical history, along with questions about home characteristics, social status of the family, allergies and other relevant factors were collected. Logistic regression analysis examined the relationship between respiratory health conditions and housing factors. The health risks (expressed as relative odds) were controlled for gender, age, parental history of asthma or chronic lung disease, and pre-term birth. Respiratory allergy and eye irritation increased in association with traffic on street adjacent to apartment. A consistent positive association between all health conditions and two indicators of cigarette smoke exposure (lifetime exposure ever and maternal smoking during pregnancy) was observed but reached significance only for bronchitis ever and eye irritation. Water damage and molds were strongly associated with all health outcomes.

1C2o2 Moisture damage at home and childhood asthma - a case-control study
A Hyvärinen, J Pekkanen, J Halla-aho, T Husman, M Korppi and A Nevalainen

The aim of the study was to determine the association between moisture damage and indoor air microbial exposure and development of asthma among young children (1-7 yrs). The study consisted of 113 children with newly-diagnosed asthma and 217 controls. The homes were examined with a standardized protocol by civil engineers. Indoor air sampling of viable microbes was done with six-stage impactors in a subsample of 54 samples of 27 homes. Results suggest that a moisture damage in the living quarters of the home may increase the risk of asthma in early childhood.

1C2o3 Indoor air quality in houses of asthmatic and non-asthmatic children
K Rumchev, J Spickett, M Phillips and S Stick

In order to evaluate indoor air quality in houses of asthmatic and non-asthmatic children, a population based case-control study was carried out in Perth, Western Australia. Measurements of indoor formaldehyde, volatile organic compounds, particulate matter with size less then 10 microns in diameter (PM_{10}), and house dust mite allergens exposure, were made on two occasions, winter and summer, over a one year period. Comparison of means for the two groups, asthmatic and non-asthmatic children, showed a tendency for significantly higher levels of indoor pollutants concentrations among cases compared to those in controls. A significant difference with season in the concentrations of formaldehyde, volatile organic compounds and allergen levels of house dust mite has been also identified. Indoor air pollutants may contribute to asthma in young children.

1C2o4 Differences in possible risk factors for allergic diseases between children living on farms and other children
CG Bornehag, J Sundell, L Hägerhed and M Bengtsson

Several recent studies have shown that children living on a farm with animals report fewer allergic symptoms than do other children. The aim of this study was to investigate differences in lifestyle factors and dwelling characteristics between farming and non-farming children. The study is part of an investigation on the impact of the indoor environment on asthma and allergy in pre-school children in Sweden. It was performed as a cross-sectional questionnaire study including 14,077 children aged 1-6 years in the county of Värmland. The study showed that farming life was associated with less allergic symptoms among children. Furthermore, the investigation identified significant differences between farmers and non-farmers concerning background and lifestyle factors as well as building characteristics. Such differences could be of interest when searching for causal factors in the etiology of allergy, which will be investigated in a forthcoming step of the DBH-study.

1C2o5 Asthma, asthma-like symptoms and allergies in Russian school children in relation to new surface materials in the home
JJK Jaakkola, JD Spengler, H Parise, V Kislitsin and NV Lebedeva

We hypothesized that children's respiratory conditions are related to recent renovation, especially recently installed synthetic materials and painting. We conducted a cross-sectional study of 5951 elementary school children in 9 Russian cities. Information about the child's health and environmental and other relevant factors were collected in a teacher-administered interview through schools. Logistic regression analysis examined the relationship between respiratory health symptoms and conditions (asthma, asthma-like symptoms, persistent cough, persistent phlegm, wheezing, persistent wheezing, respiratory infection, any allergy and respiratory allergy) and emissions from surface materials as indicated by recent renovations (linoleum, new furniture, painting, particleboard, suspended ceiling, synthetic carpet and wall covering both in the past 12 months and earlier for each material). Consistently with our hypothesis the risk of asthma, asthma-like and other chronic respiratory symptoms as well as of allergic diseases were related to presence of materials with potential chemical emissions.

1C2p1 Respiratory infections among children in moisture damaged schools
T Husman, T Meklin, A Vepsäläinen, M Vahteristo, J Koivisto, J Halla-aho, A Hyvärinen, V Koponen and A Nevalainen

The occurrence of common respiratory infections were studied with self-reported questionnaires in 32 Finnish schools and the association between respiratory infections and moisture damage in different types of school buildings was estimated. Both old and new buildings with wooden and concrete/brick frame were included. An association was found between occurrence of common colds and moisture damage in all school buildings. In addition, sinusitis, tonsillitis and bronchitis were more common in concrete/brick buildings than in buildings with wooden frame irrespective with moisture observations. Occurrence of respiratory infection was also strongly correlated with background factors such as age, female gender, smoking, atopy and moisture damage in home environment.

1C2p2 Endotoxin exposure in asthmatic children and matched healthy controls: results of IPEADAM study
G Tavernier, GD Fletcher, HC Francis, LA Oldham, AM Fletcher, L Stewart, I Gee, A Watson, TL Frank, P Frank, CAC Pickering and RML Niven

Children spend increasing time indoors therefore their domestic exposure to environmental factors may contribute to the development or the exacerbation of the asthmatic phenotype. Moreover, complex relationships between these factors might influence the manifestation of the disease. IPEADAM study investigated the exposure to endotoxin in asthmatic and matched healthy children, recruited from two general practices using a validated, screening questionnaire. Reservoir dust samples were analysed for endotoxin using a LAL assay. Of 77 asthma and control houses higher levels of endotoxin were found in the living room carpets, but not the bedroom carpet or mattress's of the asthma homes compared to the control homes (Wilcoxon test $p=0.003$). Further work of the complete data set is required to investigate this finding and observe possible inter-relationships with the other environmental pollutants measured. However the current implication is that endotoxin in domestic urban homes is a risk factor for the development of asthma.

1C2p3 Effect of indoor CO_2 concentrations on wheezing attacks in children
CS Kim, YW Lim, JY Yang, CS Hong and DC Shin

The purpose of this study was to determine whether indoor air pollutants are a risk factor for wheezing attacks in children. We investigated 181 children (≤14 years) in 110 homes. Respiratory symptoms, characteristics of housing and life style factors were obtained using a written questionnaire, which was completed by the parents. We found that wheezing attacks in the previous 12 months were only associated with asthma history and were not associated with ETS exposures, fungus spores, allergens and housing factors. Nevertheless, in children with an asthma history, wheezing attacks were associated with indoor CO_2 concentrations ($p=0.01$). In multivariate analysis, the indoor CO_2 concentrations for children with an asthma history were still associated with wheezing attacks even after adjusting for other factors (OR=1.12 per 10 ppm increase, $p<0.05$). In this study, we showed that indoor CO_2 concentrations were associated with wheezing attacks in children who had a history of asthma

1C2p4 AIRS system: a real-time monitor to measure indoor air pollutants and lung function in children with asthma
CW Bayer, AL Cook, D Roberts, PD Via, and WG Teague

Indoor pollutant exposures are thought to be important triggers for clinical exacerbations in asthmatic children. However, little is known about the temporal relationship between indoor pollutant exposures and changes in lung function in this at risk population. A portable, desktop air pollution monitor has been designed to track longitudinal changes in asthma symptoms, lung function, airborne particles, ozone, NO_2, formaldehyde, CO_2, temperature, and humidity in real-time. The device is being piloted by placement in the bedrooms of pediatric subjects with moderate persistent asthma. One teenage subject, within twenty-fours of exposure to a yellow Smog Episode, experienced a step-wise reduction in forced expired volume in one-second (FEV_1) and increased rescue medication use. Both indoor and outdoor ozone and particulate concentrations, as well as periodic patient lung function levels, were recorded. Ongoing studies are addressing the relationship among exposure to ozone and particles with lung function in a sample of asthmatic children.

1C3o1 PM_{home}: a database of continuous particle measurements in an occupied house for four years
LA Wallace, C Croghan, C Howard-Reed and A Persily

Although considerable data exist on 24-hour integrated measurements of fine and coarse particles indoors, much less information is available on moment-to-moment variation for a full range of particle sizes including ultrafine particles. Also, information is limited on the relationships between air change rates, temperature, humidity, indoor-outdoor concentration ratios, indoor source strengths due to various activities such as cooking and cleaning, penetration factors, and deposition rates under realistic conditions. Therefore EPA and NIST have collaborated on a four-year (October 1, 1996 through Dec. 31, 2000) study of particle concentrations in an occupied townhouse. Target pollutants included ultrafine, fine, and coarse particles from 10 nm to 20 mm in diameter; black carbon (BC); and particle-bound polyaromatic hydrocarbons (PAH). Ancillary measurements included air change rates, wind velocity, temperature, and relative humidity. Measurements were made continuously and the final database (PM_{HOME}) is on a 5-minute basis. PM_{HOME} is available to researchers in Statistica or SAS format.

1C3o2 Vertical distribution of occupant-generated particles in a room with displacement ventilation
M Mattsson

The vertical distribution of airborne particles in a room ventilated according to the displacement principle was measured using a vertically conveyed particle counter. The supply air was absolute-filtered and the particles generated through office-like activity of people. In general, particle concentrations increased with height, indicating a displacement effect. This effect

improved with ventilation rate. A threshold-size of the particles could be discerned, above which the displacement effect started declining. The measured threshold-size agreed well with calculations based on the settling velocity of the particles and the hypothetical vertical piston-flow velocity of the room air (ventilation rate divided by floor area). At the ventilation rates tested (normal to high), the threshold-size was in the range 5-10 µm. Slightly negative concentration gradients were observed for large particles at the lowest ventilation rate. Hence, if hazardous substances are known to be associated with fairly large particles, the use of displacement ventilation is questionable.

1C3o3 Modeling particle deposition in ventilation ducts
MR Sippola and WW Nazaroff

This paper describes predictions from two models of fractional particle loss in four typical HVAC duct runs. One model is a state-of-the-art Eulerian formulation; the second is based on empirical fits to experimental particle deposition data collected in a laboratory. The experiments are briefly described and sample results are presented. The Eulerian model only predicts deposition from fully developed turbulence, while the empirical model can be applied to duct bends and developing turbulence as well. The models predict almost no losses for particles smaller than 1 µm and nearly complete loss of particles larger than 40 µm in all duct runs. The empirical model suggests that particle loss in ventilation ducts is dominated by gravitational settling to the floor of horizontal ducts, and by deposition to zones where turbulent flow is undeveloped, such as in bends and in duct sections immediately after bends.

1C3o4 Modeling particle deposition on HVAC heat exchangers
JA Siegel and WW Nazaroff

Fouling of fin-and-tube heat exchangers by particle deposition leads to diminished effectiveness in supplying ventilation and air conditioning. This paper explores mechanisms that cause particle deposition on heat exchanger surfaces. We present a model that accounts for impaction, diffusion, gravitational settling, and turbulence. Simulation results suggest that some submicron particles deposit in the heat exchanger core, but do not cause significant performance impacts. Particles between 1 and 10 µm deposit with probabilities ranging from 1 - 20 % with fin edge impaction representing the dominant mechanism. Particles larger than 10 µm deposit by impaction on refrigerant tubes, gravitational settling on fin corrugations, and mechanisms associated with turbulent airflow. The model results agree reasonably well with experimental data, but the deposition of larger particles at high velocities is underpredicted. Geometric factors, such as discontinuities in the fins, are hypothesized to be responsible for the discrepancy.

1C3o5 Exposure to house dust from human activities
AR Ferro, RJ Kopperud and LM Hildemann

This study examines exposure to house dust resulting from a variety of prescribed human activities. Continuous laser particle counters collocated with time-integrated filter samplers measured personal, indoor and outdoor PM concentrations for a 5-day experimental period in a home in Redwood City, California. The mean daytime personal exposures to $PM_{2.5}$ and PM_5 when there were prescribed activities were 1.4 and 1.6 times, respectively, above the indoor concentration and 6 and 17 times, respectively, above the background concentration. Activities that disturbed dust reservoirs on furniture and textiles, such as dry dusting, folding clothes and blankets, and making a bed, released the highest concentrations of $PM_{2.5}$, PM_5, and PM_{10}. The vigor of activity and type of flooring were also important factors for dust re-suspension. The results provide preliminary characterization of indoor human activities and demonstrate that indoor human activities result in short-duration, high concentration peaks that increase PM exposure and contribute to the personal cloud.

1C3o6 Novel technique for measuring low molecular weight chemicals in indoor dust
A Nilsson, V Lagesson and C Tagesson

A new technique is described which can measure low molecular weight compounds adsorbed onto dust particles in a simple yet accurate way. The technique – gas chromatography / UV spectrometry (GC/UV) – comprises a one stage thermal desorption oven, a gas flow cell with a miniaturised GC column, and a nitrogen-flushed photo diode array (PDA) detector for fast UV spectra recording. This method enables analysis of volatile organic as well as inorganic compounds adsorbed onto dust particles, many of which are difficult to analyse altogether in one single analysis using conventional methods. For example, both nitric oxide and ammonia can be analysed, as well as hydrogen sulphide, pyridine, 2-furaldehyde, 2-methylfuran, and isoprene. It is concluded that GC-UV may be used as an alternative or complement to other methods for measuring chemicals in indoor dusts, thus improving survey and control of the human exposure to particle-bound irritants and other chemicals.

1C3p1 Adsorbed volatile and semi-volatile organic compounds (VOCs and SVOCs) on settled dust
H Andersson, R Fredriksson, J Oscarsson and G Stridh

Health symptoms among persons in non-industrial environments are sometimes suspected to be dependent on adsorbed volatile and semi-volatile organic compounds (VOCs and SVOCs) on dust particles. These compounds adsorbed on dust particles are supposed to reflect conditions prevailing in the indoor environment for longer periods of time. Therefore an inventory of VOCs and SVOCs on settled dust was performed in 19 rooms in offices and 9 rooms in day-care centres. The dust was sampled from high level horizontal surfaces such as picture frames, wardrobes and bookshelves. The mixture of VOCs and SVOCs adsorbed on settled dust was found to be complex. The total VOC (TVOC) were calculated and found to be 400-1700 µg/g dust in offices and 550-2300 µg/g dust for day-care centres. Some classes of chemical compounds such as aldehydes, carboxylic acids and esters were frequently found.

1C3p2 Unambiguous confirmation by GC/MS and large volume injection of residential soot contamination from the burning of candles
LD Garretson and ED Golla

The complaints are generally the same; black markings on carpets and baseboards, black particulate dusting appliance surfaces and bathroom fixtures, darkened HVAC filters and supply registers and sooty deposits on furniture, draperies and clothing. Typically, this occurs in newer homes, often under manufacturer's warranty. Candles are not the only source of soot production, but in many recent investigations, candles were related to the appearance of staining. In addition to the physical damage caused to the home, there is also some concern that the presence of these fine soot particles may present an indoor air quality health hazard. This paper will describe an unambiguous technique utilizing Gas Chromatography-Mass Spectroscopy (GCMS) combined with Large Volume Injection/Microextraction to confirm the presence of paraffin in the soot particles. While there are many sources of hydrocarbons in new residences, the unique pattern and distribution of aliphatic hydrocarbons found in petroleum-derived paraffin (candle wax), provide evidence of the source of contamination.

1C3p3 Analysis of 3-dimensional roughness elements in an indoor air filter
G Chari, C Pain, AJH Goddard and CRE de Oliveira

3-dimensional roughness elements incorporated into indoor air filters enhance deposition of $PM_{1.0}$. The heat (mass)-transfer enhancement of diamond-shaped 3-D elements (adapted from Chyu and Natarajan, 1996) is numerically investigated for laminar flow. The characteristics of flow temperature over a single diamond, with Reynolds numbers of 67 and 667, are investigated. For a Reynolds number of 67, the temperature and pressure changes over multiple elements are investigated, in aligned and offset arrangements. Pitches (streamwise spacing-to-height) of 2 and 10 are more effective than a pitch of 5, when pressure increases are accounted for. However, a pitch of 2 performs best for heat transfer alone. As shown in turbulent flow using wedge-shaped elements (Han et al., 1993), the aligned arrangement, for a pitch of 2, is 1.4 times more efficient than the offset one.

1C4o1 Exposure of population and micro-environmental distributions of volatile organic compound concentrations in five European cities
K Saarela, T Tirkkonen, J Laine-Ylijoki, J Jurvelin, and M Jantunen

Determination of volatile organic compounds, VOCs, formed one part of the EU- EXPOLIS project in which the exposure of European urban population was studied. In the project 201 subjects in Helsinki, 50 in Athens, 50 in Basel, 50 in Milan and 50 in Prague were studied. The microenvironmental and personal exposure in Helsinki and Basel were lowest within all chemical compound groups and remarkable was the complete absence of halogenated compounds in Helsinki. The far highest microenvironmental concentrations of aromatics were in Athens and somewhat lower in Milan. The study was planned in such a way, that the role of microenvironmental concentrations in covering the total exposure could be calculated and their coverage of personal exposure estimated. This comparison suggested that the aromatics and to some extent the alkanes had stronger sources elsewhere than the indoor or residential outdoor environments.

1C4o2 The a detailed study of volatile organic compounds of 5 air-conditioned buildings in Singapore
KW Tham, SC Sekhar, M Amanullah, HK Lee, D Cheong and NH Wong

A detailed study to identify and characterize the Volatile Organic Compounds (VOCs) in the indoor air of air-conditioned office buildings in tropical Singapore has been accomplished. This study reports a summary of the TVOC and formaldehyde levels for each building; the relative ranking based on frequency of occurrence and level of concentration; indoor-outdoor ratio of the ten most abundant VOCs and a summary of the ventilation parameters of all the buildings. Toluene and benzene, one suspected and the other a known carcinogen, have been found to be most frequent at over 90% of indoor locations. Sources of

abundant VOCs are found to be mostly indoors. Air distribution systems in these buildings demonstrated a well-mixed flow pattern.

1C4o3 The variability of personal chemical exposure in eight office buildings
B Glas, J-O Levin, B Stenberg, H Stenlund and A-L Sunesson

In case-referent studies of factors associated with "sick building syndrome" (SBS) the selection of referents to the cases (i.e. people with SBS symptoms) is often crucial. In this study the personal exposures of aldehydes, amines, nitrogen dioxide, ozone, particles and volatile organic compounds (VOCs) were measured in office buildings, with the aim to investigate the variability between people, floors and buildings. The study involved eight office buildings with in total 79 participants. In total 523 compounds were detected. We evaluated the variability among the 123 compounds that were found in samples from at least 20 persons. The substance variability among these was explained to the major part by the differences between individuals in 78 %, and between houses in 14 % of the compounds. In 8 % of them the variation was explained in equal amounts by the differences between individuals and buildings. This supports that referents to cases can be chosen randomly.

1C4o4 Development of measurement device (ADSEC) for aldehydes and VOCs emission rates using a diffusive sampler
J Matsumoto, S Tanabe and R Aoki

A device (ADSEC: Advanced Diffusive Sampling Emission Cell) for measuring emission rates of aldehydes and VOCs from building materials using a diffusive sampler was developed. ADSEC consists of micro-chamber and diffusive sampler. It can be operated without pump. The sampler is inserted after the installation of cell. The size of cell was designed to measure flooring material without covering gap between two pieces. Indoor air quality in the actual house was measured using ADSEC. Ventilation rate calculated from the emission of formaldehyde measured by ADSEC from floor, wall, and ceiling was slightly higher than that measured by PFT method. It was confirmed that the ventilation rate was lower in autumn because windows were closed nearly all the time. Passive method for VOCs was also developed and discussed.

1C4o5 Seasonal variation in indoor and outdoor concentrations of VOCs in New York City
S Ramstrom JD Spengler S Chillrud and P Kinney

The TEACH project (Toxics Exposure Assessment - A Columbia-Harvard Project) recruited high-school students to participate in an exposure assessment study which included personal, indoor, and outdoor sampling of multiple pollutants. This paper presents the results from the indoor and outdoor sampling of various volatile organic compounds (VOCs) in the winter and summer of 1999. Thirty-three of the homes were sampled in both seasons. Air-exchange was also measured in all apartments in both seasons. The VOCs with the highest concentrations outdoors and indoors, both in the winter and summer, were MTBE and Toluene. Consistent with the literature, indoor concentrations of VOCs were higher than outdoor concentrations sometimes by a factor of more than 10. Seasonal differences were observed for indoor-outdoor ratios of the target VOCs, with winter ratios often exceeding summer ratios. Effects of air exchange rate were seen for VOCs with the highest indoor-outdoor.

1C4p1 Development of the formaldehyde automatic analyzer and test to evaluate its performance
E Osada T Matsumura and M Andoh

In Japan, the guideline value for the concentration of indoor formaldehyde was set up in 1997. It was 0.08 ppm as the 30-minute average value, which was the same as the guideline value of WHO. At the same time, the sampling method in a newly built or renovated house was also described in the guideline. However, there have been only a few cases in which the concentration change of indoor formaldehyde was actually measured. This time, an analyzer capable of continuously measuring 30-minute average values was developed. It is based on the acetylacetone absorption spectrophotometric method. It can measure a concentration range of 0 - 0.2 ppm. It was confirmed that the analyzer was not affected by nitrogen dioxide, sulfur dioxide, ozone and aldehydes other than formaldehyde.

1C4p2 How to sample ppb levels of VOCs in the presence of ozone: an evaluation of different scrubber materials
J Fick, L Pommer, B Andersson and C Nilsson

Some reactive volatile organic compounds (VOCs) are prone to degradation during sampling in an ozone rich environment which interfers with the results. A wide variety of different chemicals have been used to remove the ozone prior to sampling but the possibility of interference by such chemicals with the sampled VOCs has not been thoroughly examined. In the present investigation the retention/degradation of four terpenes (α-pinene, β-pinene, 3-carene and limonene) and isoprene has been studied, using various ozone removing chemicals in an attempt to evaluate their potential as ozone scrubbers in the sampling of indoor air. The ozone removing capacity of the chemicals were also examined. The chemicals included in this first screening were, KI, MnO_2, Na_2SO_3, Silanized poly(1,4-phenylene sulfide) (PFS), unsilanized PFS, $Na_2S_2O_3$.

1C4p3 Underestimation of indoor air concentrations; comparison of Tenax-adsorption/thermal desorption with different sorbents/liquid extraction
C Zorn, M Köhler and N Weis

Reference procedures for determining volatile polar and non-polar organic compounds using different sorbents are compared to additional measurements of air samples adsorbed on Tenax TA followed by thermal desorption (TD). Tendencies for a relationship between absolute concentrations and divergence of measurements could be found. Results differ remarkably within compound classes with higher air-concentrations obtained by TD-analysis. Concentrations of homogeneous groups as aldehydes or terpenes show little variability. In the glycol-derivatives there is a split in a less-polar group with a factor of 1 and a polar group (acetates) with factors around 2. For alkanes and aromates continuously distributed deviations were obtained due to compound structure. Conclusions can be drawn that "real" air-concentrations are underestimated when using the liquid desorption procedures: for example for styrene a loss by a factor of 3 was found. A discussion is needed about how far reference-values and TVOC are concerned from these findings.

1C4p4 Significance of individual response factors in the detailed characterization of volatile organic compounds
SC Sekhar, KW Tham, MD Amanullah, HK Lee, D Cheong, NH Wong and Z Bin Mohd Sultan

A detailed characterization of volatile organic compounds (VOCs) in an indoor environment requires a satisfactory calibration of the Gas Chromatography-Mass Spectrometry (GC/MS) instrument for obtaining individual response factors. In a recent study in Singapore involving 5 high-rise air-conditioned office buildings, such a calibration for individual response factors was accomplished using some individual compounds and commercially available standard gas containing 35 compounds. This paper describes the sampling and analytical methodology adopted and emphasizes the calibration procedures employed in obtaining the various response factors. An extensive analysis has led to a simple means of characterizing and computing TVOC GC/MS values without having to determine the response factors of a multitude of compounds. This paper presents our key findings of this analysis with a conclusion that the response factors of 7 abundant compounds yields as much valuable information about the VOCs as that from the individual response factors of 35 compounds.

1C4p5 Indoor environment of the chemical sensitivity (CS) patient house at Asahikawa, Japan
S Nakai, Y Yanagisawa, J Kawahara, N Shinohara, K Kumagai, K Abe, K Jin, S Kobayashi E Katsura

A chemical sensitivity (CS) patient house was built at Asahikawa, Japan in 2001. The objectives for the house are to study the CS mechanism, the relationship between indoor environment and the symptoms, as well as care of the patients. It is expected that CS patients will recover and return to normal life through their temporary stay at the CS patient house. In this paper, the baseline data results of the indoor environment measurements since the construction are described. The formaldehyde concentration in each room was less than 20 ppb just after the construction and since then. VOC levels were also low. We feel the indoor environment of the house is good for CS with regard to chemical contamination, although we have discovered another environmental problem: biological contamination. This research will be continued to establish good standards for the indoor environment to prevent CS occurrence.

1C4p6 Short term exposure to volatile organic compounds (VOCs) causes impairment of skin barrier function in man
J Huss-Marp, B Eberlein-König, K Breuer, S Mair, U Krämer, E Mayer, K Gertis, J Ring and H Behrendt

Exposure to indoor concentrations of formaldehyde was reported to cause disturbance of the epidermal barrier function in healthy volunteers and patients with atopic eczema (AE). No such data are available on VOCs which are widely occurring indoor air contaminants. In a double-blind crossover study we exposed 12 adults with AE and 12 matched controls to a mixture of 22 VOCs in an exposure chamber for 4h (TVOC: 5mg/m³). The transepidermal water loss (TEWL) was measured in all subjects before, during and after exposure. Pronounced changes in TEWL were observed 48h after the VOC exposure as compared to the exposure with cleaned air alone (mean change: +34.1%; 95% confidence interval: 6.6 – 68.6%). Significant differences between the patients and controls could not be detected. The results indicate an impairment of the epidermal barrier function in patients with AE and in healthy controls induced by VOC exposure in concentrations encountered in indoor environments.

1C5o1 The current status of residential radon epidemiology
RW Field

Lung cancer is the major cause of cancer death in the United States. Because of the magnitude of lung cancer incidence and its poor survival rate, even secondary causes of lung cancer, such as prolonged residential radon exposure, are important. The primary objective of this paper is to provide a brief overview of both the major occupational radon studies and previously published residential radon case-control studies with a focus on the past, current and future residential radon epidemiologic

activities in the United States. Extrapolations from occupationally radon-exposed miners suggest that residential radon exposure is responsible for approximately 18,600 lung cancer deaths per year in the United States. Direct evidence from case-control radon epidemiologic investigations generally support the extrapolations from miners. Findings from case-control studies incorporating new radon gas and radon progeny exposure techniques suggest that earlier case-control studies may have underestimated the risk posed by residential radon exposure.

1C5o2 The effects of protocol choices on a radon-lung cancer epidemiologic study
DJ Steck

Exposure to radon progeny provides an opportunity to study the effects of low doses of ionizing radiation. Unfortunately, case control studies in the general population have failed to find a consistent association between radon and lung cancer. Since these studies did not use the same measurement and selection protocols, there may be differentially inaccurate assessment of the cumulative radiation dose between the studies. Radon concentration measurements for one year or less are the most commonly used lifetime dose surrogate. A Monte Carlo simulation was used to study the effects of protocol changes on the base design of the Iowa Radon Lung Cancer Study. Substantial loss of correlation and increase in misclassification occur when the simulation included shorter residency in the current home and less than complete, mobility-weighted radon exposure measurements. Substantial increases in correlation and decreases in misclassification occurred when airborne radon progeny dose surrogates substituted for radon measurements.

1C5o3 Residential radon and lung cancer risk: first analyses of a case-control study in the district of IMST, Tyrol/Austria
A Schaffrath Rosario, W Oberaigner, J Wellmann, M Gerken, L Kreienbrock, M Kreuzer , B Langer, G Keller and HE Wichmann

A case-control study on indoor radon and lung cancer was conducted in an alpine district of Tyrol/Austria in 1994-1998. Within the district, there is one village with very high indoor radon concentrations, up to about 3,000 Bq/m³. Cases were the lung cancer deaths from 1970-1992, and controls were a sample of deaths (excluding smoking-related deaths) in the same period. Next-of-kin of 194 cases and 198 controls were interviewed. Radon gas measurements were performed in the last residence. Seasonal correction factors were derived and applied to the radon gas measurements. We observed higher concentrations of radon in cases than in controls in an area where no underground mining takes place. Statistical analysis of the data is under way.

1C5o4 Residential air quality in interior Alaska
R Johnson, J Schmid, and R Seifert

Interior Alaska has indoor air quality issues similar to other far northern communities associated with long cold winters and reduced ventilation rates. Moreover, geological features in the hills around Fairbanks, Alaska increase the likelihood of elevated radon levels. Over thirty percent of the tested homes in the hills around Fairbanks had radon levels > 4 pCi/L compared with a nationwide average of 7%. Active sub-slab depressurization systems tested were very effective in reducing indoor radon concentrations (average reduction of over 90% for 8 homes). For homes with wood stoves, we found the indoor PM_{10} concentrations peaked after the stoves were lit. A model was developed to predict transient concentrations of particulates or gases

1C5o5 Long term performance of radon mitigation systems
R Prill and WJ Fisk

Researchers installed radon mitigation systems in 12 houses in Spokane, Washington and Coeur d'Alene, Idaho during the heating season 1985 –1986 and continued to monitor indoor radon quarterly and annually for ten years. The mitigation systems included active sub-slab ventilation, basement over-pressurization, and crawlspace isolation and ventilation. The occupants reported various operational problems with these early mitigation systems. The long-term radon measurements were essential to track the effectiveness of the mitigation systems over time. All 12 homes were visited during the second year of the study, while a second set 5 homes was visited during the fifth year to determine the cause(s) of increased radon in the homes. During these visits, the mitigation systems were inspected and measurements of system performance were made. Maintenance and modifications were performed to improve system performance in these homes.

1C5p1 Radon remediation design considerations of a New Jersey school building
B Brodhead, P McGuinness and M McGuinness

Designing radon mitigation systems for commercial buildings or schools is significantly more complicated than designing for residential buildings. This paper describes the methodology used in designing a radon system for an 18,000 sf school building

with radon levels throughout the building that were well above the EPA guideline. The remediation design was based on sub-slab communication testing. The remediation system was installed as per this design and the system effectively reduced the radon levels well below the EPA guideline.

1C5p2 Continuous and categorical trend estimators: simulation results and an application to residential radon
A Schaffrath Rosario, J Wellmann, IM Heid and HE Wichmann

Exposure variables in epidemiological studies often have a skewed distribution that can be approximated by a lognormal distribution. A typical example are indoor radon gas concentrations. In this situation, the standard continuous estimator for trend can be strongly influenced by single outlying observations. In a simulation study, we found two types of estimators that serve as useful sensitivity analyses against outliers: trimmed estimators and categorical estimators based on statistically optimal categories using expected values within categories as scores. In the West German study on indoor radon and lung cancer, the alternative estimators are used to assess the influence of two outliers among the controls.

1C5p3 Radon levels and dose estimation in some hot spring hotels
G Song, B Zhang, X Wang, J Gong, D Chan and J Bernett

Guangdong is one of the provinces that have most hot springs in China. This paper presents the results of radon measurements in hot spring hotels of Guangdong province by using NR-667A continuous radon detector. Radon concentrations were measured in hotel rooms with attached bathrooms, tap waters and outdoors air. Radon concentrations were 53.4-292.5 Bq/L in the hot spring water, and 17.2-190.9 Bq/m^3 in outdoor air. In the bathrooms radon contents ranged from 29.3 to 911.6Bq/m^3 without using hot spring water, but after bathing 15 min and 30 min with hot spring water they reached 63.6-1917.8 Bq/m^3 and 79.2-2710.7 Bq/m^3 respectively. Radon concentrations in bedrooms ranged from 32.7 to 4337.8 Bq/m^3 without natural and mechanical ventilation, and they could reduce from the highest to 137.6-213.3 Bq/m^3 after 1h ventilation. Indoor radon accumulation with bathing time was also presented. The effective dosages of radon to hotel workers and tourists are estimated.

1C5p4 Understanding of high radon concentrations observed in a well-ventilated Japanese wooden house
S Tokonami, H Yonehara, W Zhuo, Q. Sun, T Sanada and Y Yamada

Two nation-wide indoor radon surveys have been conducted in Japan. There was a significant difference between the two surveys. The first survey covered over 7000 houses using Karlsruhe passive radon detectors developed in Germany. The first survey provided relatively higher radon concentrations than expected though there are many well-ventilated wooden houses in Japan. The arithmetic mean was estimated to be 20.8 Bq m^{-3}. In the second survey, on the other hand, it was 15.5 Bq m^{-3}. In order to understand the inconsistency, passive radon detectors used in the first survey were placed in a traditional room at a Japanese wooden house. The concentration was functioned by the distance from the wall. Although passive radon detectors are designed to detect radon only effectively, a little contamination of thoron was often found in readings obtained from some detectors according to our experimental studies.

1C6o1 Cleanliness criteria and test procedures for cleanliness labeling of HVAC components
M Björkroth, V Asikainen, O Seppänen and J Säteri

A new cleanliness classification system for air-handling components and systems was officially launched in Finland at the end of September 2001. This paper describes the test procedure and summarizes all the test methods available for the classification tests and product development as well as the limit values. The main parameters are amount of dust, amount of oil residuals on metal surfaces, and odour emission. The limit value for surface dust is 0.5 g/m² in new, uninstalled components and the limit value for oil residuals is 50 mg/m² or 300 mg/m² depending on the type of the component. There are also some additional test methods, such as a measuring method of mineral fibres released into airflow and a method for measuring the odour threshold of processing oils. Additional tests are required if the component contains fibrous materials or a new type of lubricant is used in the manufacturing process.

1C6o2 Labeling system for clean ventilation components
M Björkroth, O Seppänen, J Säteri, P Neuvonen, P Pasanen and J Railio

A renewed version of the Finnish guideline "Classification of Indoor Climate, Construction, and Building Materials", first introduced in 1995, was released in 2001. The guideline has been widely used in the design and construction of healthier and more comfortable buildings and their mechanical systems. An important improvement was the inclusion of the guidelines for ventilation systems, including the general requirements for the cleanliness of air-handling equipment and detailed requirements for ventilation ducts, duct sections, air and fire dampers, and filters. Specific requirements concerning hygiene have been presented for other components as well. Based on these principles, a system for the labeling of the air handling components

was established in Finland in 2001. This paper describes the general principles of the labeling system. The details including testing protocols are described in other papers presented in the conference.

1C6o3 A visual inspection method to evaluate cleanliness of newly installed air ducts
R Holopainen, J Narvanne, P Pasanen and O Seppänen

Visual inspection is a subjective method to evaluate cleanliness level of duct. Although it is subjective, it is mostly used for estimating necessity to clean a ductwork. The aim of this study was to develop the visual inspection method more objective and to create a procedure for estimation of cleanliness level of an air duct. A visual inspection form and a visual cleanliness scale were applied in recently installed supply air ducts with a panel consisting ten members. The visual scale has been designed for evaluation if the ducts should be cleaned or not. Therefore, it is focused for the amount of accumulated dust from clean to dirty corresponding values <0.1 to 4 g/m^2 measured with the vacuum test method. The developed visual inspection method offers a suitable tool for evaluation of cleanliness especially in new installations. The more objective sampling methods are needed in borderline cases when opinions of customer and client differ.

1C6o4 Maintenance of HVAC-systems and components, definition of cleanliness!
B Müller

Maintenance of air-conditioning systems is acknowledged as an important means to run HVAC-systems properly. Although several maintenance programs and standards exist, not many systems are maintained in a proper way. Most standards and programs are not concerned with the indoor environment, they are only concerned with repair and failure-response of system components. Just now, some new guidelines come out in Europe, which contains first definition of cleanliness. These levels normally define dust concentration, or microorganism on the surface of components or the microorganism concentration in the water of humidifiers. Levels for microorganism in the air are not defined. One question that is not precise answered jet is: “Is it good enough to define cleanliness levels for surfaces, or do we need concrete definitions for the air?” First steps to answer this question are done in the presented article.

1C6o5 The effect of duct cleaning on indoor air quality in office buildings
S Kolari, M Luoma M Ikäheimo and P Pasanen

The effect of duct cleaning on supply air quality, duct cleanliness, air exchange and working environment was studied in 15 non-problem office buildings. Mass and number concentrations of particles, concentrations of microbes, volatile organic compounds and CO_2 were measured in outdoor, supply and indoor air. Samples of accumulated dust were taken from the inner duct surfaces and supply and exhaust air flows were measured. An Indoor Climate Questionnaire was delivered to over 900 employees before and after the duct cleaning. Duct cleaning had no measurable effect on supply air quality. The results showed that the average amount of dust on the inner duct surfaces decreased from 8.4±9.1 to 1.9±2.1 g/m^2. The employees perceived the working environment better after the cleaning than before it.

1C6p1 Bulk sampling of dust loading in ductwork
D Rask, T Lewis and C Maki

The demand for duct cleaning has been increasing exponentially over the last few years. There is a plethora of businesses doing duct cleaning, similar to the early 1990’s and indoor air quality businesses. Two questions that are often asked but are likely not answered objectively are, “Is my ductwork dirty?” and “Do my ducts have to be cleaned?” The ductwork in a school district (18 buildings) was assessed to answer the above two questions. All air-handling units and representative portions of their associated ductwork were assessed. A sampling protocol and criteria were developed and a means for making the "clean or not to clean" decision was implemented. Some of the ductwork was internally lined and other ductwork had a bare sheetmetal interior. The results indicated that some ductwork had relatively high levels of fungal deposition, low to high levels of dust mass per square centimeter of surface, and visual indicators of clean to very dirty. There was not always agreement between the “dirty” indicators, suggesting that at least two of the three protocol methodologies be used.

1C6p2 The amount of accumulated dust in ducts of new HVAC installations
R Holopainen, M Tuomainen, V Asikainen, P Pasanen, J Säteri and O Seppänen

The aim of this study was to evaluate the amount of dust in supply air ducts in recently installed ventilation systems. The samples for the determination of dust accumulation were collected from supply air ducts in eighteen new buildings that have been constructed according to two different cleanliness control levels classified as category P1 and category P2. In the ducts installed according to the requirements of cleanliness category P1 the mean amount of accumulated dust was 0.9 g/m^2 (0.4–2.9 g/ m^2), and in the ducts installed according to the cleanliness category P2 it was 2.3 g/ m^2 (1.2-4.9 g/ m^2). A significant difference was found in the mean amounts of dust between ducts of categories P1 and P2 ($p<0.008$). The cleanliness control

procedure in category P1 proved to be a useful and effective tool for preventing dust accumulation in new air ducts during the construction process.

1C6p3 Development of a clean installation method for ventilation systems
M Luoma and S Kolari

Ventilation ducts and accessories have been shown to get dirty during the storage and installation at the building site. Most important factor that makes the inner duct surfaces dirty is the metal dust that is accumulated while side grinder is used to cut the ducts. The aim of the study was to develop a clean installation method for ventilation ducts, by the use of which the new national ventilation cleanliness class can be achieved. The laboratory tests and field experiments showed that the side grinder widely used nowadays in Finland can be replaced with shears. Shears do not produce metal sheet dust, do not sparkle and are not as noisy as the side grinder. Also, the speed of work and work safety are good with the shears. The operating characteristics of the shears were appraised good and the assembly workers were satisfied with the new method.

1C6p4 New hospital-hygiene guidelines – new technical standards for HVAC equipment
R Meierhans

Like with „evidence-based medicine“, present hygiene requirements to be met by hospital HVAC plants are analyzed critically. Focusing on the essentials, HVAC measures for infection prophylaxis are only concentrated on confined room areas such as sterile protected areas in the operating room, sterile care and isolation rooms, and other special areas. The tasks of comfort air conditioning are adapted to the improved indoor conditions of intelligent buildings. Air is only used for ventilating, whereas heated and cooled room surfaces serve for heating and cooling. In hospitals, cooled floors are particularly suitable for this purpose. The separation of tasks and the saving of space thanks to shifting from air to water as a heat carrier allows an altogether improved quality standard while reducing investment and operating costs.

1C6p5 Assessment, cleaning & restoration of HVAC systems (ACR-2002)
C Cochrane and T Yacobellis

In the fall of 2001 NADCA released ACR 2002, which supercedes 92-01. This new standard holds to the same clearance criteria for post cleaning requirements but goes much farther in addressing pre-cleaning assessments, control and containment during the cleaning process as well as a host of other variables that can impact the indoor environment. This paper takes a look at the new standard and how it addresses the many variables that influence duct cleaning and IAQ and how the document deals with the many different building populations.

1D1o1 Interpreting microbial measurement and analysis
T Nathanson

The potential for microbial contamination exists in every building and within every HVAC system. The two basic requirements for microbial growth are first, a moisture source, and second, a nutrient. Fungal spores and bacteria are prevalent outdoors and indoors and so are nutrients such as organic materials including dust and soil. Given the right conditions, microbials will grow on any surface. Therefore control of moisture and good housekeeping will reduce the possibility for microbial growth within buildings. A rapid response to water damage using established remediation procedures will prevent microbial contamination (Nathanson, 2001). Visible mould within buildings must be remediated. In most cases however, mould growth is not evident (hidden) and airborne sampling needs judicious interpretation. There are no ‘threshold limit values’ for microbial exposure, measurement methods vary, analysis is difficult, and there are other factors which can greatly influence the results. However, there is still value in taking airborne microbial samples.

1D1o2 A fungal abatement project in an office located in arid southwestern region of the United States
L Hung, S Lindsey and K Kroehle

A single-story office building located in arid southwestern United States underwent a large-scale fungal abatement due to moisture infiltration and fungal contamination in the exterior wall system. Containment areas were built up and various microbiological samplings (baseline, during abatement, and clearance) were conducted with diverse sample types: culturable and non-culturable air samples, contact plates, and swab samples. Throughout the abatement periods, outdoor airborne fungal/spore levels were 102 – 103 CFU/m^3 and 103 – 104 spores/m^3. *Cladosporium* dominated outdoor fungal flora. Elevated fungal levels (107 spores/m^3 and 105 CFU/m^3) were detected during abatement activities with *Penicillium* as the predominant fungi followed by *Aspergillus*. Spores of *Stachybotrys chartarum* were also detected during abatement from non-culturable method. Results from clearance samples showed significant mean fungal level reduction on aboveground surface samples. Airborne fungal/spore levels returned to baseline levels with *Cladosporium* as the predominant fungal genus.

1D1o3 Cleanup of microbial contamination in major building crawlspaces
D Figley and R Sieber

Mold problems in crawlspaces have been investigated and remediated. The causes of contamination included; design, maintenance, operation and water management. Rodent infestation and sewage entry may have contributed additional moisture and contamination. The effects include; significant mold contamination within the crawlspace itself, deterioration of the building and the potential for crossover of contaminated air into occupied areas. These factors can compromise the performance and long-term sustainability of the buildings. The overall costs of the cleanup and improvements to the crawlspaces and building services range from $71 to $134 CAD per m^2 of floor area. This paper presents results from a multi-year study into the causes and rehabilitation methods, costs and results for a building improvement program. The results show that these building crawlspace foundations can be effectively and efficiently remediated at a fraction of the cost of allowing the buildings to continue to deteriorate and be subsequently replaced.

1D1o4 Mold remediation procedures at a New Jersey elementary school
M McGuinness

Microbiological remediation procedures at an Elementary School in Central New Jersey are discussed. Significant amplification was noted visually and sampling of air and surfaces confirmed visual observations. Preliminary sampling identified airborne levels of countable fungi that ranged as high as 261,000 str/m^3 with *Aspergillus*/*Penicillium*-like species comprising more 90% of the sample loading. Significant amplification was noted in the carpets (>12 million CFU/gram) dominated by either *Cladosporium* or *Penicillium*. The specific remedial plan developed by the authors and contractors addressed issues necessary to properly remediate the building and reduce occupant exposures to potentially toxigenic and/or allergenic species of fungi. Active communication procedures between concerned parties were part of the remedial plan as well. The project was successfully completed and the start of the new school year was delayed less than two weeks. Successful completion of this project resulted from appropriate remedial procedures, contractor competence and the cooperation of all concerned parties.

1D1o5 Investigation of black material on walls and household contents in two residences
M Dekermenjian and M Shum

This paper describes two investigations of single-family residences where black material was observed on walls and household contents. Initially, residents were concerned about possible mold growth. The resident in household A complained of burning of the eyes, nose and throat. Residents in household B were concerned that their son's asthma was either caused or exacerbated by the airborne black material in their home. Upon visual inspection, bulk sampling, and informal interviews with the homeowners of the two residences, the black material was determined to be soot from extensive use of candles. In household A, the soot material was particularly evident above electrical heaters, on white furniture and contents, and in and around the refrigerator. In household B, the soot material was observed mostly on walls that were either exterior or opposite the attic space, on white plastics, and in the refrigerator.

1D1p1 Effectiveness of cleaning methods after the repair of the moisture damaged building
H Kokotti, R Halonen, L Kujanpää2 E Korhonen, T Keskikuru and M Reiman

The object of this study was the library store divided into three sections covered with plastic walls. Each section was cleaned with different methods: two different types of vacuum cleaners equipped with HEPA filter and a vacuum cleaner with water filtration. After cleaning surfaces were swept by wet cloth soaked with disinfectant. Concentrations of microbes in air and on surfaces were measured before and after cleaning. The follow- up measurements were conducted half a year later. The concentrations of airborne microbes were low before and after cleaning. The concentrations and diversity of airborne microbial species were the highest during the cleaning period. During the follow-up study, concentrations of microbes in air and on surfaces were the same or lower than they were just after the cleaning. In addition, diversity of species was decreased, but moisture indicating microbes appeared in all sections. There were no differences in effectiveness between methods of cleaning.

1D1p2 Remedial procedures for water damage in buildings
T Nathanson

Within the life cycle of a facility, water damage due to plumbing leaks, flooding, major spills, sewer back-ups, etc. will occur. Water damaged building materials, interior furnishings, structural and mechanical components, if not appropriately managed, can become significant sources of microbial (bacteria and fungi) contamination. Exposure to these contaminants can lead to potential health problems ranging from simple irritation, allergic responses, infection, to environmental sensitivity. Depending on the source, extent and location of water intrusion, there are various clean-up and remedial procedures to effectively control the situation and minimise damage, microbial growth, and health risk. The intended audience for the management and

remediation of water damage in buildings are building owners and managers, operators, project managers, abatement and restoration contractors, indoor air quality consultants, industrial hygienists and building occupants.

1D1p3 A combination of cleaning and restoration can produce very significant improvement in indoor air climate
O Sjovold and TL Norum

In the central part of Norway many school buildings and upper secondary schools had problems with indoor air climate. The causal factor was most often moisture in buildings caused by leaks in the roof, outer walls both above and below ground level, or leakage from the sanitary system. Typical features of the users' health were runny nose, eye irritation, coughing and aggravation of asthma. A comprehensive restoration of buildings was usually necessary if it was recorded that fungi had taken hold. But in many cases a correct cleaning method was sufficient. Our tests showed that the indoor air climate was considerable improved following a certain cleaning process.

1D1p4 Mold damages caused by water used in cleaning - microbiological aspects
L Kujanpää, M Reiman and R Kujanpää

A school building went through the inspection of building techniques. In dry premises, lower parts of walls were damaged by molds, because they had become repeatedly wet when floor was cleaned with water. Material samples from gypsum wallboards were taken for analysis both by the cultivation and microscopy analysis to detect possible mold growth. Viable molds, especially potential toxin producers (e.g. *Aspergillus versicolor, Chaetomium sp., Fusarium sp., Trichoderma sp*.), were found in great concentrations (104-106 cfu/g) in the areas closest to the floor. In direct microscopy, some samples showed high amounts of *Stachybotrys atra* not observed by cultivation. In samples taken 60 cm above the floor, small amounts of viable spores, only *Penicillium*, were found (103 cfu/g). These results show that the excess use of water in cleaning may lead to serious and extensive mold problems in walls of dry premises.

1D2o1 An intervention study of outdoor air supply rates and sick leave among office workers
TA Myatt, J Staudenmayer, K Adams, M Walters, M Wand, S Rudnick and DK Milton

We conducted an intervention study of outdoor air supply rates and sick leave among hourly office workers employed by Polaroid Corporation. High and moderately high outdoor air supply rates were specified in a random block design in two office buildings. Indoor CO_2 concentrations were measured every ten minutes. We calculated a CO_2 concentration differential by subtracting the daily average CO_2 concentration in the study area during 1-3 AM, when the building was not occupied, from the same-day average concentration between 9-5 PM. The mean weekly, workday, CO_2 concentration differential ranged from 37 to 250 ppm as compared with the ASHRAE recommended maximum differential of 700 ppm. We determined the frequency of sick leave among 294 hourly workers scheduled to work 49804.2 days in the study areas using company records. Generalized additive mixed models showed no association of CO_2 differential at the relatively low values studied and sick leave in the studied buildings.

1D2o2 Medical cost savings obtained through asthma management programs and environmental trigger avoidance
K Cunningham, D Mudarri, M Heil and Ben Apelberg

Asthma is a serious, chronic, and potentially life-threatening illness, and the national medical costs for treatment is significant. A substantial portion of these costs are borne by managed care organizations (MCOs) and other health insurers who thus have an incentive to adopt asthma management programs to reduce those costs. This paper explores how MCOs can estimate the potential savings they could experience by combining medication management with environmental trigger avoidance in an asthma management program (AMP).

1D2o3 Worker performance and ventilation: analyses of time-series data for a group of call-center workers
WJ Fisk, PN Price, D Faulkner, DP Sullivan, DL Dibartolomeo, CC Federspiel, G Liu, and M Lahiff

We investigated the relationship of ventilation rates with the performance of advice nurses working in a call center. Ventilation rates were manipulated; temperatures, humidities, and CO_2 concentrations were monitored; and worker performance data, with 30-minute resolution, were collected. Multivariate linear regression was used to investigate the association of worker performance with building ventilation rate, or with indoor CO_2 concentration (which is related to ventilation rate per worker). Results suggest that the effect of ventilation rate on worker performance in this call center was very small (probably less than 1%) or nil, over most of the range of ventilation rate (roughly 12 L s^{-1} to 48 L s^{-1} per person). However, there is some evidence of worker performance improvements of 2% or more when the ventilation rate per person was very high, as indicated by the indoor CO_2 concentration exceeding the outdoor concentration by less than 75 ppm.

1D2o4 Worker performance and ventilation: analyses of individual data for call-center workers
CC Federspiel, G Liu, M Lahiff, D Faulkner, DL Dibartolomeo, WJ Fisk, PN Price and DP Sullivan

We investigated the relationship between ventilation rates and work performance in a call center. We randomized the ventilation controls and measured ventilation rate, differential carbon dioxide (DCO_2) concentration, temperature, humidity, occupant density, degree of under-staffing, shift length, time of day, and time required to complete two different work performance tasks (talk and wrap-up). DCO_2 concentrations ranged from 13 to 611 ppm. We used multi-variable regression to model the association between the predictors and the responses. We found that agents performed talk tasks fastest when the ventilation rate was highest, but that the relationship between talk performance and ventilation was not monotone. We did not find a statistically significant association between wrap-up performance and ventilation. At high temperatures agents were slower at both the talk and wrap-up tasks. Agents were slower at wrap-up during long shifts and when the call center was under-staffed.

1D2o5 Do indoor environments in schools influence student performance? A review of the literature
GA Heath and MJ Mendell

The goal of this paper was to critically review available evidence on relationships between indoor environmental quality (IEQ) in schools and student performance. Because available evidence from schools was limited, the review expanded to include studies on direct relationships between the performance of children and adults and the indoor environments in schools, workplaces, residences, and controlled laboratory settings. The most persuasive available evidence suggests that some aspects of IEQ, including low ventilation rate and less daylight or light, may reduce the performance of occupants, including students in schools. Other evidence identifies additional possible influences, such as pollen and some carpets. Substantial limitations in the quantity and quality of available research findings suggest many questions for future study. Sufficient evidence is available to justify (1) actions to safeguard IEQ in schools and (2) the conduct of focused, well-designed research to help guide future policies and actions regarding IEQ in schools.

1D2p1 Cost-benefit analysis of improved air quality in an office building
R Djukanovic, P Wargocki and PO Fanger

A cost-benefit analysis of measures to improve air quality in an existing air-conditioned office building (11581 m^2, 864 employees) was carried out for hot, temperate and cold climates and for two operating modes: Variable Air Volume (VAV) with economizer; and Constant Air Volume (CAV) with heat recovery. The annual energy cost and first cost of the HVAC system were calculated using DOE 2.1E for different levels of air quality (10-50% dissatisfied). This was achieved by changing the outdoor air supply rate and the pollution loads. Previous studies have documented a 1.1% increase in office productivity for every 10% reduction in the proportion of occupants entering a space who are dissatisfied with the air quality. With this assumption, the annual benefit due to improved air quality was always at least 10 times higher than the increase in annual energy and maintenance costs. The payback time of the HVAC first costs involved in improving the air quality was always less than 4 months.

1D2p2 Modeling the cost effects of the indoor environment
M Tuomainen, J Smolander, J Kurnitski, J Palonen and O Seppänen

A deteriorated indoor environment causes various symptoms, sicknesses, sick leaves, reduced comfort and losses in productivity. When all these items are estimated on an economic basis, the cost of a deteriorated indoor environment is high. Several calculations have shown that many of the measures taken to improve indoor air quality and climate are cost-effective when the potential savings are included into the calculations as benefits. However, general models on how to estimate the cost-effectiveness of various measures and strategies are missing. Two workshops within the Healthy Buildings 2000 conference discussed how to include the effects of the indoor environment on productivity into such models. The paper presents an approach based on the work of the workshops and developed further.

1D2p3 Two distinct causal paths from indoor air problems to sickness absenteeism
JL Leyten and AC Boerstra

General sickness absenteeism literature states that problems in the work environment not only directly cause invalidating illness and therefore absenteeism but that they also decrease workers' loyalty to the organisation and therefore increase the probability of reporting ill and of postponing reporting well in the case of less serious illnesses. Published data indicate that the second causal path also plays a role in the case of indoor air problems.

1D2p4 Thermal comfort and productivity
KJ McCartney and MA Humphreys

This paper discusses the link between thermal comfort and productivity of office workers and presents some limited conclusions from a European field study of office buildings. The importance of productivity measurement and current methodologies of measurement are discussed and shortcomings highlighted. The paper concludes with an introduction to a new technology developed in Japan that may provide an alternative method of measuring productivity in the field.

1D2p5 Effect of thermal environment on productivity evaluated by task performances, fatigue feelings and cerebral blood oxygenation changes
N Nishihara, Y Yamamoto and S Tanabe

Subjective experiments were conducted in a climatic chamber to evaluate the effect of thermal environment on productivity. Chamber was conditioned at operative temperatures of 25 C, 28 C, or 33 C. Several computer tasks were given to the subjects to evaluate task performance. The effects of thermal environment on task performance were contradictory among the task types. According to the evaluation of subjective symptoms of fatigue, the subjects complained of the feeling of mental fatigue more at operative temperature of 33 C than 25 C and 28 C. The cerebral blood oxygenation was monitored by the near infrared spectroscopy. At operative temperature of 33 C, an increment in oxygenated hemoglobin, an increment in total hemoglobin, and a decrement in deoxygenated hemoglobin were found. Evaluation of fatigue feeling and monitoring cerebral blood oxygenation might be applied to the measurement of productivity.

1D2p6 Health, energy and productivity in schools: measures of occupant performance
PK Freitag, JE Woods, B Hemler, NP Sensharma, BA Penney and G Marx

In this age of accountability, school districts fail to consider how the poor conditions of their facilities affect teacher and student performance. The Health, Energy, and Productivity in Schools (HEPS) study introduces a questionnaire that extends medical and building sciences research. The teacher questionnaire includes classroom environment acceptability ratings, teacher and student health conditions, and changes in student performance. Relationships between thermal, acoustic, lighting, and indoor air quality exposures to the performance of teachers and students in elementary schools are linked for the first time quantitatively through this questionnaire. Teachers' questionnaire responses, exposure data, student quarterly grade reports and student standardized test scores are used to quantify the changes in indoor environmental quality and student performance between pre and post intervention conditions of each school and classroom. The questionnaire is being validated for use in future studies of schools, as well as to study performance and productivity in other settings.

1D2p7 The contribution of restoration and effective operation and maintenance programs on indoor environmental quality and educational performance in schools
MA Berry

There is a demonstrated link between effective facility management programs for cleaning and maintenance, and environmental quality of schools. The quality of the school environment, to include air quality, determines an overall sense of well-being, and shapes attitudes of students, teachers and staff. Attitudes affect teaching and learning behavior. Behavior in tern affects teaching and academic performance.

1D3o1 The effect of penetration factor, deposition, and environmental factors on the indoor concentration of $PM_{2.5}$ sulfate, nitrate, and carbon
TL Thatcher, MM Lunden, RG Sextro, S Hering, and NJ Brown

Indoor exposure to particles of outdoor origin constitutes an important exposure pathway. We conducted an intensive set of indoor particle measurements in an unoccupied house under differing operating conditions. Real-time measurements were conducted both indoors and outdoors, including $PM_{2.5}$ nitrate, sulfate, and carbon. Because the time-scale of the fluctuations in outdoor particle concentrations and meteorological conditions are often similar to the time constant for building air exchange, a steady state concentration may never be reached. The time-series experimental data were used to determine the effect of changes in air exchange rate and indoor/outdoor temperature and relative humidity differences on indoor particle concentrations. A multivariate regression was performed to investigate the difference between measured indoor concentrations and results from a simple time-dependent physical model. Environmental conditions had a significant effect on indoor concentrations of all three $PM_{2.5}$ species, but did not explain all of the model variation.

1D3o2 Micro-environmental model of personal exposure to particles and microbial aerosols
M Toivola, S Alm, T Reponen, S Kolari and A Nevalainen

The personal exposure and microenvironmental particle mass concentrations, absorption coefficient of filters (black smoke) and microbial concentrations were measured among 81 teachers of two municipals in Finland during wintertime 1998 - 1999. Samples were collected using 24-hour measurement periods in personal exposure and microenvironmental measurements in homes and 8-hour measurement periods in workplaces. The concentrations of personal particle mass exposures were higher than home or workplace concentrations. Absorption coefficients of personal exposure and workplace filters were on same level but they were higher than absorption coefficients of home filters. Microbial concentrations in workplaces were higher than home or personal exposure concentrations. The time weighed microenvironmental model was useful to assess absorption coefficient of personal exposure filters but underestimated personal exposure concentrations for particle mass and total microbes. Our study indicates that personal exposure deserves to be measured to assess the real exposure to bioaerosols and other particles.

1D3o3 The influence of building features on air exchange rate and particle penetration
RB Mosley and C Whitfield

Exposure to fine particles of outdoor origin continues to receive increased attention. Since people spend up to 90% of their time indoors, the relationship between indoor and outdoor fine particles has a large influence on their exposure. This paper discusses some measured values of particle penetration into an unoccupied research house under a variety of conditions. The effect of house tightness on air exchange rate and, consequently, on particle penetration is addressed. It is shown that air exchange rate can be reduced 90% by closing leaks. It is also shown that only particles with aerodynamic diameters in the range of 20 to 3000 nm enter the house in significant numbers. In this unoccupied research house, with no resuspension assumed, the deposition rate constant is shown to have minor influence on the steady state particle concentration.

1D3o4 Particle penetration through windows
D-L Liu and WW Nazaroff

This study aims to characterize the fractional penetration of airborne particles through windows, one of the important sites of air leakage through building envelopes. Two aluminum windows were evaluated, one with weatherstripping and one without. For each experiment, a finished window was mounted and sealed in a plywood panel that separated two well-mixed compartments. A small pressure difference was established between the compartments to induce a constant rate of airflow through leakage paths in the window. Particles were injected into one chamber and their concentrations were measured in both chambers. Two methods were employed to evaluate the size-resolved particle penetration: a steady-state method and a dynamic, concentration growth method. The results indicate that airborne particles of 0.2 to 3 mm penetrate through both test windows fairly effectively, while significant particle losses are observed for particles smaller and larger than this range.

1D3o5 Reducing particulate levels in houses
D Fugler and D Bowser

This study started as an evaluation of the effectiveness of different furnace filters in reducing the amount of airborne particulate in houses. The research quantified the filtration efficiencies of a range of residential furnace filters in several houses. The monitoring showed that even good filters had a relatively minor effect on house particulate levels during periods of occupant activity. Subsequent research has looked at alternative methods of lowering indoor particulates. This includes the relative effectiveness of various vacuum cleaners and a comparison of particulate levels in rooms with smooth floors versus rooms with carpets. The filtration effect of the building envelope on incoming air is being studied as well as the effect of house ventilation with and without outdoor air filtering using filtered air. It is likely that it will take a combination of these measures to eliminate high levels of house particulate.

1D3p1 Indoor, outdoor and regional profiles of $PM_{2.5}$ sulfate, nitrate and carbon
SV Hering, MM Lunden, TW Kirchstetter, TL Thatcher, KL Revzan, RG Sextro, NJ Brown, J Watson and J Chow

Fine particle concentrations were measured simultaneously at three locations: a regional monitoring site in Fresno, California, a backyard of an unoccupied residence in Clovis, California located 6 km northeast of the regional site; and indoors at the same residence. Measurements included 10-min determination of $PM_{2.5}$ nitrate, sulfate and carbon using an automated collection and vaporization system, and black carbon measured by light attenuation through a filter deposit. Specific outdoor $PM_{2.5}$ constituents were compared to assess the appropriateness of using regional data to model indoor concentrations from outdoor sources. The outdoor data show that, in general, the regional results provide a good representation of the concentrations seen at the building exterior. The indoor concentrations showed considerable attenuation as well as a broadening and time-lag for the

concentration peaks. The concentration reduction was the largest for $PM_{2.5}$ nitrate, which appears to undergo phase changes in addition to indoor deposition and penetration losses.

1D3p2 Characterization of particle types in modern offices
K Kruse, L Madsø, A Skogstad, W Eduard, F Levy, K Skulberg and K Skyberg

We studied particle types in six office buildings in Oslo. None of the buildings were identified to have "sick building" problems. 20 samples in one of the office buildings were analysed for bacteria and fungal spores by fluorescence microscopy (FM). 32 samples in 6 office buildings were analysed for fungal spores, chemical particle types and particle size by scanning electron microscopy (SEM) with energy dispersive X-ray spectroscopy (EDS). The particles were divided into four different size groups: > 10 µm, 5-10 µm, 1-5 µm and < 1 µm. No bacteria and fungal spores were found. The following particle types were recognized: concrete, gypsum, other mineral particles, metallic, iron oxide, other inorganic particles, skin scales, organic fibres, other organic particles and aggregates of small particles (probably diesel exhaust and soot). Particles < 1 µm could not be classified because chemical typing was not possible due to their small size. As expected the particle concentration dramatically increased for finer particle classes

1D3p3 Indoor pollutant measurement and modeling comparing impact of surface characteristics
WX Braun, BA Cicciarelli, DL Davidson, EH Hart, A Luedtke, K McIntosh, and PR Peoples

It is estimated that Americans spend 90 percent of their time indoors and there has been an epidemic increase in asthma and allergy worldwide. These observations have driven debate on the role of carpeting and its impact on indoor air quality and health. This paper reviews studies, employing computational fluid dynamics modeling, to elucidate the interaction of dust mite antigen (modeled as spherical particles) with soft vs. hard flooring surfaces and their ability to allow resuspension into the breathing zone. We have found, contrary to conventional wisdom, carpet can play an important positive role in the health of an indoor space. Quantitative results indicate carpet can function in a filter-like capacity by trapping and holding particulate matter out of the breathing zone. When used in combination with proper maintenance and cleaning equipment, carpeting may function to maintain and improve a healthy indoor air environment.

1D3p4 HEPA air filtration: an effective method of reducing household pm exposure
K White, S Smith and P Dingle

Carpeted bedrooms of 36 asthmatic children were monitored to examine the mass concentration of indoor aerosol particulate matter (PM), from non-smoking households, and the effect high efficiency particle arresting (HEPA) air filtration had on PM concentration. Concurrent indoor and outdoor monitoring was also undertaken. Mass concentration was determined gravimetrically using time weighted concurrent virtual impaction sampling. Indoor PM mass concentration was higher than outdoor PM mass concentration. The intervention reduced PM mass concentration in the air-filter group by approximately 50% ($P<0.01$); with mean indoor PM_{10} and $PM_{2.5}$ mass concentrations falling from 42mg m^{-3} and 25mg m^{-3} to 21mg m^{-3} and 14mg m^{-3} respectively. PM mass concentration remained low for the length of the experiment while the control group PM mass concentrations fluctuated throughout the monitoring period.

1D3p5 The indoor fine particulate organic carbon measurement artifact in Seattle
CS Claiborn, Y Pang, L Gundel, TV Larson and LJS Liu

The objective of this work was to compare indoor and outdoor concentrations of fine particulate organic carbon (OC) and elemental carbon (EC), determined from undenuded quartz filters. $PM_{2.5}$ samples were collected in Seattle at a central site and indoors and outdoors at private residences between February 22 and May 25, 2000, and analyzed for OC and EC content. Indoor and outdoor denuded quartz filters were also analyzed for OC and EC. Indoor OC sampled onto undenuded quartz filters was typically higher than outdoor OC, while outdoor EC was higher than indoor EC. For denuded quartz filters, the indoor OC was not typically higher than the outdoor OC. Indoor OC mass collected on an undenuded quartz fiber filter frequently exceeded the $PM_{2.5}$ mass collected on a Teflon filter. This anomaly results from a positive sampling artifact from the adsorption of semi-volatile organic components from the vapor phase onto quartz filters.

1D4o1 Assessment of subsurface vapour transport through triassic sandstone and quarry fill into indoor air in Weston Village, Runcorn, UK
T McAlary, P Dollar, P deHaven, G Wilkinson, R Moss, J Llewellyn and D Crump

Subsurface vapour intrusion into indoor air by volatile organic compounds (VOCs) associated with contaminated land is a potential exposure pathway of increasing interest. This paper describes a comprehensive case study of this pathway, including: indoor air quality (IAQ) monitoring at 0.003 parts-per-billion (ppb) quantitation limit (QL), a detailed geologic characterization, extensive subsurface vapour sampling and analysis, pneumatic testing at the laboratory and field scales,

building pressure and ventilation studies, a comprehensive statistical analysis of the vapour attenuation coefficient ("alpha factor"), and a comparison to the USEPA spreadsheet version Johnson and Ettinger (1991) model. The results show that the vapour concentrations in indoor air are dramatically influenced by the gas permeability and structure of the subsurface geologic materials. Properties built on the sandstone bedrock had IAQ that was barely distinguishable from outdoor air quality (OAQ); whereas, properties built on poorly consolidated quarry spoil backfill typically had IAQ 2 to 3 orders of magnitude more concentrated than OAQ.

1D4o2 Estimating indoor air exposure to VOCs from subsurface releases - field methods and model limitations
PM Krasnoff, PE Morris and RE Roat

Exposure to carcinogenic volatile organic compounds (VOCs) poses a potentially significant risk due to vapors associated with migrating subsurface releases of chlorinated solvents. The evaluation of the cancer risk associated with subsurface releases is generally estimated using fate and transport models adopted by the USEPA, i.e., Johnson-Ettinger model. Field verification of the Johnson-Ettinger model has identified that it underestimates exposure concentrations up to 1000 times especially through the use of default parameters. The model is characterized as a non-deterministic numerical model that requires evaluation of site-specific parameters and performance of sensitivity analyses. Field methods have been developed and tested that result in more reliable exposure evaluation techniques. Data from field studies in varying soil and atmospheric conditions have been evaluated to generate more representative estimates of exposure concentrations.

1D4o3 Efficacy of sub-slab depressurization for mitigation of vapor intrusion of chlorinated organic compounds
DJ Folkes and DW Kurz

Active soil depressurization systems have been installed in over 300 residential homes in Denver, Colorado to control indoor air concentrations of 1,1 DCE resulting from migration of vapors from groundwater with elevated DCE concentrations. Over three years of monitoring data have shown that these systems are capable of achieving the very high reductions in concentrations necessary to meet the concentration levels currently mandated by the State regulatory agency. Prior to installation of the system, 1,1 DCE indoor air concentrations ranged from below the reporting limit of 0.040 ug/m^3 to over 100 ug/m^3. Post-mitigation monitoring showed that most 90 watt fan, single suction-point systems were able to reduce 1,1 DCE concentrations by 2 to 3 orders of magnitude to below the State mandated levels. Approximately, 1/4 of the systems required minor adjustment or upgrading after initial installation in order to achieve the levels.

1D4o4 Background concentrations of selected chlorinated hydrocarbons in residential indoor air
JP Kurtz and DJ Folkes

Groundwater plumes containing volatile organic compounds are a potential source of organic vapors in indoor air. At the same time, many household products and building materials are known to be sources of background VOCs in indoor air. More than 2000 pre- and post-remediation indoor air samples have been collected in residences at a site in Denver, Colorado. These were collected over 24-hours in passivated SUMMA canisters and analyzed by EPA Method TO-14/15 using part per trillion detection limits. An evaluation of background concentrations of 8 chlorinated VOCs in this database was performed. The data were screened to exclude site-impacted results by evaluating VOCs in homes with vapor intrusion mitigation systems that successfully reduced concentrations of the principle groundwater contaminant, 1,1-DCE, by up to three orders of magnitude. Based on over 280 background residential indoor air samples from nearly 100 residences, the results provide well-characterized background concentrations for these chlorinated hydrocarbons.

1D4o5 Assessment of the uncertainty of measurement results of hexachlorobutadiene in indoor air
T Hafkenscheid and G Wilkinson

Within the frame of the development of a method for the measurement of concentration levels from 0.003 to 10 parts per billion by volume of hexachlorobutadiene in indoor air an assessment has been performed of the uncertainty of the measurement results. This assessment - fully based on the principles of the ISO Guide to the Expression of Uncertainty in Measurement (ISO-GUM) - has shown that – even for the measurement of such extremely low concentrations – uncertainty levels of < 25% (95% confidence) are achievable.

1D4p1 Background indoor air risks at selected residences in Denver Colorado
SJ Foster, JP Kurtz, and AK Woodland

Groundwater contaminated with 1,1-dichloroethene (1,1-DCE), trichloroethene and 1,1,1-trichloroethane was the source of chemicals migrating into indoor air in an area of Denver Colorado. The affected dwellings were successfully remediated by sub-slab depressurization, using 1,1-DCE as an indicator. Indoor air from 427 samples were analyzed using EPA Method TO14/15 in Selective Ion Monitoring mode for 1,1,1-trichloroethene, 1,2-dichloroethane, dichloromethane, trichloroethene,

vinyl chloride, benzene, chloroform and tetrachloroethane. The data were used to determine background indoor air risks assuming residential (30-year) exposure. Background single compound and summed cancer and noncancer risks were estimated. The maximum single compound risks were highest for chloroform and benzene both at risks of two in ten thousand ($2x10^{-4}$). The maximum summed risk was $2.4x10^{-4}$. The data for all eight compounds were log normally distributed. Also included are summary statistics applicable for risk assessments using Monte Carlo analysis where background indoor air risk subtraction is required.

1D4p2 Risks to indoor air quality from volatile organic compounds in groundwater
A Barnard, CIH, CSP, L Breyer, CIH, and J Cowart, PE

This paper describes an approach developed to address the impacts of volatile organic groundwater contaminants on indoor air quality. The use of this approach at a site in Denver, Colorado is described. A conceptual site model is developed, contaminants of concern are identified, and risk goals are established. Predictive tools are discussed as well as sampling and analytical protocols. The potential for background contamination from other sources is evaluated. Interim remedial measures and final remedy options are then developed. A summary of recent regulatory action is also presented. The paper introduces recent U.S. Environmental Protection Agency draft guidance (EPA, 2001) which, if adopted, would require predictive modeling, indoor air sampling, and potentially indoor air remediation at a large number of groundwater solvent contamination sites throughout the U.S.

1D4p3 Sampling of hexachlorobutadiene in the air of homes at a site contaminated by industrial waste in England
D Crump, V Brown, J Rowley, J Llewellyn, G Wilkinson and R Moss

As part of an assessment of the legacy of more than 160 years of industrial activity on and around the former ICI Runcorn site in Northwest England, a borehole investigation was undertaken around the edge of quarries formerly used as a disposal site. Hexachlorobutadiene (HCBD) was found at levels that gave cause for some concern in respect of air quality in neighbouring properties. ICI then worked with BRE to develop and implement a programme of indoor air monitoring. Initially an investigation of 240 buildings in Weston Village was undertaken using a technique developed for occupational monitoring of HCBD. Subsequently further monitoring of 145 buildings was undertaken over a 15 month period using a more sensitive sampling and analytical method. This paper describes the sampling strategy and findings. The study demonstrates the role of indoor air monitoring in the process of assessing risks from volatile organic compounds (VOCs) present in contaminated land.

1D4p4 Quality control and quality assurance procedures used during the indoor air quality monitoring programme in Weston Village, Runcorn
G Wilkinson, R Moss , D Crump, V Brown, J Rowley, T Hafkenscheid, R Kearn, A Carp, J Kristensson, P de Haven, P Dollar and T McAlary

As part of an assessment of the legacy of more than 160 years of industrial activity around the former ICI Runcorn site, an indoor air quality survey of 145 properties in Weston village, Runcorn in Northwest England was performed. Two redundant quarries near the village had been used for the historical disposal of chemical waste from about 1930 until the 1970's. A borehole investigation showed concentrations of hexachlorobutadiene (HCBD) in the subsurface that had the potential to impact air quality in neighbouring properties. The Building Research Establishment (BRE) and QinetiQ developed an analytical method (Crump et. al., 2002), with a linear working range of 0.003 parts-per-billion by volume (ppbv) to 10 ppbv, and the development work has been peer reviewed. This paper describes the importance of detailed quality control (QC), quality assurance (QA) and peer review procedures to ensure that air quality monitoring data meets data quality objectives and the expectations of all stake holders.

1D4p5 A new method for measurement of the intrusion of VOCs to indoor air from contaminated soil
K Fuglsang

This paper describes a new method for determination of the intrusion of VOCs from polluted soil to indoor air. The method uses an inert film to cover an area of the floor where intrusion from contaminated soil occurs. With the method, measurements of the emission can be performed on irregular surfaces such as concrete floors with cracks and pipe penetrations. From the results of laboratory and field measurements, the precision of the method is estimated to be fully acceptable for field applications. The results showed a good agreement with the flux calculated from prediction models, especially on concrete floor areas where diffusive transport is dominant. It is concluded that the method has a high potential as a tool for quantifying the intrusion from "hot spots", e.g., where cracks occur in concrete floors located at highly contaminated zones.

1D5o1 VOC- and SVOC-emissions from adhesives, floor coverings and complete floor structures
O Wilke, O Jann and Brödner

VOC/SVOC-Emissions from materials for flooring installation (primer, screed, adhesive, floor covering) were measured by means of emission test chambers and cells over a time period of at least 28 days at 23 C, 50 % relative humidity and an area specific air flow rate of q = 1.25 m^3/m^2h. Single components were tested in comparison to three complete structures (same concrete, primer, screed, adhesive) with different types of floor covering (PVC, carpet, linoleum). Sorption into concrete/screed and different sealing by the flooring materials affected the emissions from the complete structures. The complete structures with linoleum and PVC showed the same emissions and emission rates as the flooring materials alone. Emissions from the carpet-covered structure resulted mainly from the lower layers. For two adhesives the formation of secondary emissions (aldehydes and organic acids) was observed starting after the standard testing time of 28 days.

1D5o2 Floor heating may cause IAQ problems
A Sjöberg and Lars-Olof Nilsson

Moisture distribution in five different floor constructions has been evaluated theoretically, and the risk of alkaline hydrolysis of the floor adhesive has been assessed. Degradation of the floor adhesive due to alkaline hydrolysis may cause elevated, secondary emissions from the floor. The evaluation has been made both qualitatively and quantitatively, and for the sake of clarity the results are presented in figures. In the study, the difference between permeable and impermeable floor coverings on the same floor construction has been evaluated, and it has been found that the impermeable floor covering consistently poses a greater risk of moisture damage. In two cases the risks due to floor heating have been evaluated, both when the heating is installed during construction and when it is retrofitted. The results show that floor heating markedly increases the risk of moisture damage and thus elevated emissions.

1D5o3 Preliminary study of flooring in school in the U.S.: airborne particulate exposures in carpeted vs. uncarpeted classrooms
RJ Shaughnessy, B Turk, S Evans, F Fowler, S Casteel and S Louie

Data sets from 16 schools (grades K-6 and a Junior High), spanning 5 southwestern states in the USA, have been analyzed to examine classroom airborne particulate levels and the buildup of contaminants on flooring systems. The data have been collected from 2 separate sites (one carpeted, one hard flooring) within each of the schools. Measurements included indoor/outdoor airborne particulate mass concentration ($PM_{2.5}$), indoor/outdoor particulate counts (> 0.5 microns), and CO_2/T/RH to characterize ventilation in the classrooms. The study must be considered more of a preliminary survey due to the limited number of schools examined. A comparative analysis of the data sets suggests that school carpeted floor covering may present an increased exposure risk to children from particulate matter harbored on the flooring material as compared to hard-surfaced flooring. The study emphasizes the need for fastidious maintenance of all types of floor coverings in schools.

1D5o4 A comparison of biocontaminant levels associated with hard vs. carpet floors in non-problem schools: results of a year long study
K Foarde and M Berry

Choosing the appropriate floor surface for a school environment is a complex issue. To assist school personnel in determining which flooring is best for their school, we studied the biocontaminant levels associated with carpeted and hard surface flooring. Two schools, as similar as possible with the exception of their floor coverings, one predominantly tiled and one predominantly carpeted, were selected. Neither school was a 'problem' building. Multiple biocontaminants were measured. For flooring, there were statistically significant differences for all the tested contaminants except fungi. The carpeted surfaces, being strong sinks, contained higher levels of the contaminants except for fungi. However, airborne allergen levels were significantly higher over hard floors than over carpeted floors. Significant differences were found for spores, fungi, and dust mass. The results suggest that carpet floor covering was not the major contributor to airborne levels of biocontaminants in these two non-problem schools.

1D5o5 Textile floor covering as part of indoor environment
IE Dahl, SB Holøs and SK Nilsen

To be able to compare textile floors to hard floors (linoleum) and their influence on the indoor environment, a project was initiated in an office building. Textile floor covering tiles were installed in four offices. Six similar, neighbouring offices having linoleum flooring were chosen as references. Measurements of airborne particles showed only minor differences between rooms with textile floors and rooms with hard floors. Dust deposition rates were lower in rooms with hard floors than in rooms with textile floors. The proportions of viable micro-organisms in dust were on average lower in samples from hard

floors than in samples from textile floors. Cost calculations showed that cleaning and maintenance costs are higher for textile floors than for floors covered with linoleum.

1D5p1 Real-time measurement of (PM_{10}) dust levels in a carpeted and non-carpeted school gym room
WA Turner, SC Caulfield, T Ellis and R Lewia

During the snow-covered period of 2000 to 2001 real-time (10-min. avg.) particle data were collected in two school gyms for fifteen weeks in Kennebunk, Maine, USA. VCT (Vinyl Composition Tile) floor covering was installed in one facility and VCTT (Vinyl Cushioned Tufted Textile) floor covering, referred to as a specialty high-grade commercial "carpet", was in the other. Intensive one-minute data was also collected during three "experiments" which evaluated the measured effect of typical sweeping, vacuuming, and burnishing of VCT. The effect of "cleaning" activities and occupancy can readily be observed in the data sets. From the data it can be concluded that: dry sweeping hard-surface floors should be avoided, advances to contain breathable dust during burnishing activities are needed, and that modern vacuum cleaning devices likely produce the least impact on indoor air quality. In the two rooms studied, monitored (PM_{10}) dust levels were similar in the hard and soft-surface floors. The data points to a need to further understand factors that affect particle exposures in schools.

1D5p2 Contaminants in residential floor dust
A Hedge, AA Kline, AT Lemley, SK Obendorf, T Dokuchayeva, and V Gaskins

Indoor dust levels of eighteen pesticides, biological contaminants, lead and ambient conditions were measured during summer and winter seasons in 42 homes in central New York State. Floor dust samples were obtained by vacuuming carpet and hand vacuuming and wet wiping adjacent smooth floor. Pesticide levels were higher in carpet dust than smooth floor dust. Dust mite allergen levels were higher in carpet dust than smooth floor dust, but only for summer samples. Fungal levels were higher in smooth floor dust than carpet dust. Lead levels were lower for summer than winter and unaffected by flooring. Bacteria counts were higher during summer than winter and unaffected by flooring. Cat allergen levels were higher in homes with cats but unaffected by flooring. Cockroach allergen levels were low and unaffected by flooring.

1D5p3 Indoor air pollution by volatile organic compounds (VOC) emitted from flooring material in a technical university in Switzerland
R Reiser, A Meile, C Hofer and R Knutti

A case study was conducted at a technical university where employees and students complained about deteriorated indoor air after the building had been renovated. Some employees even suffered from sickness and headache. Indoor air concentrations of total volatile organic compounds (TVOC) were elevated in both laboratory halls and reference rooms. Concentrations of most chemicals decreased considerably after six months. The smell intensity decreased in parallel but still was rated as highly annoying. The source of the odorous compounds and most probably of the health problems was identified to be the vinyl (PVC) flooring. The vinyl flooring emitted, among others, phenol and 2-ethylhexanol. Emission factors correlated inversely with the frequency of room usage. The results provide an example of the use of unsuitable building products with respect to healthy indoor air. In future projects it is suggested to focus on the effect of co-exposure to multiple component mixtures of pollutants.

1D5p4 Effects on health related symptoms of carpet removal and ventilation improvement in eleven schools - a controlled intervention study
HM Mathisen, JA Jenssen and R Johnsen

An intervention study was carried out in eleven elementary schools in Trondheim, Norway. Three schools with poor ventilation standard, four schools with carpets, and four reference schools participated. Carpets were replaced by vinyl flooring and the poor ventilation systems were upgraded. Altogether 1100 children aged twelve to thirteen years and 400 teachers were all included in the study. The baseline registration of health related symptoms was performed during January/February 1997. The questionnaires were repeated, after the interventions, in February 1998 and 1999. The questionnaire used corresponds to questions in the Örebro questionnaire, but was adjusted to be performed with three repetitions during two weeks. In addition, a questionnaire on symptoms and asthma management to identify hypersensitive children was used in 1998 and 1999. Compared to reference schools the results from the intervention schools showed that the number of health related symptoms were reduced for both children with and without hypersensitivity.

1D5p5 Variant indoor fungal levels in residential environments following a cleaning intervention on carpets and soft furnishings
CD Cheong, HG Neumeister-Kemp, PW Dingle and GSJ Hardy

Changes in indoor fungal levels in residential environments were investigated over a 16-week study period following a cleaning intervention on carpets and soft furnishing. Comparable indoor and outdoor air quality and fungal levels were observed in the study homes. On average, the test homes had a 26% reduction in airborne indoor fungal levels, and a 28% reduction in corresponding outdoor levels. Data did not reveal substantial verification that the cleaning intervention resulted in reductions in indoor fungal levels, rather that the variant indoor fungal levels could be attributed to changes to fluctuations in outdoor levels.

1D5p6 Indoor monitoring of homes with wool carpets treated with Permethrin
E Berger-Preiß, K Levsen, G Leng, H Idel and U Ranft

Textile floor coverings with wool are usually treated with the moth repellent permethrin, an insecticide belonging to the pyrethroid group, to protect against insect damage.To clarify whether this may cause adverse health effects, we investigated the indoor exposure to permethrin in 80 private homes with wool floor coverings (monitoring of permethrin concentrations in wool fibers, house dust, and on suspended particles in the air). Furthermore, three permethrin metabolites were determined in the urine of the inhabitants.The permethrin concentrations found in house dust ranged from <1 to 659 mg/kg. The concentrations observed in the air varied between <1 and 15.2 ng/m³. Correlations between house dust permethrin concentrations and permethrin concentrations in the air were not found. The metabolite concentrations determined in the urine of the inhabitants were in the same range as those of the general population.

1D5z1 Two types of carpet with reduced house dust mite prevalence
SK Brown

Live mite and allergen levels were determined during autumn in “flock” carpets in 11 buildings in Melbourne, Australia. Mite levels in “traditional” carpets in adjacent rooms were also measured. Subsequently, the flock carpets were professionally cleaned and measurements were repeated. Flock carpets were found to support mite populations at levels of significance to asthmatics, but this was linked to the presence of traditional carpets inhabited by mites. Four buildings which contained only flock carpets exhibited very low mite levels. Cleaning did not remove mites or degrade allergen from flock carpets, but it removed 90% of allergen. In another study, samples of traditional wool carpet with and without a new method for applying permethrin were exposed in a residence for 15 months. Live mite levels were similar in the carpeted floor and untreated carpet, but were significantly lower in the treated carpet, showing it was less favourable for mite habitation.

1D6o1 Air-conditioning in nursing homes till death do us part?
PG Luscuere and V Borst

Heat wave periods coincide with raised levels of mortality in general and particularly among in-patients in nursing homes. There are several studies which confirm this phenomenon, among them one in The Netherlands (Borst, Schols and Mackenbach, 1997; also Mackenbach, Schols and Borst, 1997). This study showed the correlation between mortality rates and the weekly average of maximum daily ambient air temperatures at intervals of 5 ºC. As mortality rates were more evidently raised in hot periods the correlation with specifically the hot period (summer 1994) was analysed in more detail. The correlation is striking, with a correlation factor of R^2= 0.8988. This result generates the question as to what extent nursing homes should be equipped with air-conditioning even in moderate climates, and provides a start towards a quantification of indoor temperature limits in heat wave periods.

1D6o2 Thermal sensation and comfort with transient metabolic rates
T Goto, J Toftum, R de Dear and PO Fanger

This study investigated the effect on thermal perceptions and preferences of controlled metabolic excursions of various intensities (20%, 40%, 60% relative work load) and durations (3-30 min) imposed on subjects that alternated between sedentary activity and exercise on a treadmill. The thermal environment was held constant at a temperature corresponding to PMV=0 at sedentary activity. Even low activity changes of short duration (1 min at 20% relative work load) affected thermal perceptions. However, after circa 15 min of constant activity, subjective thermal responses approximated the steady-state response, after both up-steps and down-steps of activity.

1D6o3 Double skin façade and hybrid ventilation of the ING house Amsterdam (ING Bank HQ)
J van Meurs and PG Luscuere

The ING-HQ is characterised by a full transparent 2nd skin façade. This transparency in combination with high indoor temperature requirements and the wish for low energy consumption was an interesting design challenge. The cavity between inner and outer façades can be ventilated in a controlled way using glass vents to: either discard excess heat or for hybrid ventilation. Interaction between active façade and climate system results in an intelligent building. The big amount of glass was only acceptable in case of very low solar energy transmittance (g-value). TNO Building and Construction Research (Delft, The Netherlands) did research to check our prognosis. The "Advanced Window Information System", was used in combination with the CFD code WISH-3D. Validation of the CFD-model for this specific situation was done by laboratory measurements in a full-scale model. The g-value measured in the laboratory proved to be 0.07. After corrections a practical value of 0.08-0.11 was derived.

1D6o4 Thermal comfort - thermal mass: housing in hot dry climates
IA Meir and SC Roaf

The concept of thermal mass as a means of ameliorating diurnal temperature swings seems to be ideally suited for hot dry regions, which are characterized by wide daily temperature fluctuation in summer, and a considerable number of sunny days in winter. Furthermore, recent years in Israel (and the Middle East in general) have been following a worrying pattern of climate changes and "freak" weather events. Under such conditions, within an energy market where demand grows faster than supply, and with an ever increasing awareness of the environmental consequences of uncontrolled energy consumption patterns, thermal mass and its storage potential seem to be one of the most appropriate strategies to deal with energy conservation and thermal comfort issues within the broader framework of indoor air quality (Givoni, 1976).

1D6o5 Dynamic building energy modeling: the significance of tuning based on measurements
M Colombari, M Kragh, M Zobec, M De Carli, A. Franceschet and R Zecchin

The rising attention paid to environment, energy savings and thermal comfort in buildings leads to investigate new solutions for HVAC systems and façade types. During the design process, building energy models provide a useful means to study parameters and alternative solutions. Nevertheless, such models must always be validated with measurements. To this aim measurements of temperature, relative humidity and fuel consumption are becoming increasingly important. The present paper describes three full-scale test rooms with different thermal plants and façade types, which are monitored in terms of energy consumption and environmental conditions. The test rooms have been modelled by means of two transient simulation software tools and the results are compared with measurements.

1D6p1 Numerical and experimental investigation of the conditions in the double solar energy facade
M Jaros, R Gorny, P Charvat, J Katolicky and J Sedlak

The paper deals with the numerical modeling and on-site measurements of the thermal conditions in the solar energy facade of the Moravian Library building in the city of Brno, Czech Republic. The numerical computations were done with the aim to determine the operation parameters of the facade, in particular the air temperatures and velocities. The obtained results show that the facade enables preheating of supply air in winter up to 15-20 C so that it can be directly used for building ventilation. During summer season, free ventilation is able to detract the whole solar gain impacting the facade. The air velocities in the facade do not exceed 1 $m.s^{-1}$ and so the noise generation does not occur. The facade is therefore able to improve the inner environment and indoor air quality without additional energy costs.

1D6p2 Energy consumption and thermal comfort for domestic buildings in Seiyun, (Yemen)
FH Al-Shibami and IC Ward

In Seiyun, like other old Yemeni cities, most of the houses of the region were built using the traditional materials of sun dried mud bricks. In order to improve construction time, concrete is used extensively for new dwellings but this does not have the equivalent thermal properties of traditional bricks. Given the variations in climate between hot dry summers and cool winters there is a suggestion that the resulting thermal comfort experienced inside the traditional and new house type will vary. Due to increased energy consumption in the Yemeni domestic sector, energy utilization and efficiency also require urgent review. This paper investigates thermal comfort and compares the amount and use of heating and cooling equipment fitted in three different construction types: Traditional, New Mud and Concrete. This case study was carried out in the summer of 2001 in Seiyun utilising measuring equipment and verifies that traditional building is the best.

1D6p3 Program of energy audit for residential and public buildings
B Petrov, I Puikevica-Puikevska and N Zeltinsh

A programme "Energy Audit" has been developed at the Institute of Physical Energetics (IPE) based on the energy balance of a building that allows estimating the technical and economical characteristics of measures taken in order to improve the thermal features of building envelopes. By request of the Ministry of Environmental Protection and Regional Development of Latvia and by means of this programme the parameters of thermal modernisation were determined for more than 1,200 public buildings under the auspices of local municipalities. As a result of these calculations both the potential economy of thermal energy and the amount of insulating materials were determined, as well as the investments required for the implementation of thermal modernisation. The programme ²Energy Audit² is supposed for the use in mapping out business plans designed to carry out thermal modernisation and the energy audit of buildings in Latvia.

1D6p4 The exploitation of solar energy for energy-saving in ventilation
P Charvat and M Jaros

Solar preheating of ventilation air has the potential significantly to reduce energy consumption for heating of ventilation air. The paper deals with the investigation of the performance of solar air systems. The investigations were carried out by means of long-term on-site measurements lasting several years. The data acquisition systems were installed in three buildings employing solar energy, located in and around the city of Brno in the Czech Republic.

1D6p5 Optimization of energy performance of solar system using hybrid collector
M Yoshinaga and M Okumiya

Utilization of solar energy is effective as an energy conserving measure in improving and maintaining thermal quality of indoor air. Thus photovoltaic/thermal hybrid collectors are considered in this paper. A hybrid collector is composed of a single-cover, an absorber integrated with silicon cells, an air duct, and back insulation. We proposed and simulated two different systems each with 27.6 m^2 hybrid collectors. One has a pebble bed and an auxiliary ambient-source heat pump, and the other has a pebble bed and an auxiliary dual-source heat pump to select storage or ambient air as heat source. In both systems, solar thermal energy is used for hot water supply as well as heating. We simulated other three systems, two non-hybrid systems, each with flat plate collectors and solar cells, and a non-solar system, for comparison. As a result, the hybrid solar system with the ambient-source heat pump showed the highest performance.

1D6p6 Practical application of energy conservation with ASHRAE Standard 62
WBM Stanley and CO Muller

The Indoor Air Quality (IAQ) Procedure described in ASHRAE Standard 62 is an alternative and often neglected method for complying with the ventilation requirements of the standard. Practical applications of the IAQ Procedure are presented to show that filtration can effectively achieve acceptable air quality as well as reduce outdoor air requirements thus saving energy required to condition ambient air. Requisite information for applying the IAQ Procedure was obtained from published studies of similar building types, government databases of contaminant concentrations, and investigations of building HVAC systems. The example buildings presented here were able to realize significant capital and HVAC equipment and system renovation savings as well as energy savings by employing the IAQ Procedure. In times when energy conservation is at the forefront of many peoples' minds, the IAQ Procedure should be considered as a proven option to lead down that path.

2A1o1 Case studies of the role of research in the development of indoor air policies
L Bero

In the United States, the development of risks assessments and regulations involves reviewing scientific literature, preparing a draft report, collecting written and oral public commentary, and revising the report based on the commentary. We conducted case studies of the development of the California environmental tobacco smoke risk assessment and Washington and Maryland indoor air regulations to describe the role of the public commentary in the process. We used content analysis to examine the sources, quantity and quality of arguments presented by supporters or opponents. We also examined the type and quality of publications cited to support the arguments. Opponents dominated the public commentary. Supporters and opponents used different criteria to evaluate science and different bodies of evidence to support their claims. Opponents used lower quality evidence to support their arguments than supporters. Disagreement among experts during public testimony reinforced the uncertainty of the data.

2A1o2 The construct of comfort: a framework for research
WS Cain

How we view comfort in scientific terms will determine how we study it. The intuitive model of comfort implicit in research and guidelines until now adapts poorly to failure and to integration across sensory domains. Almost any explicit model will entail recognition of comfort as a construct, not measurable per se, but seen through manifestations. The explicit model can mix physical and nonphysical variables, can accommodate relationships between constructs, and indeed will encourage the search for explanatory constructs, such as health status and vulnerability to discomfort. Structural equation modeling provides a means to analyze interactions between constructs (latent variables) and motivates formalization of the process of discovery.

2B1o1 A risk assessment approach to controlling *Legionella* bacteria
M Hodgson

Legionella bacteria, the etiological agent of Legionellosis, are environmentally sourced organisms. The range of environmental sources associated with the bacteria is constantly increasing as new cases emerge, and epidemiology and environmental investigation techniques improve. As a system owner and operator it is incumbent upon you to identify the potential risk systems and take suitable action to minimize the risks. The level of action taken should of course be proportional to the risk, with the greatest level of resources being directed to the systems that present the highest risk. This paper presents some of the basics of risk assessment that have been learnt over several years applying the United Kingdom Health and Safety Commission's Approved Code of Practice for the Prevention or Control of Legionellosis (L8) (Health and Safety Commission, 2000).

2B1o2 Development and validation of a design tool for avoiding mould growth in dwellings to provide a validation method for the performance based New Zealand building code
MJ Cunningham

The development and validation of a design tool for avoiding mould growth in dwellings to provide a validation method for the performance-based New Zealand Building Code is described. Since heating in New Zealand dwellings is intermittent and humidity is uncontrolled the design tool was based around simplifying indoor and outdoor temperature and humidities to sinusoids. The model was validated with a field study during the winter of 2000 using 21 houses. The "moisture lifestyle" of people was assessed by a telephone survey of 613 houses around New Zealand. An important relationship between the number of showers taken per week and the number of bedrooms in the house was uncovered. The design tool takes the form of nomograms that enable the designer to set ventilation levels required to avoid mould growth according to the level of insulation and heating, and according to location and building envelope design.

2B1o3 Hospital airborne infection prevention (HAIP)
G Flatheim

May 2000 a Norwegian group started to develop a new concept for control of air movements in protection isolates, operating theatres and other risk areas in hospitals. The HAIP project focuses on air movements as a whole – not only through the ventilation system. Outdoor conditions and thermal forces (weather, wind etc.) decide the degree of transportation of air and contamination from room to room – from façade to façade – from floor to floor. Due to thermal forces bacteria and viruses can move from the rooms and up to the space above the suspended ceilings. This space can therefore become a pathway for transportation of both contamination and infections. Through HAIP we will develop a system for total control of air movements – in and outside the ventilation system, above and below the suspended ceilings and through doors and other openings in walls.

2B1o4 How public agencies address indoor mold hazards in California
JM Waldman, JM Macher, S McNeel, E Wersinger and D Gilliss

In California, local and state agencies are facing an increasing demand for information, guidance, and enforcement on indoor environmental quality. This paper presents results from a survey of local (county and city) environmental health agencies of the types and magnitude of their services to the public regarding requests for assistance on mold complaints. While agency responses vary throughout the state, upon request most provide verbal or printed information on the potential health effects of mold and recommendations for its remediation. Queries to the State IAQ program, as indices of public concern, continue to rise; phone volume has increased nearly ten-fold since 1997, while Internet visitors have tripled in the past two years. New California regulations are pending on exposure limits, remediation guidelines, disclosure requirements, and enforcement for indoor mold.

2B1o5 A practical guideline for evaluating moisture damaged buildings
T Syversen, J V Bakke, O Bjørseth, L N Johannessen and M Løvik

Numerous complaints were received a short time after a new building at the university campus was taken into use. Evaluation of and measurements in the building indicated abnormal growth of moulds. The university asked a panel to review the scientific issues involved and to provide a set of guidelines on how administrators and health officials should meet similar problems in the future. The panel reviewed the issue and suggested a set of practical guidelines to be followed in such cases. The key recommendations were: Moisture exposure during construction and operation of buildings must be avoided Moisture damaged buildings may cause serious and chronic health effects Proper planning, construction and maintenance procedures of buildings is critical in order to prevent moisture damage Suspected moisture damage should be inspected prior to any chemical or microbiological sampling and analysis. If inspection confirms moisture damage, corrective measures must be taken immediately under proper protective measures.

2B1o6 A case study for proactive health care construction management to prevent indoor air pollution
AJ Streifel and M Mazzarella

Construction in healthcare facilities is a major risk for airborne agents infecting immune compromised patients. Standard air quality analysis has included air sampling for airborne fungi. These culture data require weeks for transport, incubation and identification. During a demolition and construction of a new medical facility an infection control risk assessment(ICRA) determined pre-construction precautions and surveillance methods. The surveillance utilized real time air particle analysis and culture methods to determine relevant indicators of potential hazards. The results show little correlation of air analysis and patient infection outcome due to variable conditions. Proactive measures such as filtration verification, entrance door maintenance, pedestrian dirt control, street cleaning and patient education are valid for minimizing exposure. Employee education is an essential component and lack of such a measure may have created an unusual infection situation during the demolition phase of the construction project.

2B2o1 Health, energy and productivity in schools: overview of the research program
JE Woods, BA Penney, PK Freitag, G Marx, B Hemler and NP Sensharma

A research program has been initiated to focus on obtaining quantitative data in existing elementary schools through a longitudinal study with controls, interventions, and cross-sectional components. The overall objective of this program is to quantify the effects of simultaneous control of indoor exposures (i.e., thermal, indoor air quality or IAQ, lighting, and acoustics) on specific measures of human response, student and teacher performance, and productivity. The pilot study is being conducted in six elementary schools in Montgomery County Maryland. Two matched triplets of schools have been selected, each with three 3rd grade and three 4th grade classrooms. Exposure, questionnaire, and system performance data are being acquired periodically before and after interventions. The sets of data being acquired are unique as they provide information on daily profiles of simultaneous exposure to six indoor environmental stressors.

2B2o2 Energy and indoor environmental quality in relocatable classrooms
MG Apte, AT Hodgson, DG Shendell, D Dibartolomeo, T Hochi, S Kumar, SM Lee, SM Liff, LI Rainer, RC Schmidt, DP Sullivan, RC Diamond and WJ Fisk

Relocatable classrooms (RCs) are commonly utilized by school districts with changing demographics and enrollment sizes. Four energy-efficient RCs were designed and constructed for this study to demonstrate technologies that simultaneously attempt to improve energy efficiency and indoor environmental quality (IEQ). Two were installed at each of two school districts, and energy use and IEQ parameters were monitored during occupancy. Two (one per school) were finished with materials selected for reduced emissions of toxic and odorous volatile organic compounds (VOCs). Each RC had two HVAC systems, alternated weekly, consisting of a standard heat-pump system and an indirect-direct evaporative cooling (IDEC) system with gas-fired hydronic heating. The hypothesized advantages of the IDEC include continuous outside air ventilation at ≥ 7.5 L s^{-1} per person, ~70% less cooling energy and efficient particle filtration. Measurements include: carbon dioxide, particles, VOCs, temperature, humidity, thermal comfort, noise, meteorology, and energy use. Preliminary IEQ monitoring results are reported.

2B2o3 Air quality and ventilation rates in schools in Poland - requirements, reality and possible improvements
J Sowa

The goal of the paper is to compare real state of indoor air quality in classrooms in Poland with national and international requirements and standards. The evaluation of existing situation is based on indoor environment measurements in 28 classrooms in Warsaw. Both temperature and carbon dioxide concentration were measured with 1 minute interval during the workweek. Measurements of formaldehyde and total volatile organic compounds (TVOC) were used to characterize level of air

pollution caused by building materials and furnishing. Special questionnaire helped to collect all-important information about localization, construction and furnishing. The investigation indicated that Polish regulations on indoor air quality not only seem to drop behind similar regulations in developed countries as far as their rigidity is concerned, but also, generally, are not observed.

2B2o4 Carbon dioxide levels and dynamics in elementary schools: results of the TESIAS study
RL Corsi, VM Torres, M Sanders and KA Kinney

The Texas Elementary School Indoor Air Study (TESIAS) involved several phases, including single-day continuous monitoring of carbon dioxide (CO_2) in 120 randomly selected classrooms in two school districts. The median time-averaged and peak CO CO_2 concentrations were 1,286 ppm and 2,062 ppm, respectively. The time-averaged CO_2 concentration exceeded 1,000 ppm in 66% of the classrooms. The peak CO_2 concentration exceeded 1,000 ppm in 88% of the classrooms and 3,000 ppm in 21% of the classrooms. Mean and peak occupied CO_2 concentrations were statistically different (a = 0.05) between the two districts, and peak CO_2 concentrations were statistically greater in classrooms that employed packaged terminal air conditioning (PTAC) systems. Statistically significant differences in both mean time-averaged and peak CO_2 concentrations were not observed for portable vs. traditional classrooms, classrooms with outside vs. inside entries, or when data were separated amongst teacher responses to questions related to classroom odors.

2B2p1 Texas elementary school indoor air study (TESIAS): overview and major findings
V Torres, M Sanders and R Corsi

A study of 120 randomly selected classrooms in 30 schools in central and south Texas, USA was conducted to begin assembling baseline information on the condition of indoor air in Texas elementary schools. Part I of the study consisted of questionnaires sent to all teachers and staff in the schools to obtain information about the use of their rooms, room contents and their perceptions of its indoor air quality. Part II consisted of walkthroughs in each school and the 120 classrooms to obtain information on the building design, HVAC system and condition of the space/building. It also included making measurements of temperature, relative humidity, carbon dioxide, and carbon monoxide in the selected classrooms. Additionally, air samples were analyzed for fungal and bacterial genera, counts of airborne particles, and volatile organic compound levels in 18 classrooms.

2B2p2 Indoor air pollutants, limited resource households and childcare facilities
J Laquatra, LE Maxwell and M Pierce

This paper presents findings from an indoor air quality study of homes and childcare facilities in nonmetropolitan counties of New York State. Specific pollutants examined were lead, radon, carbon monoxide, asbestos, and mold. High pollutant levels were observed in some of the homes, and significant relationships between certain pollutants and household income were observed. High levels of pollutants were also observed in the childcare facilities survey, which raises questions about constant pollutant exposure to children. Recommendations are made for lowering exposure levels in low income households and childcare facilities.

2B2p3 Multidisciplinary evaluation of a public high school
R Anderson, W Anis, M Feeney, M Goldman, R Gregor, S Nichols and T Oleary

The Indoor Air Quality Committee of the Boston Society of Architects was invited to evaluate a large brick school building erected in 1963 to serve 1600 students. The investigation included a written questionnaire, evaluation of air using the ASTM E981 (modified) bioassay, fungal and bacterial testing, real time monitoring of carbon dioxide, carbon monoxide, respirable particulate, total volatile organic compounds, relative humidity and temperature. The survey and testing enumerated many potential causes for poor IAQ. The walkthrough included evaluations by a building envelope specialist, HVAC specialists, non-industrial indoor air quality investigators and filter use specialists. The reported human data, the animal bioassay data, the microbial data, real time monitoring and observations provided strong support for remediation actions.

2B2p4 Total dust exposure and size distribution of air borne particles in day-care centres, schools and offices
G Stridh, H Andersson, B Linder, J Oscarsson and Ch Sahlberg Bang

Values for total dust concentration in indoor air in day-care centres, offices and schools with no reported problems are measured. These are: day-care centres 41 ± 14 µg/m^3, offices 16 ± 5 µg/m^3, schools 20 ± 10 µg/m^3. In parallel the particle size distribution in six interval from 0.3 µm - >20 µm are reported. No seasonal variation in total dust concentration could be seen. Sudden increase in number of the particles in the smallest intervals are found at night for some systems when they are shut down or working on reduced speed.

2B2p5 Vertical profile particulate matter measurements in a California daycare
P Beamer, A Castaño and JO Leckie

As children are increasingly cared for outside the home due to the changing work force, indoor air quality studies in daycares have become more important. This study focuses on the difference between children's and adults' particulate matter (PM) exposure due to suspected differences in the vertical profile. We conducted experiments at a daycare center for a exposure analysis class at Stanford University, measuring PM_{10} concentrations in two rooms with children of different ages (12-24 and 24-36 months). The results showed that the children were exposed to higher amounts of PM_{10} than the adults in the same room, and indoor PM_{10} concentrations were considerably higher than those measured outdoors on the same day. The PM_{10} concentrations were related to the number of people and specific activities occurring in the room. The investigators hope that results from these types of studies will encourage legislation for indoor standards affecting children's increased exposure toPM_{10} .

2B2p6 Indoor air quality in schools: the impact of ventilation conditions and indoor activities
J Ribéron, P O'Kelly, F Maupetit and E Robine

The indoor air quality of two nursery schools and one primary school of Paris suburb is documented regarding ventilation strategy and occupants behaviour. Physico-chemical and microbiological measurements are performed indoors in two classrooms of each school and outdoors. Indoor air quality is better in mechanically ventilated classrooms than in operable windows classrooms. CO_2 concentration ranges usually from 750 to 1500 ppm. The air change rate - derived from CO_2 monitoring - is around 0.4 ach in mechanically ventilated classrooms. In other classrooms, it ranges from 0.1 to 0.6 ach with regard to airtight conditions. TVOC concentrations are much higher indoors (from 200 to 620 $\mu g\ m^{-3}$) than outdoors. Indoor benzene and toluene originate from outdoors while school activities can explain high concentrations of some compounds like glycol ethers. Main source of bacteria indoors is human presence whereas fungi mainly originate from outdoors. The maximum bacteria concentrations range from 600 to 4000 cfu m^{-3} with regard to ventilation conditions.

2B3o1 The efficacy of strategies to reduce environmental tobacco smoke concentrations in homes, workplaces, restaurants, and correctional facilities
SK Hammond

A variety of strategies have been implemented to protect nonsmokers from second hand smoke; these include separation or restricting smoking to selected areas, installation of air cleaners, increased ventilation, and outright prohibition of smoking. The concentrations of nicotine were measured and examined in different venues as a function of the techniques employed. The weekly average concentration of nicotine was significantly lower in the homes of smokers and in workplaces where smoking was not allowed indoors compared to homes or workplaces without such restrictions; opening windows was less effective. Air cleaners with HEPA filter and charcoal removed some of the particles but had little effect on nicotine concentrations. Evaluation of the efficacy of these strategies is imperative in the public health efforts to reduce SHS exposures.

2B3o2 Measurements and modeling of environmental tobacco smoke leakage from a simulated smoking room
J Wagner, DP Sullivan, D Faulkner, LA Gundel, WJ Fisk, LE Alevantis, and JM Waldman

The purpose of this study is to quantify the effect of various design and operating parameters on smoking room performance. Twenty-eight experiments were conducted in a simulated smoking room with a smoking machine and an automatic door opener. Measurements were made of air flows, pressures, temperatures, two particle-phase ETS tracers, two gas-phase ETS tracers, and sulfur hexafluoride. Quantification of leakage flows, the effect of these leaks on smoking room performance and non-smoker exposure, and the relative importance of each leakage mechanism are presented. The results indicate that the first priority for an effective smoking room is to depressurize it with respect to adjoining non-smoking areas. Another important ETS leakage mechanism is the pumping action of the smoking room door. Substituting a sliding door for a standard swing-type door reduced this source of ETS leakage significantly. Measured results correlated well with model predictions (R^2 = 0.82-0.99).

2B3o3 Mitigation strategies for reducing childhood exposure to ETS in the home
LK Shuker, C Courage, P Holmes and PTC Harrison

In the light of difficulties associated with giving up smoking, which is the most effective strategy for household members to adopt to reduce children's exposure to environmental tobacco smoke (ETS) in the home, an evaluation has been undertaken of other mitigation strategies, such as changes in smoking behaviour, use of physical barriers, ventilation, air cleaning devices and regulation. Smoking outside the home may be the most effective mitigation strategy other than not smoking. Counselling carers of children about ways to reduce ETS exposure may have a beneficial role.

2B3o4 Reducing bartenders' exposure to ETS by a local ventilation - field evaluation of the solution
M Hyvärinen, K Hagström, I Grönvall and P Hynynen

Restaurant workers have a high risk to be exposed to environmental tobacco smoke (ETS) in their work. In Finland the latest tobacco Act has set more stringent requirements for the smoking in restaurants. Despite of the tightened legislation most of the restaurant employees are still continuously exposed to ETS. Ventilation techniques enable significantly to reduce employee's exposure to ETS in hospitality facilities, where smoking is permitted. . The results of this study shows that with especially designed bar local ventilation solution it was achieved even lower exposures to ETS in smoking area workplaces than in nonsmoking area.

2B3o5 Effect of sorption on exposures to organic gases from environmental tobacco smoke (ETS)
BC Singer, AT Hodgson and WW Nazaroff

The effects of sorption processes on dynamic ETS organic gas concentrations and potential exposures were studied in a carpeted and furnished 50-m^3 room ventilated at 0.6 h^{-1}. Ten cigarettes were machine-smoked on six of every seven days over four weeks. Concentrations of ETS-specific tracers and regulated toxic compounds were quantified during daily smoking, post-smoking and background periods. Potential exposures were calculated by period and day. Large sorption effects were observed for the widely used tracers 3-ethenylpyridine and nicotine, and for several toxic compounds including naphthalene and cresol isomers. Short-term adsorption to indoor surfaces reduced concentrations and potential exposures during smoking, while later reemission increased concentrations and exposures hours after smoking ended. Concentrations during nonsmoking periods rose from day to day over the first few weeks, presumably from increased reemission associated with increased sorbed mass concentrations. For sorbing compounds, more than half of daily potential exposures occurred during nonsmoking periods.

2B3p1 Passive smoking exposure and risk for Irish bar staff
M Mulcahy and JL Repace

Ventilation failed to protect the health of bar staff. Carbon monoxide from environmental tobacco smoke (ETS-CO) measured in 14 bars in Galway, Ireland showed mean ETS-CO levels of 6.36 ppm (St. Dev. 4.36 ppm), with median levels at 6.00 ppm. Peak CO exceeded 63 p.p.m. in two premises. Passive smoking at the level of 6 ppm of ETS-CO for 30 minutes is known to induce as much dysfunction of the coronary circulation as that in smokers. Exposure to ETS-CO levels equivalent to 6 ppm for 40 years carries an estimated combined excess mortality risk from heart disease and lung cancer sufficient to cause the premature death of 1 out of 5 bar staff. Of the 78,000 workers in alcohol-licensed premises throughout Ireland in 1999, about 56,000 were employed in pubs. Assuming only half are employed full-time, this translates into an estimated 150 deaths per year in the full-time pubworkers alone.

2B3p2 Control of exposure to environmental tobacco smoke in restaurants and bars
M Hyvärinen, T Johnsson, T Tuomi, M Rothberg, T Mielo and K Reijula

On March the 1st 2000 the Finnish Tobacco Act was amended, and now includes restrictions on smoking in restaurants and bars. Establishments can reserve a maximum of 50% of their service area for smokers, and the spreading of tobacco smoke into non-smoking areas must be prevented. In addition, the working areas at bar counters have to be smoke-free. 16 restaurants and bars participated in the study both before and after the introduction of the Finnish Tobacco Act. The average airborne nicotine concentration corrected with smoked cigarettes was lower in 9 (out of 16) establishments after the introduction of the Act. At bar desks the nicotine concentration was lower in 10 establishments. Improvements in the ETS levels were seen in establishments that had introduced changes into the ventilation system. When placing non-smoking areas in existing establishments knowledge about the ventilation is of utmost importance.

2B3p3 Environmental tobacco smoke in rental housing - perceived problems & interest in smoke-free buildings
MJ Hewett, SD Sandell, DJ Reece and DL Bohac

Six hundred Minnesota renters were surveyed to determine the perceived extent of secondhand smoke transfer in multifamily buildings and to assess the marketability of smoke-free rental housing. Forty-eight percent of renters reported that, at times, tobacco smoke odors get into their current apartment from elsewhere in or around the building. Ten percent said this occurs often or most of the time, a proportion that would translate to roughly 37,000 households statewide. Thirty-seven percent of those experiencing secondhand smoke transfer say it bothers them a lot or so much they are thinking of moving. Forty-seven percent of households are extremely or very interested in living in a building where smoking is prohibited. Fifty-four percent would be very likely to choose a smoke-free building all other things being equal, and 34% would be willing to pay more to live in one.

2B3p4 Characterizing size-specific ETS particle emissions
NE Klepeis and WW Nazaroff

We report a method for estimating the size distribution of particle emissions from indoor sources. The method is applied to concentration data from a series of cigar and cigarette experiments to characterize environmental tobacco smoke particles. The method incorporates a particle dynamics model, which provided good fits to observed concentrations when using, as input, optimal values of mass emission rate and deposition velocity for each particle size range. The optimal particle emissions were fit to log-normal distributions, yielding mass median diameters of approximately 0.2 mm and an average geometric standard deviation of 2.3. The total particle emissions obtained by integrating the empirical size distribution were 0.2 - 0.7 mg/min for cigars and 0.7 - 0.9 mg/min for cigarettes. The measurements of particle size characteristics agree well with prior research, but the integrated mass measurements are consistently lower than those determined from filter-based measurements.

2B4o1 Effect of outside air ventilation rate on VOC concentrations and emissions in a call center
AT Hodgson, D Faulkner, DP Sullivan, DL DiBartolomeo, ML Russell and WJ Fisk

A study of the relationship between outside air ventilation rate and concentrations of VOCs generated indoors was conducted in a call center. Ventilation rates were manipulated in the building's four air handling units (AHUs). Concentrations of VOCs in the AHU returns were measured on 7 days during a 13-week period. Indoor minus outdoor concentrations and emission factors were calculated. The emission factor data was subjected to principal component analysis to identify groups of co-varying compounds based on source type. One vector represented emissions of solvents from cleaning products. Another vector identified occupant sources. Direct relationships between ventilation rate and concentrations were not observed for most of the abundant VOCs. This result emphasizes the importance of source control measures for limiting VOC concentrations in buildings.

2B4o2 Influence of the inhabitants on indoor air quality
A Saarinen, T Vartiala and M Viinikka

The influence of inhabitants on indoor air quality (IAQ) was studied. The aim of the study was to find out how the inhabitants themselves and their living activities affect the IAQ. The concentration of volatile organic compounds (VOCs) and ammonia (NH_3) in indoor air was measured in inhabited and in empty dwellings. A air change rates were also defined. Altogether 24 dwellings were examined. The results were compared with the surface floor area of the dwellings, the number of inhabitants, the number of pets and the absence or presence of smoking. The results showed that the effect of the inhabitants on IAQ was significant. The average values of total volatile organic compounds (TVOC) and NH_3 concentrations were nearly twice as high in occupied dwellings compared to empty ones.

2B4o3 Emission of aldehydes from paints containing linseed oil: a field study
P Fjällström, B Andersson, and K Andersson

Two different workplaces where paints containing linseed oil were used have been studied. Air samples were collected with 2,4-dinitrophenylhydrazin samplers and analysed for aldehydes with liquid chromatography and UV detection. At the first object, the paint was sprayed onto ceilings and parts of the walls. Stationary samplers showed high amounts of formaldehyde, which exceeded the Swedish occupational ceiling value (1.2 mg/m^3), during the first four hours after painting. The amount of aldehydes generally peaked two days after the paint was applied. At the second object, paint was applied by brushing onto woodwork. No limit values were exceeded. The emissions had their maximum at approximately two days after the paint was applied. The emission profile had lower initial values probably due to the absence of paint mist. The large surface area created by spraying the paint causes a burst of emissions due to the accelerated oxidation process.

2B4o4 Identification and quantification of VOCs sources in air-conditioned office buildings in Singapore
MS Zuraimi, KW Tham and SC Sekhar

This paper reports the contributions of VOCs attributable to different sources in four tropical commercial office buildings. The results indicated that the biggest contribution of VOCs within office buildings is from the occupants and their activities which amount to 64%. Ventilation systems too contributed significantly to the total emission rates (27%). Results indicated that a ducted return system can be the least contributor of VOCs and also that VOCs desorption from the dusts, filters and the back of ceiling boards can be an issue that needs to be addressed. Building materials has the least contribution (9%) but effects of renovation can significantly elevate the levels.

2B4o5 Transient analysis of VOC concentrations for estimating emission rates
A Persily, C Howard-Reed and SJ Nabinger

While VOC emissions rates have been obtained for building materials and furnishings in chambers, field measurements are more difficult due to the existence of multiple and time-varying sources, variations in ventilation rates, impacts of adsorption and desorption, and other complexities associated with field testing. Procedures to estimate emission rates and sink parameters using transient analysis of VOC concentrations are applied in a two-story classroom/office building. The analysis is based on semi-realtime VOC concentrations determined with a portable GC/FID and simultaneous air change rate measurements using tracer gas decay. The results of the analysis yield consistent values of emission rates for building materials, but less consistent estimates of emission rates associated with occupant activities and of sink model parameters. The approach can be used in other buildings, and the results indicate that simultaneous air change rate measurements are critical to estimating VOC emission rates in the field.

2B4p1 An investigation of styrene contamination in apartment properties due to refurbishment of concrete walkways
C Yu, DR Crump and M Waugh

BRE undertook an investigation of styrene contamination in two apartment buildings in London. The contamination was due to resin treatment of the steel reinforcement in concrete walkways during a refurbishment project. The resin was found to have penetrated the interior structure of the apartments. Soon after the work began, the residents complained of odour, tainted food, nausea, dry throat, sore eyes and headaches. Complaints continued for months after the work had been completed. A strong smell of styrene was detected in the properties, where the concentration exceeded the 260 mg m^{-3} WHO guideline value in many cases. An emission chamber test of samples of concrete floor slab and cured resin found in the properties showed a high level of styrene emission being maintained, nine months after treatment of the walkway.

2B4p2 Indoor air quality and material emissions in new buildings
H Järnström and K Saarela

A research project was established to create numeric reference data for material emissions during the time of construction as well as for indoor air quality follow-up in new buildings. 10 measurement sites, representing the present construction practice in Finland, were chosen for investigation. Material emission measurements for surfaces, using the field and laboratory cell (FLEC) technique, were performed during the time of construction. The emission rates for VOCs (Volatile Organic Compounds), formaldehyde and ammonia of the floor structure were measured for the floor structure build-up stages. In addition, decay behaviours for the emissions of underlying floor structures were investigated. The concentration of VOCs, formaldehyde and ammonia in indoor air as well as the air exchange rate were defined for the newly finished building. The results obtained were compared to indoor air concentration and emission rate target values, defined in the Finnish ”Classification of Indoor Climate 2000”.

2B4p3 Correlation between VOCs emitted from building materials and diagnosed building related symptoms
K Villberg, K Saarela H Mussalo-Rauhamaa, M Malmberg and T Haahtela

This study is a part of the Finnish Research Programme on Environmental Health project ‘Indoor Air Quality Control’ and it aims at finding causality between indoor air quality and different symptoms. In addition one object was to study the single VOCs emitting from materials to be used as health, irritation and comfort related evaluation criteria in the Finnish classification and their correlation with perceived air quality. The patients were treated in Helsinki University Central Hospital Departments of Dermatology and Allergic diseases because of building related symptoms and illnesses. VOCs, formaldehyde and ammonia were measured in homes of patient families and controls. Statistical correlations were drawn by combining the chemical data and the clinical history of the patients, and the answers of the questionnaire of their health symptoms and living conditions. As a result many essential correlation between single building material based VOCs and different symptoms and diagnosed illnesses are recognised.

2B4p4 Flame retardants in the indoor environment. Part IV: classification of experimental data from house dust, indoor air and chamber tests
T Salthammer and M Wensing

Organophosphate esters are frequently applied as flame retardants in building products and other materials for indoor use. Exposure of residents to flame retardants mainly results from accumulation in house dust and indoor air. Some agents of this compound class are suspected to cause adverse health effects. However, risk assessment for the indoor environment is difficult due to the lack of measured indoor air concentrations and toxicological data. In this paper, results of house dust analysis, indoor air measurements and chamber tests are summarised. The data provide an overview about distribution and range of concentrations in house dust and indoor air and enable estimation of daily rates for oral intake and air inhalation.

2B4p5 Measurement of VOC emissions from wood remedial treatment: chamber tests and field experiments
F Maupetit, O Ramalho, A Mienne, PO'Kelly and C Yrieix

The purpose of this study is to document the impact of wood preservative products on indoor air quality. The emissions of two wood remedial treatment products (water-based and petroleum-based solvent formulations) representative of the market were characterized by two laboratories using emission test chambers. For most identified VOC, concentrations sharply decrease with time reflecting the solvent evaporation. VOC emissions from wood remedial treatment were also directly measured in real conditions during a roof renovation work in an old building. A petroleum-based solvent product was used by a professional applicator on the roof trussing. VOC were monitored up to 6 days after treatment. Identified VOC and emission patterns in test chambers and on the field are comparable. Emissions have been modeled and the models used to estimate the necessary time before re-entry in the treated space.

2B4p6 An estimate of greenhouse gas emissions from common Kenyan cookstoves under conditions of actual use
R Bailis, M Ezzati and DM Kammen

We report on greenhouse gas emissions from wood and charcoal cookstoves measured during actual conditions of use in 19 randomly selected rural Kenyan households. CO, particulate matter (PM_{10}), mass of fuel, and the state of combustion were measured or recorded in real-time. Emissions of pollutants other than CO and particulates were estimated using data adapted from extant literature. We find the average daily emissions from charcoal stoves are lower than woodstoves when measured in terms of carbon released. However, when the emissions are weighted to account for global warming potential, charcoal stoves are much more polluting than wood stoves by any metric. Further, accounting for emissions from charcoal production increases the disparity between charcoal and firewood. However charcoal still carries potential health benefits at the household level because of reduced particulate emissions relative to firewood combustion. Some policy options are discussed in light of these potentially conflicting findings.

2B5o1 Perceived air quality and sensory pollution loads in six Danish office buildings
P Wargocki, P Krupicz, A Szczecinsk, PO Fanger and G Clausen

Perceived air quality and sensory pollution loads were measured in 6 office buildings with mechanical ventilation without recirculation, in each building in 6 representative non-smoking medium-sized and small offices with mixing ventilation. An untrained panel of 43 subjects assessed the air quality on a normal weekday when the building was occupied, and on a weekend without occupants in the building. On both occasions the ventilation system was in operation as on normal working day. Outdoor air supply rate, air temperature, relative humidity, concentration of carbon dioxide and ultrafine particles were measured. The percentage of persons dissatisfied with air quality ranged from 3 to 30%, decreasing with increasing outdoor air supply rate from 1 to 4 L/(s×m^2floor). Total sensory pollution loads ranged 0.08 to 0.37 olf/m^2floor in occupied buildings and 0.04 to 0.27 olf/m^2floor in unoccupied buildings. They are somewhat lower than the loads measured in earlier studies.

2B5o2 Sensory detection of VOCs singly and in mixtures: odor and sensory irritation
JE Cometto-Muñiz, WS Cain, MH Abraham and JMR Gola

To increase our understanding of the olfactory and trigeminal (i.e., sensory irritation) impact of chemical mixtures we have studied the binary mixture butyl acetate/toluene. First, we measured complete concentration-response (i.e., psychometric) functions for the odor, nasal pungency, and eye irritation detectability of the single chemicals. Second, we selected fixed detectability levels between chance (p=0.0) and perfect (p=1.0) detection (e.g., p=0.6). Finally, we compared the detection of the single chemicals at the concentration producing these selected levels with the detection of binary mixtures at proportions that, if a rule of dose additivity were to hold, should be as detectable as the single chemicals. The outcome revealed that the degree of dose additivity is larger for the irritation modalities than for the odor modality.

2B5o3 Addition and mixture of different pollution sources
O Böttcher and K Fitzner

A study has been carried out to develop mathematical methods to calculate the perceived air quality caused by a combination of two materials on base of the data for the single materials. Three different pollution sources have been investigated under laboratory conditions. A trained panel of 10 – 12 people assessed the perceived air quality in decipolB directly. During the assessments the temperature, relative humidity and velocity of the unpolluted air and the emission of the sources were kept constant. The emission was controlled for 2-propanone only. The behaviour for the other materials was assumed by analogy. The perceived air quality of the mixture and the addition of two odours were investigated. Logarithmic relations are more suitable to reproduce the experimental results as the commonly assumed linear. That was concluded from a mathematical analysis. Further investigations showed that sorption has a significant influence on the results.

2B5o4 Personal computers pollute indoor air: effects on perceived air quality, SBS symptoms and productivity in offices
Z Bakó-Biró, P Wargocki, C. Weschler and P. Ole Fanger

Perceived air quality and Sick Building Syndrome (SBS) symptoms were studied in a low-polluting office space ventilated at an air change rate of $2h^{-1}$ (10 L/s per person with 6 people present) with and without personal computers (PCs). Other environmental parameters were kept constant. Thirty female subjects were exposed for 4.8 h to each of the two conditions in the office and performed simulated office work. They remained thermally neutral by adjusting their clothing and were blind to the interventions. In the absence of PCs in the office the perceived air quality improved, odour intensity was reduced and air freshness increased; all effects were significant. In the presence of PCs the performance of text typing significantly decreased. The sensory pollution load of the PCs was found to be 3 olf per PC, i.e. three times the load of the occupants. Present results indicate negative effects of PCs on human comfort and performance.

2B5o5 Evaluation of indoor products by sensory and chemical testing. Part I: application of olfactometry in test chambers
T Salthammer and V Kühn

Olfactometers were developed in order to measure and evaluate odor emissions in the outdoor environment. Olfactometry nowadays is indispensable for registering odor problems in the outdoor air. For example it is used to determine efficiency levels in odor reduction technology or as a starting platform for the computation of odor propagation. As yet, olfactometry has not played an important role in indoor environments as the concentrations of odorants in the indoor environment are present mostly to a much lesser extent than in outdoor environments. In the past, the presence of these odorants was difficult to prove using conventional olfactometers. Using new olfactometers, with much improved and more precise measuring properties in comparison to older models, it is possible to use olfactometry in the indoor environment as well.

2B5p1 Evaluation of indoor products by sensory and chemical testing. Part II: comparison of olfactometric and VOC analysis
E Massold, V Kühn and T Salthammer

Evaluation of building products for indoor use with respect to an influence on human well-being is a topic of multi-disciplinary concern. Climatic parameters, inorganic and organic contaminants as well as psychological factors, etc., are frequently discussed as contributors to an impact on indoor air quality and SBS. Two approaches were compared for their usability for evaluation of emissions from indoor products in emission test chambers. The first is olfactory testing in which odor units, odor intensity and hedonic effects are determined by a sensory panel. The second is VOC analysis in which concentrations of compounds in the test chamber are quantified by sampling on Tenax TA and thermal desorption GC/MS. The latter also employs the TVOCGC/MS-method according to ECA-report no. 19. No simple correlation between VOC analysis and sensory testing was found. Both methods bear their assets and drawbacks and for that reason complement one another.

2B5p2 Perceived air quality, thermal comfort, and SBS symptoms at low air temperature and increased radiant temperature
J Toftum, G Reimann, P Foldbjerg, G Clausen and PO Fanger

This study investigated if low air temperature, which is known to improve the perception of air quality, also can reduce the intensity of some SBS symptoms. In a low-polluting office, human subjects were exposed to air at two temperatures 23 C and 18 C both with and without a pollution source present at the low temperature. To maintain overall thermal neutrality, the low air temperature was partly compensated for by individually controlled radiant heating, and partly by allowing subjects to modify clothing insulation. A reduction of the air temperature from 23 C to 18 C suggested an improvement of the perceived air quality, while no systematic effect on symptom intensity was observed. The overall indoor environment was evaluated equally acceptable at both temperatures due to local thermal discomfort at the low air temperature.

2B5p3 Odor intensity of a real room field evaluation and laboratory investigations
O Ramalho

A simple method was used to assess odor intensity in indoor environments by a trained panel. Reliable results were obtained. Other factors, i.e., interaction with other senses, annoyance and other cognitive processes seemed to influence individual evaluation, especially during adaptation. Therefore, laboratory experiments could be useful to assess immediate odor intensity with minimum context influences. Comparison of odor sampled in Tedlar® bags and in the living room were acceptable in terms of intensity but not in terms of recognition and description, indicating presence of biases. Chemical analysis revealed some differences in VOC composition that could explain the change in the nature of the stimulus.

2B5p4 Determination and evaluation of odour emissions from building materials using a test chamber according to the European pre-standard ENV 13419-1
E Mayer and K Breuer

The determination of emissions of volatile organic compounds (VOC) by means of an emission test chamber is well described in the European Prestandard (ENV 13419-1, 1999). In the Fraunhofer Institute for Building Physics (IBP) a procedure was developed to apply this method to determine odour emissions from building materials. In detail: olfactory intensity, hedonic sensation and acceptance can be measured, using that method. These procedures and results of a screening of building materials are presented in the paper. In addition, a new evaluation (ranking) system for odour emissions is presented.

2B5p5 Impact of ventilation rate, ozone and limonene on perceived air quality in offices
HN Knudsen, A Afshari, L Ekberg and B Lundgren

The objective was to clarify to what extent ozone (O_3) and O_3/limonene, in interaction with surface materials, have an impact on the perceived air quality in typical low-polluting offices at realistic outdoor air change rates. Three offices furnished with similar materials and ventilated with charcoal filtered outdoor air were investigated. Eight environmental conditions with different realistic combinations of air change rate, O_3 level and limonene were studied. A sensory panel entered the offices and immediately assessed the acceptability of the air. Decreasing the air change rate from 1.0 to 0.3 h^{-1} deteriorated the perceived air quality considerably, most pronounced in the presence of O_3. Adding more polluting materials to the offices with a low air change rate kept at 0.3 h^{-1} deteriorated the perceived air quality, most pronounced in the presence of O_3 and O_3/limonene. The results confirm the importance of maintaining sufficient ventilation even for low-polluting offices in order to ensure good perceived air quality.

2B5p6 Integrating innovative POE technique for workspace assessment
B Gumbaketi

This paper describes a post-occupancy evaluation (POE) technique of the haptic kinesthetic aspects. Basically, it is the ISOKIN measures developed for assessing constraints in specialised working environment using quantitative measures, which is now combined with qualitative measures for perceptual environmental assessment. Hence, the technique is called the Integrated POE Technique aimed at defining the level of physical and psychological environmental constraints that a workspace imposes on the occupant or worker. This technique provides both the analyst and the designer the means to opertationalise and measure formerly intuitive notions about the suitability of various proposed workspace and their physical settings for the activities being planned for them.

2B5p7 The perceived physical and psychosocial climate in Swedish schools from 1989 to 2000 - a database analysis
K Andersson, L Bodin, I Fagerlund and W Aslaksen

A database including data about the perceived physical and psychosocial environment, SBS symptoms, allergy status and sex from 19 973 personnel in 650 Swedish schools was analysed. Binomial regression modelling with time, sex and allergy status as explanatory variables was performed to establish the relative risk for some effect parameters and to evaluate if there was any linear trends over time. The complaints of fatigue, noise, “dust and dirt” and stuffy air increased significantly between 1994 and 2000. The prevalence of work stress increased dramatically from the middle of the decade and it is intriguing to attribute this, at least partly, to an effect of the changed work situation in the schools.

2B6o1 A comparison of indoor humidity behaviors: all-air and chilled-ceiling with desiccant cooling
L Zhang, J Niu, and H Zuo

Indoor humidity behaviors with a system combining chilled-ceiling and desiccant cooling (CC+DC) in hot and humid climates are investigated and compared with a conventional constant volume all-air system (CAV). Room mean temperature, mean humidity, maximum RH on the ceiling panel surfaces, annual condensation hours are predicted using a building energy simulation code ACCURACY and a moisture balance analysis method in an office room under Hong Kong weather conditions. The results show that the system controls the indoor humidity poorly in transient seasons, but in comparison, the CC+DC system provides better indoor humidity environment most of the year. For CC+DC, air dehumidification and ventilation system should be operated at least one hour earlier than the operation of ceiling panels. Otherwise, condensation may occur.

2B6o2 Dehumidification capabilities of cold-coil air-conditioning systems
D Stanke and R Davidson

Modern buildings use a wide variety of mechanical cooling systems with different control approaches to match cooling capacity with sensible load. Many of these cold-coil systems, however, do not successfully match dehumidification capacity to

latent load. Unacceptably high levels of space relative humidity can result. If allowed to persist, high humidity levels can lead to microbial growth. Annual dehumidification performance depends upon the weather, building construction, and space use, as well as the configuration and control logic of the HVAC system. An HVAC-system modeling program was therefore used to study the hour-by-hour dehumidification performance of three common HVAC system configurations, which were applied to classrooms and offices in several different locations. The results show that commonly used HVAC systems may provide inadequate humidity control when applied in certain combinations of building type and climate.

2B6o3 A multi-zone climate control system for single-family homes
JH Hwang, JD Chang, and JJ Kim

Most single-family homes in America today are designed with a single-zone climate control system. This is typically an energy inefficient and ineffective method of conditioning a home. Multi-zone climate control systems are considered to provide improved means of conditioning single-family homes. More so is the case with multi-story homes where thermal balance is difficult to achieve between the lower and upper floors using a single-zone system. Computational fluid dynamics (CFD) was applied in this research to study the performance of a single zone and two multi-zone systems in a two-story building. The study has revealed significant thermal stratification under both the single and multi-zone systems. Results also indicate there to be moderate differences in temperature distribution between the single-zone and multi-zone systems.

2B6o4 A heat and mass transfer analysis of cross-flow air-to-air total heat exchangers made of moisture-permeable paper
Y-C Lee, M-S Jeng, C-Y Huang, J-C Perng, Y-W Chou, F Tsau and H-C Chiang

Operation of the total heat exchangers (THXs) discussed in this article is based on thin fibrous paper, permeable to moisture but highly impermeable to air, capable of recovering both sensible and latent heat from air. The efficiencies of these exchangers are heavily influenced by air leakage from exhaust air channel to supply air channel, which renders traditional efficiency definitions of heat exchangers ambiguous. A concept of effective fresh air efficiency defined on the basis of per-unit-effective-fresh-air is proposed and the leakage effect on the efficiency is examined with experiments. Experimental results indicate that there might exist a best leakage rate (~12%) in so far as the energy saving is concerned, beyond which the performance of the total heat exchanger is highly unstable. Below the threshold leakage rate, within the experiments conducted in this study, the energy saving ratio of total heat exchanger increases with the leakage rate.

2B6o5 Efficiency of electrically heated windows
J Kurnitski

This study calculated the efficiency of electrically heated windowpanes which may be used for improving thermal comfort near glazing. In recent years electrically heated windows with heat output controllable within the range of 50-600 W/m^2 have been became available as standard products. In a cold climate, a warm glazing surface is a unique possibility for thermal conditioning. The efficiency of heated windows in respect of electrical energy use was determined. The effects of surface and outdoor temperatures and U-value of the window on efficiency of heated window were analyzed. Efficiency of a common heated window with U-value of 1.1 W/m^2K was about 78% at –10 ºC outdoor temperature. Highest efficiency value of 89% was calculated for window with U-value of 0.6 W/m^2K. Efficiency was slightly dependent on outdoor air temperature and practically independent on inner surface temperature of window which effect was less than 1%. Efficiency was inversely proportional to U-value of the window.

2B6p1 Influence of different pollutant sources on selection of ventilation system in rooms with cooled ceilings
A Novoselac and J Srebric

Cooled ceilings (CC) represent a hydronic cooling system usually combined with mixing ventilation (MV) or displacement ventilation (DV). The ventilation systems are employed to remove contaminants and part of the cooling loads. The contaminant removal effectiveness depends on the type and position of contaminant sources. For passive pollutant sources, which are not associated with heat sources, the advantage of DV over MV to improve air quality may vanish. This paper analyses contaminant distributions for active and passive pollutant sources in an office when the space is cooled by CC combined with either MV or DV systems. When main contaminants are passive and only fresh air is supplied, the simulation results show that the more economical CC/MV provides similar air quality to CC/DV. However, for active pollutants, CC/DV performs better than CC/MV. Finally, the study reveals that well-designed systems without recirculation may provide better air quality than systems with recirculation.

2B6p2 Identification of ventilation problems in an underground bus terminal in Korea
H Han and Y-I Kwon

It is the objective of the present study to identify ventilation problems and to suggest design modifications of the ventilation system to improve IAQ in the terminal. Numerical results on air velocity and concentration distributions are presented along with some of field experimental data on indoor concentrations of NO_x, CO and suspended particles. Results show many interesting aspects of airflow patterns affecting the ventilation characteristics of the building. System modifications on airflow rates and grille locations have been suggested from the numerical results in order to prevent direct short-circuiting of outdoor air and recirculation of contaminated indoor air. The overall exhaust performances of the modified conditions are compared quantitatively with existing ventilation condition using the concept of the mean residual-life-time of contaminated air.

2B6p3 HVAC designers and indoor air quality in Poland
J Sowa

The paper describes a questionnaire survey of heating, ventilation and air-conditioning (HVAC) designers. The protocol used in the study was based on the questionnaire developed by both the University of Illinois and U.S. Environmental Protection Agency for the similar, but much wider, study organized in U.S. in 1993. Questionnaires filled out by 32 Polish HVAC designers have been compared in details with results of the study organized in U.S. (group of 60 designers). "Typical designers" for both investigated groups have been created and their attitudes to indoor air quality (IAQ) have been described. Surprisingly, the comparison has not shown really important differences with respect to the role of ventilation systems. However American designers seemed to have had more knowledge about other factors having impact on IAQ (pollutant emission from building materials, factors affecting perception of air quality, etc.)

2B6p4 Energy consumption of air conditioning systems in UK office environments
IP Knight and GN Dunn

Interim findings are presented from a 3-year field-monitoring programme researching the energy consumption of air-conditioning (A/C) systems in UK Offices. The premise of the work is that little published data exists concerning the energy use of A/C systems in practice. Preliminary findings from the work indicate that laboratory system efficiency tests are not sufficient to predict whether one A/C system will be more efficient than another when installed in a real building. The work suggests instead that the primary factors affecting A/C system energy performance “as installed” are system design, system control, and the loads served by the system. Further analysis using dynamic thermal modelling is planned to assess the heating and cooling loads throughout the monitoring period and the resulting system efficiencies,, including accounting for the loads placed on the system in relation tothe effects of plant sizing and part-load performance.

2B6p5 The mixing effect in large enclosure with nozzle jet fan
M-S Park, D-W Lee, K-H Kim , J-H Lee and Y-C Lim

The problem of temperature stratification in large enclosure as hangar began to be figured out in Korea recently. Due to temperature stratification in hangar, occupants as inspectors or workers in the space may feel uncomfortable. In present study, the hangar space which represent the situation of winter season were simulated by CFD technique for making the design concepts. As the results of the computer simulation the case without nozzle jet fan shows severe temperature stratification. So the circulation ventilation system with nozzle jet fan was suggested to solve these problems in hangar. The space with circulation ventilation system shows that the average temperature for the residential area was increased as much as 2 ºC comparable to the space without nozzle jet fan.

2C1o1 Measuring the efficacy of mold remediation on contaminated ductwork
JD Krause and YY Hammad

Published guidelines on mold remediation do not specify sampling protocols to measure the efficacy of remediation efforts. The purpose of this study was to evaluate fungal remediation of contaminated ducts by comparing the amount of residual surface contamination to the amount in new ducts. Fungal contamination of galvanized metal and rigid fibrous glass ducts were evaluated using fluorometric and microscopic methods. Fungal contamination was measured in newly installed ducts in addition to pre- and post-remediation. Newly installed ducts had low levels of fungal debris. Findings demonstrated that both fluorometry and microscopy methods detected fungal surface contamination. After cleaning, metal ducts were statistically less contaminated than when new. Fungal contamination of rigid fibrous glass ducts was reduced by ~90%, but was statistically more contaminated than when new. The fluorometric method performed as well as the microscopic method in detecting fungal contamination and provided faster results for monitoring efficacy of fungal remediation.

2C1o2 Effect of liner and core materials of plasterboard on microbial growth, spore-induced cytotoxicity and production of TNFα in macrophages
T Murtoniemi, A Nevalainen, M Suutari and M-R Hirvonen

In the present study, we cultured a fungus *Stachybotrys chartarum* and a bacterium *Streptomyces californicus* on liners and cores of six different plasterboards in order to examine the effects of plasterboard components on microbial growth and the bioactivity of the spores. The microbes were grown under saturated humidity conditions on wetted liners and cores of six different plasterboards. The spores were collected and applied to RAW264.7 macrophages at different doses. The bioactivity of spores was evaluated 24 h after exposure as their ability to evoke cytotoxicity and to stimulate the production of tumor necrosis factor alpha (TNFα) in the macrophages. The cores supported microbial growth better than the liners. Both microbes induced dose-dependent production of TNFα, which was consistent with their cytotoxicity. These results indicate that the previously reported bioactivity associated with microbial growth on plasterboard is not only due to the cardboard liner, but the core material also has an essential role.

2C1o3 Evaluation of air ducts interior liners with and without biocide coating in terms of extent of fungal growth under high humidity, water condensation and soiling conditions
BS Samimi and KR Konar

Various brands of fiberglass duct liners with and without biocides installed within ducts were exposed to high RH, excess moisture and nutrient. Each group of eight ducts was exposed to one of the three conditions within an environmental chamber for a period of 15 days. Air sampling and visual inspection indicated that biocide-contained Permacote and Toughgard inhibited fungal growth under high humidity but failed in presence of excess moisture and nutrient. Biocide-contained Aeroflex Plus was effective even when wet. ATCO Flex with Mylar coating exhibited low fungal activity in presence of high RH and excess moisture. All duct liners failed under excess moisture and nutrient. It was concluded that biocide-treated liners could be less promoting to microbial growth under high humidity as long as kept dirt free and dry. Impermeable smooth liners were less promoting to microbial growth under most conditions than biocide-contained liners having porous and or rough surface.

2C1o4 Use of in-duct UVC lamps to inactivate airborne environmental bacteria and fungi
DW VanOsdell and KK Foarde

Germicidal UV (UVC) lamps have a long history of use for inactivation of microbial aerosols. The majority of the literature has considered control of infectious diseases, such as tuberculosis (TB) in medical facilities. Emphasis has recently been on ventilation duct use of UVC. Under these conditions, infections agents are usually of less concern than environmental organisms. Much less information is available regarding common environmental organisms. The present work reports the ability of UVC lamps to inactivate 7 representative microbial aerosols in ventilation duct conditions. Substantial inactivation of airborne environmental fungi was accomplished with UVC dose levels readily achievable using multiple lamps. The vegetative bacteria tested were relatively easy to inactivate, while the bacterial spores tested displayed an intermediate response. Fungal spores were difficult to inactivate.

2C1p1 Investigation of the prevalence of *Legionella* species in heating ventilation air conditioning (HVAC) systems
F Martz, S Parat, H Fricker-Hidalgo, C Pinel and C Pascual

The aim of this study was the *Legionella* risk assessment in the water of HVAC systems equipped with cooling coils in France. Here, that means assess whether or not a HVAC system could actually be a source of *Legionella* by itself, or if it only remains a potential means for conveying a contamination. The prevalence of amoebae was also performed at the same time. Forty three different HVAC systems were investigated during the summer of 2000. All samples were collected from cooling coils condensate tanks. Despite the presence of a great number of other organisms, no *Legionella sp* was isolated by culture from any water sample. No correlation between *Legionella*, total bacteria and Gram negative bacteria was found. Out of 43 samples, 27 (63%) were found positive for amoebae with high semi-quantitative levels. Different criteria like the climate and the *Legionella's* ecology account for the absence of *Legionella*.

2C1p2 Efficacy of soft electrolyzed water in eradicating *Legionella* in contaminating water
T Yamayoshi, H Doi, A Dedagawa, F Kondou, T Noro, T Mikuni and N Tatsumi

Legionella, a genus of gram-negative bacteria that cause respiratory infections, thrives in the water of air handling systems. To prevent infections by it, it is necessary to suppress its growth in reservoirs at risk for contamination with *Legionella*. We evaluated the effectiveness of soft electrolyzed water in preventing growth of *Legionella*. The microbicidal rate of 99% for 2.69×10^4 coulomb was observed. Soft electrolyzed water containing activated oxygen species and hypochlorous acid is a colorless solution generated by the electrolysis of tap water, has no harmful chemical by-products, as do biocidal agents, and is simple to use. Soft electrolyzed water should be useful for disinfection of water contaminated with *Legionella*.

2C1p3 Healthy sauna
M Saari, M-L Pallari, M Salonvaara, H Kääriäinen, H Viitanen, K Laitinen, I Humala, S Liski-Markkanen and A Malin

Finnish sauna is a traditional hot room for sweating, relaxing as well as mental and physical cleaning. Healthy Sauna field study produced the practical guidelines for a good, clean, comfortable and desirable sauna. We were relieved that no dangerous microbes or diseases were found in saunas. However, cleaning procedures, methods and materials should be further developed. Cooled ceramic seats in sauna are quite popular in swimming halls. The low temperature level (40 C) offered the microbes very pleasant living conditions. Even cleaning had almost no effect on them. The traditional wooden seats were much cleaner than the ceramic ones. The surface temperatures of the wooden seats were typically 70 C. Adequate ventilation and total drying once a day reduced the microbe level efficiently.

2C1p4 Fungal spores from wet gypsum boards relationship between release and age of culture
J Kildesø, P Kruse, AM Madsen, H Würtz and K Wilkins

In this study, the release of fungal spores from wet gypsum boards was measured as function of incubation time. The release of fungal spores was induced by jets of air impacting from rotating nozzles. *Penicillium chrysogenum* and *Trichoderma harzianum* were cultivated on wet wallpapered gypsum boards. In one experiment, the release from undisturbed boards was measured at 5-7 days intervals. In a second experiment, the release was measured at 5-10 days intervals on the same boards, simulating repeated disturbance. Released spores were either measured by a particle sizer or sampled on a filter. The results show that incubation time is important for the fraction of spores released from the surface, and that repeated disturbance by air on fungal growth does not induce further release. The age of the culture did not influence on the size of the released spores

2C1p5 Development of circulating electrolytic disinfecting system and its application for *Legionella* species
F Kondo, T Noro, T Yamayoshi, H Doi, A Edagawa and T Mikuni

In a circulating water system such as circulating baths, which are commonly seen in places such as welfare facilities for the aged, water pollution by *Legionella sp*. is recognized as a problem. Up to now, disinfection has been done by using bactericides such as chlorine, but in recent years the negative environmental impact of residual chlorine and by-products from this method has been recognized. Therefore, a circulating electrolytic disinfecting system has been proposed and developed. This system does not use bactericides such as chlorine, but efficiently generates hypochlorous acid and active oxygen species by electrolyzing the water. In the development of this system, the bactericidal effect of active oxygen species generated by electrolyzation of water which does not contain chlorine ion has been recognized. As this circulating electrolytic disinfecting system is easy to operate and control, it is assumed to be effective for disinfection of a circulating water system.

2C1p6 Detection of *Legionella pneumophila* in environmental aerosols of cooling towers by impact sampling methods
L Bordenave, S Dubrou, A Mouilleseaux, V Bex, D Carlier and F Squinazi

To evaluate the efficiency of classic air sampling methods in case of suspicious bioaerosols of *Legionella*, we tested 3 biocollectors in outdoor conditions : a six-stage microbial air sampler (S6, Andersen sampler), a single-stage multiple-hole impactor (ATW) and a liquid impinger sampler (AGI 30). The 3 biocollectors were used simultaneously in 7 assays on-site near cooling towers. The selected sites were located in Paris city and the samples were obtained close to the installations in aerosols discharged from the towers. Each of the 3 sampling methods allowed the detection of airborne Legionella pneumophila (2 to 4 CFU /m^3) but was not related to the concentration of bacteria in water. The background flora present in the water of cooling towers could inhibit the growth of *Legionella* on culture media. The results showed that the impact sampling methods are useful in heterogeneous and variable conditions.

2C1p7 One step towards the reduction of indoor allergens
I Holcátová, V Jirk , J Masák and M Holcát

In this paper we would like to demonstrate completely natural product, which is able to hold enormous (in comparison to its amount) volume of the biological contaminant (bacteria and moulds) in materials normally used in households (e.g., carpets). We would like to demonstrate tests, that verified this effect in laboratory conditions and then in “clinical” trial, with household dust. Under the laboratory conditions, samples of carpets were treated with the tested product. The mixture of germs and moulds in different media impregnated these samples for different time and the effect was analyzed by microphotography. In “clinical” trial the effect of the tested product was observed after the mixing the tested product and dust obtained from the different carpets, normally used in households. All tests gave very promising results that enable us to recommend the product for use in homes of allergic people and also in some area with very high relative humidity.

2C1p8 Self-cleaning and antibacterial surface - first tests
I Holcátová, B Potužníková, V Jirk, J Masák, D Koukalová , M Kolá, V Pochmanová and M Holcát

Self-cleaning and antimicrobial effects of new tiles (H) were reported. To clarify the real effect and durability of this effect was the aim of several tests. We started with the tests recommended by the producer. These tests were rather quick, but far from the practical use. Anyway we would like at first to make clear that these tests are positive also in different standard microbiological laboratories. Then we would like to start with more clinical tests, especially long-term tests. The first portion of tests was done in several laboratories with different bacterial species with very promising results. The self-cleaning effect was confirmed and also the positive effect to the reduction of bacterial contamination was observed, the effect to moulds contamination was not so clear. We also confirm the long-term effect of these tiles with some exceptions. Effects of disinfections on the quality of surface differ according the type, concentration and frequency of use of the disinfections.

2C2o1 Environmental factors for asthmatic children in public housing
D Brugge, J Vallarino, L Ascolillo, N-D Osgood, S Steinbach and J Spengler

Nine families of a public housing development in Boston were enrolled in a pilot asthma intervention program, now being scaled up into a full-scale longitudinal study. The project team succeeded in gaining support for the project by forming a partnership with a community-based organization. Indoor temperature was high and relative humidity low during the winter. Cockroach, mouse and pet antigen levels were variable and frequently high in settled dust. Viable fungal spores levels were variable and high in some apartments. Dust mite allergen levels were below the level of concern. Industrial cleaning led to transient reduction in antigen burden. Nitrogen dioxide levels exceeded ambient concentrations and elevated concentrations of $PM_{2.5}$ were due to smoking. Several VOCs were above adverse risk concentrations. Our findings are consistent with a multifactoral model for exacerbation of asthma in this population and that no single problem dominates.

2C2o2 Efficacy of environmental interventions to reduce asthma triggers in homes of low-income children in Seattle
TK Takaro, J Krieger, L Song, N Beaudet and J Roberts

The Seattle-King County Healthy Homes Project is a randomized, controlled trial of an outreach/education intervention to improve health status in asthmatics by reducing exposure to allergens and irritants in the home. The homes of 274 low-income children with asthma age 4-12 were assigned to either a high or low intensity intervention group for one-year. Vacuuming behavior improved in the high intensity group and exposure reduction was found for dust weight, dust mite and dog antigen, roaches, tobacco smoke, moisture, any of five antigens, and asthma trigger score. The low intensity group also had reductions in some exposures. These findings show that a one- year comprehensive home intervention is effective at reducing many triggers in homes of low-income children with asthma.

2C2o3 Inflammatory potential of dust from schools associated with building related symptoms
L Allermann, HW Meyer, OM Poulsen and F Gyntelberg

The aim was to test whether the inflammatory potential of dust might be used to differentiate schools with high and low prevalence of building related symptoms (BRS). 10 schools with a high prevalence of BRS and 10 with a low prevalence were selected. The potency (PF) of dust samples to stimulate an IL-8 secretion from the A549 cell line was associated with the organic content of the dust. Dust from schools with low prevalence of symptoms had a significantly lower PF than high prevalence schools, and the PF of the floor dust correlated with the prevalence of symptoms (high or low). Using a cut-point value of 4.5 ng IL-8/mg floor dust, significantly more schools with high prevalence of BRS were found above the cut-point than below. The substances in the dust causing the inflammatory potential are at present time unknown.

2C2o4 Comparison of airborne microbial levels in school kitchen facilities and other school areas
P Kalliokoski, U Lignell, T Meklin, J Koivisto and A Nevalainen

Airborne microbial conditions of the kitchens, dining halls, and main study areas were compared in six moisture damaged index schools and two non-damaged reference schools. The average total viable fungal concentrations were lower in the reference than in the index schools in all three types of spaces investigated; however, the difference was statistically significant only for the main study areas. The levels were also always rather low. The same fungal genera and groups, *Penicillium*, yeasts, *Cladosporium*, and *Aspergillus* were dominant in all space types. The amount of different fungal genera detected in a certain type of space was found to have a linear relationship with the amount of samples taken. The bacterial concentrations increased in the order: kitchens, dining halls, and other spaces. This was mainly due to differences in cleaning, occupant density, and ventilation efficiency.

2C2o5 Indoor allergens in schools: a comparison between Sweden and China
Y-H Mi, L Elfman, S Eriksson, M Johansson, G Smedje, J Tao, Y-L Mi and D Norbäck

There are few studies comparing indoor allergens schools from different parts of the world. We measured allergens levels in 23 classrooms in Uppsala, Sweden, and 30 classrooms in Shanghai, China. Dust was collected by vacuum cleaning, and analysed for allergens from cat (*Fel d* 1), dog (*Can f* 1), horse (*Equ cx*), house dust mites (*Der p* 1, *Der f* 1), cockroach (*Bla g* 1), and mould (*Alternaria alternata, Alt a 1*) by ELISA. All Swedish classrooms had cat allergen, and most had dog and horse allergens. In Shanghai, 13% had cat allergen, and 7% dog allergen, while none had horse allergen. House dust mite, cockroach and *Alternaria* allergen were not detected in any sample from either country. Pet allergy and current asthma were less common in Shanghai. Causative factors could be less furry pets at home, wearing of school uniforms resulting in reduced influx of allergens, and less fittings and textiles.

2C2p1 Hidden mold sometimes enters the indoor air
P Morey, M Andrew, B Ligman, and J Jarvis

Air sampling for culturable fungi was carried out in two new school buildings each with hidden mold colonization on envelope construction materials. An objective of the study was to determine if spores from the moldy envelope were entering indoor air. *Penicillium*, *Aspergillus* and *Stachybotrys* species were major colonizers of envelope construction materials in both buildings including stucco paper. Air sampling in one of the two buildings showed that *Penicillium* species from hidden mold reservoirs were entering the indoor air. However, *Stachybotrys* did not enter the indoor air in significant amounts in both buildings. A medical surveillance program concurrent with environmental monitoring was carried out to identify occupants with symptoms of new onset allergic disease.

2C2p2 Indoor air quality in two urban elementary schools: comfort parameters and microbial concentrations in air and carpets
G Ramachandran, JL Adgate, TR Church, D Jones, G Fischer, A Fredrickson, and K Sexton

Indoor air quality parameters in two urban schools in Minneapolis were compared. One school is a new building constructed to minimize indoor air quality problems, while the other is older and of more traditional construction. CO_2, CO, temperature, and relative humidity were measured continuously over three seasons (fall, winter, and spring) in four classrooms and one outdoor location per school. Air concentrations of saprotrophic fungi as well as carpet levels of fungi and three allergens (cat, cockroach, and dust mite) were measured once every two weeks at the same locations. CO_2, CO, temperature and relative humidity were not significantly different between the two schools. Bioaerosol levels were similar between the schools during winter and spring, while the newer school had lower levels in the fall. No differences between the schools were observed in terms of carpet fungal or allergen levels. All measurements, except for carpet fungi and cat allergens, were within currently acceptable guidelines.

2C2p3 Pollen allergen concentrations in a pre-school building and a day-care centre
U Matson, M Kvernes and LE Ekberg

This present paper focuses on pollen allergens in children's environments. A field study was conducted in one pre-school and one day-care centre. Concentrations of birch pollen allergens were measured simultaneously indoors and outdoors, using sampling pumps equipped with membrane filters. Analysis of the data was done by means of the ELISA method. The results showed that the allergen concentrations indoors were influenced by the indoor activity and ventilation. The indoor/outdoor pollen allergen concentration ratio was about twice as high with indoor activities and with the ventilation system on compared to the case without indoor activities and ventilation. The measurements showed a significant increase of indoor pollen allergen levels caused by the open windows, ventilation and indoor activities when the pollen concentration in the outdoor air was above 1 ng/m^3.

2C2p4 Occurrence and characteristics of moisture damage in school buildings
J Koivisto, U Haverinen, T Meklin and A Nevalainen

A total of 30 school units, including 41 school buildings, were technically investigated according to a standardized protocol by trained surveyors, and moisture damage status of each building was assessed. Based on the assessment, the buildings were classified into two categories: 31 index buildings had notable moisture damage observations, whereas 10 reference buildings had not. This classification was used in order to evaluate the effect of different building characteristics, such as age of the building, predominant building materials, and type of structural assemblies, on the occurrence of moisture damage. Moisture damage characteristics, such as location of damage, damaged structure type, and presence of mold/mold odor, were analyzed in order to assess their distribution and inter relationships. With these analyses we seek further insights of such building- and

moisture damage characteristics that may be significant for causes and effects of indoor air pollution related to excessive moisture in school buildings.

2C3o1 Inhalation of hazardous air pollutants from environmental tobacco smoke in US residences
WW Nazaroff and BC Singer

In the United States, 48 million adults smoke 5 x 10^{11} cigarettes per year. Many cigarettes are smoked in private residences causing regular environmental tobacco smoke (ETS) exposure to at least 31 million nonsmokers (11% of the US population), including 16 million juveniles. ETS contains many chemical species whose industrial emissions are regulated by the US federal government as hazardous air pollutants (HAPs). In this paper, average daily residential exposures to 15 HAPs in ETS are estimated for US nonsmokers who live with smokers. The evaluation is based on material-balance modeling, and utilizes published data on smoking habits, demographics, and housing. Newly measured exposure-relevant emission factors are incorporated. Comparison of exposure concentration estimates with health-based guidelines for chronic exposure suggests that aldehydes — specifically acrolein, acetaldehyde, and formaldehyde — should be of particular concern in ETS. Cumulative population intake results are compared for these compounds against other sources of exposure.

2C3o2 Household environmental tobacco smoke (ETS) exposure and risk of childhood asthma - techniques to reduce between-study heterogeneity in a meta-analysis
KL Vork, RL Broadwin and MJ Lipsett

The relationship between physician-diagnosed childhood asthma and ETS exposure has been examined in numerous epidemiological studies, 73 of which we have included in a meta-analysis to develop pooled risk estimates and explore how study characteristics affect them. Variability among study results from "hidden" differences in exposure may distort pooled estimates. This paper presents methods to address two potentially problematic exposure differences. First, we normalized how smoking intensity was presented, improving the precision of some odds ratios and raising their weight in the meta-analysis. Second, most studies did not address the extent to which other airborne exposures might influence estimates of ETS effects. We incorporated supplemental data on outdoor air pollution and regional home design to categorize exposure groups and observed that higher estimates of asthma risk tended to occur in areas with low pollution. We did not find regional differences that may be due to home design to be influential.

2C3o3 Assessment of environmental tobacco smoke (ETS) exposure: urinary cotinine concentrations in children are strongly associated with the house dust concentrations of nicotine at home
S Willers, HO Hein and L Jansson

In the present study the possibility of using nicotine in house dust as an index of ETS exposure was evaluated in an environmental investigation of 23 children with asthma. A standardized procedure for house dust sampling of nicotine with a filter holder connected to a vacuum cleaner, for a defined time and area was developed (F-nicotine). Also, house dust sampling was done from the vacuum cleaner bags of the homes (VC-nicotine). There was a larger variation in VC-nicotine (13-655, median 66 µg/g) compared to F-nicotine (15-393 median 156 µg/g). There were statistically significant associations between an inquiry data based ETS exposure index on the one hand, and urinary cotinine concentrations in children (U-cotinine), F-nicotine and VC-nicotine of their homes, on the other. The strong correlation between U-cotinine and F-nicotine (r_s=0.93; $p<0.0001$) indicate that the new standardized house dust sampling method should be useful in ETS exposure assessment.

2C3o4 The effects of smoking status and ventilation upon environmental tobacco smoke concentrations in UK public houses and bars
J Carrington, AFR Watson and IL Gee

UK public houses generally allow smoking and customer ETS exposure can occur. To address this, the UK Government and the hospitality industry initiated the Public Places Charter (PPC), to increase non-smoking facilities and provide better ventilation in public houses. A study involving 60 UK pubs, located in Greater Manchester, was conducted to investigate the effects of smoking status and ventilation on ETS concentrations. ETS markers RSP, UVPM, FPM, SolPM and nicotine were sampled and analysed using established methodologies. The ETS marker concentrations were significantly higher in the smoking areas compared to the non-smoking areas. The ventilation systems did not have a significant effect on ETS marker concentrations. Consequently, the proposed PPC customer signs for ventilation in pubs may be inappropriate, whilst the signs are appropriate for non-smoking facilities. However, customer ETS exposure will still occur because ETS was detected in non-smoking areas.

2C3o5 A pilot study of the behavior of gas- and particle-phase ETS tracers in residences
MG Apte, LA Gundel, RL Dod, GM Chang and RG Sextro

Our previous study of environmental tobacco smoke (ETS) in a three-room environmental chamber showed that smoking history significantly influenced inter-room ETS transport , particularly of gas-phase nicotine. We conducted a three-home pilot study where smoking was limited to one room. Single-smoker residences were monitored during five one-week periods while the smoker participated in a smoking cessation program. Nicotine traced ETS particles were detected reliably in the smoking rooms (SRs) and unreliably in the non-smoking rooms (NSRs). On average, the ventilation- and volume-normalized smoking rate, 0.1 Cigarette-$h^{-1}m^{-3}$, added about 17 and 4 mg m^{-3} of ETS particles into the SR and NSR, while average nicotine concentration increases were 2 and 0.06 mg m^{-3}, respectively. Thus, nicotine tracers may underestimate ETS particle exposure in a NSR (e.g., a child's bedroom) by a factor of 2 to 8. In other words, ETS exposure predicted from nicotine concentrations could be almost an order of magnitude lower than actual exposure.

2C3p1 Exposure to environmental tobacco smoke in an automobile
FJ Offermann, R Colfer, P Radzinski and J Robertson

We measured exposures to ETS in a moving minivan under three different ventilation scenarios: drivers window open/ventilation off, windows closed/ventilation on, and windows closed/ventilation off. The driver smoked a single cigarette while we measured the concentration of ETS using laser aerosol monitors and the outside air exchange rate using a tracer gas decay technique. The indoor concentrations of respirable particulate matter increased during smoking by factors of 13 to 300 depending upon the ventilation configuration. The calculated exposure for a five hour automobile trip with the windows closed/ventilation off and with a smoking rate of 2 cigarettes per hour is 25 times higher than the same exposure scenario in a residence. Smoking low tar cigarettes or operation of air cleaners or ventilation equipment cannot reduce concentrations in automobiles to acceptable levels. The most effective solution to protecting passengers from ETS exposure is not to smoke in the automobile.

2C3p2 Indoor air quality in smoking and non-smoking households
IL Gee, L Stewart, AFR Watson, G Fletcher, and R Niven

Indoor air quality parameters (RSP, environmental tobacco smoke (ETS) markers, nicotine, nitrogen dioxide and , formaldehyde) have been monitored in 69 homes in the Wythenshawe district of Manchester. This paper examines the differences between smoking and non-smoking households. The homes identified by the presence of the ETS marker solanesol (SolPM) as smoking homes had higher levels of RSP, FPM and UVPM than the non-smoking homes. Occupants were exposed to higher levels of particles, ETS markers and NO_2 in the living room compared to the child's bedroom. High NO_2 levels may be related to the common use of gas fires in living rooms. Tobacco smoking is more likely to occur regularly in the living room although ETS markers were identified in many of the children's bedrooms implying either that ETS is infiltrating from other rooms or that the children themselves are smoking. Tobacco smoking is likely to make a considerable contribution to levels of RSP in the homes but was not related to levels of NO_2.

2C3p3 Neonatal nicotine withdrawal syndrome: in utero environmental tobacco smoke
Ó García-Algar, C Puig, C Méndez, O Vall, P Zuccaro, R Pacifici and S Pichini

A pilot study was designed to assess if neonatal nicotine withdrawal syndrome might exist among newborns exposed to maternal cigarette smoke. Urinary cotinine and hair nicotine from newborns were analyzed to investigate an eventual acute and chronic exposure to tobacco smoke constituents. The Finnegan clinical score for neonatal withdrawal syndrome was assessed three times a day for three consecutive days. Finnegan scores varied between zero and eight, especially by irritability and tremor over the first twenty-four hours of life in newborns with urinary cotinine in the higher part of the concentration range (> 500 ng/ml). In these specific cases, neonatal hair analysis revealed a chronic high exposure to tobacco constituents in all gestational period. The results show that neonatal nicotine withdrawal syndrome is uncommon, despite the observation of isolated temporary symptoms in newborns from heavy smoker mothers.

2C3p4 Passive exposure to tobacco smoke: hair nicotine levels in preschool children
N Kalinić, Lj Skender, V Karačić, I Brčić and V Vađić

Hair nicotine levels were measured in children to establish the utility of the method in assessing exposure to environmental tobacco smoke (ETS). All 33 children (22 girls and 11 boys), aged five to seven, were recruited from a kindergarten in Zagreb, Croatia. Parents were asked to fill in a questionnaire the purpose of which was to indicate the degree of ETS exposure. Nicotine in the hair was measured using Gas chromatography/mass spectrometry. Hair nicotine levels ranged from below the detection limit (<0.1 ng/mg of hair) to 7.89 ng/mg of hair. The difference in hair nicotine levels between children who lived

with smokers (N=20; mean=4.43 ng/mg of hair) and those who did not live with smokers (N=13; mean=0.68 ng/mg of hair) was very significant (t=5.456001; P<0.01).

2C3p5 Relationship between environmental tobacco smoke and urinary cotinine levels in passive smokers at their residence
YW Lim, HJ Kim, DC Shin, SJ Lee, SE Park, JY Yang and CS Hong

Studies on the effects of environmental tobacco smoke (ETS), using recorded air concentrations, may be subject to bias. Cotinine, a metabolite of nicotine, is recommended as a valid quantitative measure of exposure to ETS. The purpose of this study is to correlate environmental tobacco smoke with urinary cotinine levels in passive smokers at home. We measured urinary cotinine concentrations in 57 housewives and the nicotine level in the indoor air of their living rooms over a period of 24 hours. Levels of nicotine and urinary cotinine were analyzed using GC/MS and HPLC/UV. At the same time, we gave a spirometric test to the subjects and questionnaires about smoking to the subjects' families. We found significant correlation between nicotine levels in the indoor air and the passive smokers' urinary cotinine to creatinine ratio(CCR). On the other hand, age and urinary cotinine levels were not significantly correlated. The smoking habits of the smokers were also a major determinant factor in the urinary cotinine levels of the passive smokers.

2C3p6 Biomarkers of acute and chronic environmental exposure to tobacco smoke during pregnancy
S Pichini, Ó García-Algar, C Puig, O Vall, J Segura, JA Pascual, D Diaz, J Sunyer, L Muñoz, P Zuccaro and R Pacifici

Biomarkers of acute and chronic exposure to environmental tobacco smoke (ETS) were investigated in a group of non smoking mothers and their newborns. Cotinine content in maternal and neonatal urine and in cord serum was measured to assess exposure to ETS at the end of the pregnancy. Hair nicotine was measured in fetal hair and in maternal hair, accounting for the whole pregnancy. Cord serum cotinine, newborn urinary cotinine and maternal hair nicotine were associated with levels of maternal exposure to ETS. In contrast, nor maternal urinary cotinine, nor foetal hair nicotine could differentiate between exposure to ETS. In comparison with data from other European and American cohorts, biomarkers of acute and chronic exposure to ETS disclosed an underestimation of ETS exposure by pregnant women.

2C4o1 Emissions of halogenated volatile organic compounds from residential dishwashers
DA Olson and RL Corsi

This research involved measurements of halogenated volatile organic compound emissions from residential dishwashers. It was hypothesized that "in-home" formation from use of chlorinated dishwasher detergents may be a significant source of human exposure to these chemicals. A major goal of this research was to characterize chemical emissions from dishwashers experimentally. Liquid and gas samples were collected for each experiment. All liquid samples were analyzed using a purge and trap autosampler plumbed to a gas chromatograph (GC) equipped with a mass selective detector (MSD). Gas samples were collected by drawing headspace air through Tenax™ adsorbent tubes, with subsequent analysis by GC/MSD. Typical chloroform concentrations in the dishwasher headspace were between 1 and 10 mg/m^3.

2C4o2 Air toxics emissions from a vinyl shower curtain
JCS Chang, R Fortmann and N Roache

Three static chamber tests were performed to measure the headspace concentrations of the curtain when stored in a sealed container. Four air toxics--toluene, methyl isobutyl ketone (MIBK), ethylbenzene, and phenol-- were detected. Although the chamber loadings varied by a factor of 3.1, the average headspace equilibrium concentrations differed by less than 32% among the three chambers. The emission patterns of the four air toxics were measured by a dynamic chamber test. An emission model was developed to interpret both the static and dynamic chamber data. The model verified that the measured static chamber headspace equilibrium concentration should represent the maximum air toxics level achievable by the shower curtain in an enclosed environment. Analysis of the dynamic chamber data indicated that the air toxics emissions were controlled by a solid-phase diffusion process and could result in elevated indoor air toxics concentrations for more than a month.

2C4o3 3d-CFD analysis of diffusion and emission of VOCs in a FLEC cavity
S Murakami, S Kato, Q Zhu and K Ito

In this paper, the flow field and the emission field of volatile organic compounds (VOCs) from the surface of indoor building materials in a FLEC (Field and Laboratory Emission Cell) Cavity are examined by 3D CFD analysis. Two types of emission phenomena from building materials are studied here: (1) emission controlled by external diffusion; (2) emission controlled by internal diffusion. The flow field within the FLEC cavity is laminar. With a ventilation rate of 200 ml/min, the air velocity near the test material surface ranges from 0.1 cm/s to 1.4 cm/s. In the case of the internal diffusion material, with respect to the concentration distribution in the cavity, the local VOC emission rate becomes uniform and the FLEC works well. However, in

the case of evaporation type materials, the FLEC is not suitable for emission testing because of the thin FLEC cavity. The diffusion field and emission rate depend on the cavity concentration and on the Loading Factor.

2C4o4 Emissions from electronic devices: examination of computer monitors and laser printers in a 1m^3 emission test chamber
M Wensing, T Kummer, A Riemann and W Schwampe

Investigations were carried out using the test chamber method to determine which influence VOC emissions from computer monitors and laser printers in normal operation can have on the quality of indoor air. Theoretical indoor air concentrations were computed for a model room using specific emission rates. In individual cases it was determined that concentrations may occur during the initial start-up of the devices, which are above the indoor recommended values for TVOC. The VOC emissions from the monitors revealed a clearly defined decay behaviour within a few hours after the initial start-up as a result of ageing. Therefore a comparably low contribution to the indoor air composition is to be expected with long-term use. The emissions from laser printers are influenced decisively by the printing process. In this case recurring emissions on the same level are to be expected over limited periods.

2C4o5 Emissions of air pollutants from burning of incense by using large environmental chamber
S-C Lee, H Guo and N-H Kwok

A large environmental chamber with controlled temperature, relative humidity and air flow rate is used to investigate emissions of target air pollutants from incense, before, during and after burning. The target air pollutants include particulate matters (PM_{10} ,$PM_{2.5}$), volatile organic compounds (VOCs), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur dioxide (SO_2) and total hydrocarbons (THC). $PM_{2.5}$ and PM_{10} concentrations are measured using Dust-Trak portable samplers. Selected volatile organic compounds emitted are identified and quantified by Gas Chromatograph - Mass Selective Detector (GC-MSD). CO is analyzed with a Thermo Electron Gas Filter Correction CO Ambient Analyzer. SO_2 is measured using Pulsed Fluorescence SO_2 Analyzer and nitrogen oxides are monitored with Chemiluminescence NO-NO_2-NO_x Analyzer. It is shown that the $PM_{2.5}$ and PM_{10} mass emission rates increased significantly during incense burning. The levels of CO, NO-NO_2-NO_x, SO_2 and THC have also increased during the burning of incense. The results confirm that incense is a significant source of indoor pollution.

2C4o6 Comparison between full- and small-scale sensory assessments of air quality
P Wargocki, J Sabikova, L Lagercrantz, G Clausen and PO Fanger

Thirty-nine untrained subjects made small- and full-scale evaluations of the acceptability of the quality of air at 22 C and 40% RH, polluted by either carpet, felt floor covering, painted gypsum board, linoleum or chipboard. Small-scale evaluations were made on the air extracted from 200-L glass chambers ventilated at an airflow of 0.9 L/s. Full-scale assessments were made immediately upon entering offices ventilated at an outdoor air supply rate of 1.9 h^{-1}. The ratio of ventilation rate to surface area of a building material was identical in the chambers and in the offices. Full-scale sensory ratings of acceptability of air polluted by carpet and by linoleum were systematically better than small-scale assessments, but not for the other three materials. Calculated sensory emission rates from carpet and linoleum were significantly lower in full scale than in small scale. When modelling the perceived air quality in spaces, sensory emission rates estimated in small scale may require a correction, probably depending on the nature of the chemicals emitted by a building material.

2C4p1 TVOC indoor emission from wood based materials and lacquers
A Dziewanowska-Pudliszak and P Gaca

In the Department of Environment Protection in the Wood Technology Institute we carried out research of emission of Volatile Organic Compounds from materials used in furniture production. VOC emission research from lacquered veneers made from nitrocellulose and acrylic lacquer put on glass board showed minimal higher total TVOC concentration observed in air collected from the chamber filled with lacquered boards comparing with its concentration in air supplied to the chamber. Similar low TVOC concentration was observed in research of basic wood based materials like: chipboard, veneered and laminated chipboard, MDF board and plywood. Coatings from chemsetting and polyurethane lacquer were emitted higher amounts of volatile organic compounds. Our research confirmed that lacquers play a main role in VOC emission from wood-borne materials applied in furniture production.

2C4p2 Full scale test system for indoor impact study of volatile organic compound emissions from building materials
L Antonelli, E Mapelli, S Sanguinetti and A Strini

A full-scale (36 cubic meters) test chamber was developed for the study of the effects of volatile organic compounds (VOC) emissions from materials in real indoor environments. This test chamber is located outdoor and was designed to optimize the realism of the test. The chamber is supplied with unfiltered air and is realized in concrete with gypsum-finished walls and ceiling. The air supply system allows the operation in static conditions (no air change) and dynamic conditions (controlled air

change). An arbitrary time schedule of different air change rates can be established in order to simulate variable indoor conditions. A ceiling fan assures the proper air mixing. The temperature control system is based on electrical heating elements in winter, while in summer the temperature is given by a balance of the solar radiation, the thermal inertia of the chamber structure, the temperature of external air and the air change rate.

2C4p3 Laboratory and real scale comparative study of benzyl alcohol emissions from a two-component epoxy paint
L Antonelli, E Mapelli, A Strini, T Cerulli, R Leoni and S Stella

The benzyl alcohol emissions from a two-component epoxy paint were studied in a 30 litres laboratory test chamber and in a 30 cubic meters real scale test system. The real scale measures were done in a test system realized with concrete and finished with gypsum. The laboratory scale experiments were done in a glass chamber with minimized sink an in another chamber simulating the walls and ceiling sink with gypsum surfaces. The laboratory scale experiment without sink demonstrates a high emission rate during the first hours, and a quick abatement of the emission after the polymerization. The simulated sink laboratory experiments demonstrate lower concentrations during the first hours and higher concentrations after the sample polymerization, due to the secondary emissions from gypsum surfaces. In the real scale experiments however the release effects from walls was were not observed, possibly due to a permeation through the walls under the gypsum layer.

2C5o1 Upper airway and pulmonary effects of terpene oxidation products in BALB/c mice
AC Rohr, CK Wilkins, PA Clausen, M Hammer, GD Nielsen, JD Spengler, and P Wolkoff

Terpene oxidation products (OPs) have previously been shown to cause upper airway irritation in mice during 30-minute exposures. This study evaluated the effects of the OPs of d-limonene, (+)-α-pinene, and isoprene on the upper airways, conducting airways, and lungs over a longer 60-minute exposure period. Respiratory parameters in male BALB/c mice were monitored via head-out plethysmography during exposure to reaction mixtures comprised of 3.4 ppm ozone with 47 ppm a-pinene, 51 ppm d-limonene, or 465 ppm isoprene. Upper airway irritation was a prominent effect; however, over the longer exposure period we further observed the development of airflow limitation that persisted for at least 45 minutes post-exposure. These findings suggest that terpene OPs may have moderate-lasting adverse effects on both the upper airways and pulmonary regions, which may be important in the context of lower airway symptoms in office and sawmill workers, or of occupational asthma in cleaning personnel.

2C5o2 Health effects of a volatile organic mixture with and without ozone
N Fiedler, J Zhang, Z Fan, K Kelly-McNeil, P Lioy, C Gardner, P Ohman-Strickland, and H Kipen

Volatile organic compounds (VOCs) and individual characteristics contribute to building related health effects. This study tests the effects of controlled exposures to VOCs, VOCs + ozone (VOCO), and clean air masked with VOCs on symptoms, neurobehavioral performance, nasal inflammation, and lung function. Healthy women (N=75), ages 20 to 45, completed measures at baseline, during, and after each exposure. The 26.3 mg/m^3 VOC mixture consisted of 23 compounds including d-limonene. Secondary products of the VOCO reaction confirm the presence of respirable particles. Relative to baseline, symptoms and neurobehavioral performance during exposure were not significantly different between conditions nor were post-exposure cell counts from nasal lavage or lung function. Individuals with higher levels of negative affect or chemical odor intolerance reported more symptoms in each exposure while individuals lower in these characteristics reported more symptoms only in the VOC and VOCO conditions. These preliminary results will be clarified as more subjects are accrued.

2C5o3 Eye irritation from exposure to ppb levels of limonene oxidation products
JG Klenø and P Wolkoff

Terpene/ozone reaction products in realistic indoor concentrations may cause eye/airway irritation. This hypothesis has been tested by exposing the left eye in 8 male subjects single blind for 20 min to limonene oxidation products (LOPs) and the residual reactants, including clean air, in random order, while viewing an educational film. The reaction mixture of ozone and limonene was 10.5 min old and 65% completed with residual concentrations of 31 and 75 ppb, respectively. The subjects reported eye irritation and their blinking activities were recorded during exposure. The mean blink frequency (BF) increased 21-66% during exposure to LOPs relative to clean air ($p<0.0001$). The BF was unaffected by exposure to ozone, while a negligible reduction in BF was observed for limonene. Limonene and LOPs resulted in weak subjective eye irritation, but the perceptions differed. Only for LOPs, the increase of BF and irritation coincided. The findings substantiate the above hypothesis.

2C5o4 Terpene/ozone reaction products (TOPS). Dependence of irritation on reaction time and relative humidity
CK Wilkins, P Wolkoff, PA Clausen, M Hammer and GD Nielsen

Earlier, we reported the formation of unidentified strong irritants in reaction mixtures of terpenes and ozone. The identified products included aldehydes, ketones and carboxylic acids. Here we report the effects of relative humidity and reaction time on irritant formation in our flow reaction system using limonene and isoprene. Upper airway irritation was measured in mice (via reduction of respiratory rate) using ca. 5 and 35% relative humidity and long and short reaction times. Maximum irritation was observed for low humidity/short time reaction mixtures for both terpenes and the combination of high humidity and long reaction time gave the least irritation. In order to estimate the comparative irritation of limonene/ozone mixtures, we studied irritation effects at four ozone concentrations using low humidity/short time conditions holding other parameters constant. The mixture containing limonene/ozone at 46/0.5 ppm exhibited an irritation effect, which was the same magnitude as that of pure limonene.

2C5o5 Eye irritation caused by indoor pollutants - an in-depth approach
P Wolkoff, P Skov, C Franck and L Nüchel Pedersen

Eye irritation (incl. dry eyes/tired eyes) is one of the most common symptoms reported in the office environment with mean symptom rates up to ca. 40%, and background rates about 10%. Atopi, gender, psychosocial and psychological factors influence reporting. Common risk factors are VDT and photocopiers, and possibly mechanical ventilation. The higher odd ratios found for women may be explained by objective differences and hormonal factors. Visual attention and poor lighting, including high room temperature have a destabilization effect of the precorneal lipid layer of tear film. Rupture and dry spots are formed which lead to desiccation or facilitate the access of irritants. Both high and low relative humidity promotes instability, and similarly contact-lenses and eye make-up. Reactive organic compounds known to form strong airway irritants, when mixed with ozone, are possible candidates for eye irritation. Destabilization of the tear film by airborne particles, is only possible if their content of surface-active compounds is high.

2C5p1 A weighted sum parameter to simplify discussion on aldehyde exposure
R Meininghaus, E Bastin, N Gonzalez-Flesca, and A Cicolella

In the present work, the personal exposure of a French urban population to several aldehydes is assessed. For this reason, a weighted sum parameter is used which takes into account the differences in sensory irritation of aldehydes. The personal exposure of 17 volunteers was assessed with personal passive samplers during one week. Simultaneously, aldehyde concentrations were determined in different microenvironments. The results show that formaldehyde is the most important sensory irritant of the aldehydes included in this study, due to a particularly high sensory irritation and because it is a ubiquitous compound found at high concentrations. Personal exposure is strongly linked to indoor exposure (homes and offices). By using a weighted sum parameter, the discussion of large data sets is considerably simplified. This sum parameter could be easily extended to other strong sensory irritants, leading to a weighted TVOC value for sensory irritation.

2C5p2 Sensory irritation of mixture of ethylbenzene and 2-hexanone in mice
J-P Kasanen, A-L Pasanen, K Villberg, K Saarela, P Pasanen and P Kalliokoski

Volatile organic compounds (VOCs) are assumed to play a role in the prevalence of sensory irritation (SI) in indoor environments. Data on the irritation potency of VOC mixtures are sparse. In this study, we evaluated SI for the mixture of 2-hexanone and ethylbenzene in mice. A group of four naive mice at time were exposed to both 2-hexanone and ethylbenzene. Respectively, mice were exposed to the mixture of ethylbenzene and 2-hexanone to test the hypothesis that at lower concentrations of a mixture, SI response would be additive (a sum effect of single chemicals). The responses caused by the single chemicals were then compared to those caused by the mixture. This comparison suggests that at the low concentrations, the SI response of the single chemicals in the mixture was additive or hyperadditive, i.e., the mixture was equal or slightly more potent than expected from the results of the individual compounds.

2C5p3 Effects on nasal mucosa during experimental exposure to mixtures of aldehydes and alcohols-a climate chamber study on humans
G Stridh, K Andersson, J-E Juto, A Hempel Jörgensen, S Kjaergaard and L Mølhave

In the climate chamber study performed under well controlled conditions two groups of healthy, non-smoking, non-allergic persons, drafted from the public register of the city of Aarhus, participated. One study group consisted of persons hypo-reactive and one of persons hyper-reactive nasal sensitivity to histamine. The study on aldehydes comprised n-hexanal, n-nonanal and n-decanal and the concentrations were measured both continuously by a flame ionisation detector and integrated by sampling on Tenax. In the alcohol study the mixture consisted of n- butanol, 2-ethylhexanol and benzyl alcohol. Total expected concentrations for both the aldehyde and the alcohol study were 0 µg/m³, 50 µg/m³ and 300 µg/m³. Also a mixture of 22 VOCs

at a concentration of 10,000 µg/m³ was tested. The tests were arranged in a Latin-square design. In short term experiments neither the aldehyde mixture nor the alcohol mixture did cause any significant swelling of nasal mucosa.

2C5p4 Toxic emissions from British and American brands of disposable diapers
R Anderson and J Anderson

Mice were exposed to the volatile emissions of 4 samples of disposable diapers. Two samples (X-Brit and Y-Brit) were manufactured in Britain, the other two (X-Amer and Y-Amer) were of the same brands but manufactured in America. A modification of ASTM-E 981 was used to measure Sensory Irritation (SI), Pulmonary Irritation (PI), and Airflow Limitation (AFL). A Functional Observational Battery was used to evaluate neurotoxicity. The British diapers had little odor, while the American diapers appeared to contain a fragrance addition. The British diapers produced only mild neurotoxicity during the first exposure, but X produced significant SI, PI, and AFL during the second exposure. The American diapers caused respiratory and neurotoxicity during both the first and second exposures, the results generally being more severe during the second exposures. Products with identical brand names may have very different toxic effects (i.e., emit different toxic air pollutants) if manufactured in different countries.

2C5p5 Acute toxicity of marking pen emissions
R Anderson and J Anderson

Groups of mice were exposed for one hour to the emissions of 8 brands of felt tip markers (A-H). A modification of ASTM-E 981 test method was used to measure changes in respiratory cycle parameters and diagnose Sensory Irritation (SI), Pulmonary Irritation (PI), and Airflow Limitation (AFL). A Functional Observational Battery was used to evaluate neurotoxicity. Pens A through F produced respiratory toxicity and neurobehavioral changes including abnormal posture and gait, tremors, falling, and/or hyperactivity, facial swelling, severe lacrimation, and gasping. Pens G and H were much less toxic. The TVOC concentrations used in the chamber tests were similar to those near marking pens in actual use. These results document that some felt tip markers emit mixtures of chemicals which can cause respiratory and neurobehavioral abnormalities. These toxicity results explain human complaints concerning respiratory and neurological reactions to marking pen emissions.

2C5p6 Studies on the mutagenicity and tumor inducing potency of artificial fragrances
V Mersch-Sundermann, M Emig, WQ Lu, H Hoelzke, R Gminski and S Boehmer

5 Nitro musks and 6 polycyclic musks were studied for genotoxicity using Salmonella assay (*S.typhimurium* TA97, TA98, TA100, TA102), sister chromatid exchange (human lymphocytes), *in vitro* (human lymphocytes, human HepG2 cells) and *in vivo* micronucleus test (polychromatic erythrocytes in CD1 mouse bone marrow), single cell gel electrophoresis (HepG2 cells), cogenotoxicity assays with CD1 mice, Sprague Dawley (SD) rats and HepG2 cells, cytochrome P450 ELISA (CYP1A, 2B, 3A, 4A) and mouse skin I/P protocol for tumor promoting and co-initiating effects. Except musk ambrette none of the nitro musks exhibited direct mutagenicity. As the most important result we identified co-mutagenic and co-initiating effects of musk ketone in combination with benzo[a]pyrene (Bap) in SD rats (*ex vivo*), 7,12-DMBA in CD1 mice (*in vivo*), and Bap in HepG2 cells (*in vitro*) indicating that the combination of MK and polycyclic aromates (PAH) could cause a genetic risk. Polycyclic musks exhibited no genotoxic effects.

2C6o1 Measurement and simulation of the indoor air quality impact of gaseous air cleaners in a test house
C Howard-Reed, SJ Nabinger, and SJ Emmerich

Residential and commercial gaseous air cleaning technologies have not gained wide acceptance in the marketplace, in part due to the lack of performance data from field tests or simulation studies. This paper describes a field study of the performance of two gaseous air cleaners in a single room test house and simulations based on these tests with an indoor air quality model (CONTAMW). Air cleaner effective cleaning rates (ECR) were experimentally measured for toluene and ranged from 93 m^3/h to 202 m^3/h compared to the average toluene loss rates of 18 m^3/h due to infiltration and 7.7 m^3/h due to sorption on surfaces in the house. As a result, the effectiveness of the air cleaners for toluene in these tests ranged from 82 % to 94 % for different experimental conditions. CONTAMW proved to be an effective tool for predicting the impact of air cleaner performance in the single zone environment.

2C6o2 Measuring method of reducing effect of pollutant concentration with absorptive building material
S Kato, Q Zhu, K Ito, Y Ataka and S Murakami

In this paper, measuring method of performance of passive adsorption building materials that are used for reducing pollutant concentration in a room is considered. The convective mass transfer characteristic has a great influence on its performance. In order to control the convective mass transfer precisely in the performance test, the authors have developed the Boundary Layer Type Small Test Chamber in which precise control of airflow along the test materials can be done. The equivalent ventilation

rate (Q_{ads}) of adsorption performance is drawn as the new index that corresponds to the rate of convective mass transfer rate in the case of the adsorption surface concentration to be zero. To demonstrate the performance test, the adsorption test of the gypsum board that has the ability of decomposing HCHO within the board by the addition of some chemical materials is performed. The absorption rate of the gypsum board predicted by the CFD corresponds well with the experimental result.

2C6o3 Improved test methods for electronic air cleaners
JT Hanley, DL Franke, MK Owen, DS Ensor, and LE Sparks

The objective of this project was to develop a fractional filtration efficiency test protocol for residential ESPs that avoids the limitations of the ASHRAE 52.2 method. Specifically, the objectives were to a) determine the change in efficiency that residential ESPs undergo in real life and b) develop accelerated laboratory methods that reasonably reproduce the real life changes. This work was conducted as part of the Environmental Protection Agency's (EPA) Environmental Technology Verification (ETV) program for Indoor Air Products. Results from the real life study revealed that the observed decrease in ESP filtration efficiency was due to reduced corona discharge from the ionizing wires, as opposed to dust collection on the precipitator plates. Analysis of the wires showed that they had become coated with a silicon compound, presumably silicon dioxide formed by a corona-enhanced vapor deposition process. A laboratory method to reproduce and accelerate the vapor deposition process was developed.

2C6o4 Indoor ozone and electronic air cleaners
D Bowser and D Fugler

Plate and wire type Electronic Air Cleaners (EAC) are frequently found in Canadian houses. They are often sold based on their potential to improve respiratory health. EAC's produce ozone, a respiratory irritant, during operation. This project involved experiments with an air-handler and EAC in one house under varying air-change and EAC air-flow conditions. Ozone, EAC device airflow and weather data were measured continuously. Indoor ozone levels were predicted for a variety of air-change rates and outside ozone levels. The continuous operation of the EAC in these experiments could raise indoor ozone levels by up to 9 ppb over that which would be expected without EAC operation. The proposed outdoor guidelines by the Canadian Federal-Provincial Working Group on Air Quality range from 20 to 25 ppb, depending upon susceptibility. An addition of 9 ppb will push many houses to indoor ozone levels higher than proposed outdoor guidelines.

2C6o5 Impact of an ozone generator air cleaner on styrene concentrations in an indoor air quality research chamber
M Mason, L Sparks, K Krebs and X Liu

We investigated the impact of an ozone generator air cleaner on vapor-phase styrene concentrations in a full-scale indoor air quality test chamber. The time history of the concentrations of styrene and ozone is well predicted by a simulation model using the reaction rate constant for styrene/ozone that has been determined for the troposphere at atmospheric pressure and room temperature. In three tests, the reaction products, formaldehyde and benzaldehyde, were produced in ratios of 0.64±0.22 and 0.82±0.19 mole (average ± standard deviation), respectively, for each mole of styrene consumed. Two tests were conducted in near-static- chamber conditions, and one test was conducted at 1 air exchange per hour (ACH). The test results demonstrate that, where reactive volatile organic compounds (VOCs) arestyrene is present, ozone generator air cleaners increase indoor exposure to formaldehyde and other oxygenated organic compounds as well as to ozone and nitrogen dioxide.

2C6p1 Improvement of IAQ by coating of adsorptive polymer: the development of material, evaluation and its application
M Hori, T Ohkawara, S Handa and T Wakui

A coating material of adsorptive polymer by graft polymerization was developed for the purpose of improving IAQ to decrease formaldehyde and VOC concentrations. The material was evaluated by a simple method with a small glass chamber of a circulation system. The ability of sealing of both of formaldehyde and VOC and adsorption, respectively, was performed by emission rate test and adsorption test. The polymer with three kinds of function group of sulfonic, amino and carboxyl was relatively effective to sealing and adsorption. The material was superior to the other materials on market in Japan. The material was applied to improve IAQ in two kinds of new multi-family house, and was evaluated by concentrations of indoor air and emission rate from individual parts. It was shown that formaldehyde concentration and TVOC, respectively, decrease to one fifth or one sixth and a half in the room treated with the coating material.

2C6p2 The simple performance testing method for passive type products to remove gaseous formaldehyde
A Hasegawa, H Kimura, H Komine and M Kamata

This paper aims to establish the simple testing method for gaseous HCHO removal performance of passive type products. The testing equipments comprise of stainless tanks, which are substituted for small chambers and air pumps. These are original and

costless. For HCHO emission source in chambers, 3 kind of engineered wood materials were examined and medium density fiberboard (MDF) was optimum as its homogeneity. To measure HCHO concentrations in chambers, photo acoustic spectroscopy method (PAS) was available for monitoring with identified by active DNPH method. The testing method is based on comparing with HCHO concentrations in a pair of chambers where a passive type product is placed in and not. We suggest this simple procedure as the screening test for more detailed and expensive test to evaluate removal efficiency of passive type products.

2C6p3 Reduction of formaldehyde concentration with charcoal board in a room model
K Shibano, S Yoshizawa, S Goto and Y Ogawa

We newly developed charcoal board by binding charcoal powder with superfine natural fibers as adhesive. The superfine cellulose and collagen fibers were prepared from defiberized milk cartons and leather scraps with a grinder, respectively. Reduction of volatile organic compounds (VOCs) concentration in room model of 21.6 m^3 was studied by adsorbing formaldehyde with the charcoal board. Formaldehyde emitted from flooring plywood in the room models was adsorbed with the charcoal board set on the wall. The formaldehyde concentration in the room changed corresponding to the change of the room temperature. The concentration decrease was dependent on the setting ratio, which was defined as the charcoal board area on the wall for the room volume (m^2/m^3). The concentration under 0.01 ppm was observed during measurement time in the room at the setting ratio of 1.2 m^2/m^3 irrespective of the room temperature change.

2C6p4 Investigation of air pollution purification process by a bioelectrical potential analysis
Y Hasegawa, H Uchida, S Asada, T Katsube and T Oyabu

It is known that various plants have purification ability for indoor air pollutants. In this paper the purification mechanism of foliage plant was investigated by analyzing bioelectrical potential. It was first shown that the air purification ability of a plant depends on various environmental conditions, especially on light irradiation. It was then clarified that the bioelectrical potential responds to pollutant (formaldehyde) concentration change and also to the photosynthesis activity of the leaflet. The correlation between gas purification process and generated bioelectrical potential were discussed to make clear the gas reduction mechanism.

2C6p5 Application of heterogeneous photodegradation of indoor air level NO_x under UV irradiation
CH Ao and SC Lee

Only a few studies have focused on the photodegradation of pollutants at typical indoor air concentration. In this study, the photodegradation of NO_x in typical indoor air level is investigated. Sensitive analyses of the photodegradation of NO_x are conducted by investigating the effects of initial concentration, residence time and relative humidity. The removal of NO_x are conducted in a 57 l reactor, using TiO_2 as a photocatalyst and irradiated by a 365nm ultra violet light. NO, NO_2, and NO_x are simultaneously measured by a chemiluminescence NO analyzer. It was found that a minimum of 60% and a maximum of 90% of NO are removed from the system under different variations. At a higher initial NO concentration, the removal efficiency is higher, but generates a higher secondary pollutant, NO_2. Removal efficiencies of NO are higher at a longer residence time and lower relative humidity. Relative humidity affected the conversion most significantly.

2C6p6 Using scanning electron microscopy to visualize photocatalytic mineralization of airborne microorganisms
HT Greist, SK Hingorani, K Kelley and DY Goswami

In order to support the previous evidence of photocatalytic oxidation (PCO) effectively mineralizing airborne microorganisms, scanning electron microscopy (SEM) techniques were implemented to visualize stages of cellular destruction. SEM was used to observe three different microorganisms exposed to various durations of PCO. Purified microorganism suspensions were applied to photocatalyst coated aluminum disks, exposed to UV-A or stored in the dark, then processed by traditional fixation methods. The extent and characteristics of mineralization varied between organisms. Serratia marcescens showed the most significant changes in cell morphology by 11.75 hours and more than 99 percent destruction by 36 hours. Purified Bacillus subtilis and *Aspergillus* niger spores began showing changes by 11.75 hours and by 36 hours there were significant reductions in spores detected with nearly all the remaining spores showing some morphological changes. This visual evidence of microorganism mineralization supports using PCO in applications where a self-cleaning air purification system is needed.

2C6p7 Effectiveness of portable air cleaners and upper-room ultraviolet germicidal irradiation for infection control
E Kujundzic, C Howard, M Hernandez and S Miller

Air filtration and ultraviolet germicidal irradiation (UVGI) are engineering control methods that can prevent the spread of airborne bacteria through indoor environments. Upper-room UVGI has been shown to inactivate airborne bacteria at significant rates and filtration has been shown to be effective in removing bioaerosols. This study investigated three portable air cleaners

(PACs) and determined their rates for removing airborne bacteria. In addition, the effectiveness of combining UVGI with PACs was investigated. With the ventilation system providing 0 or 6 air changes per hour, the air cleaners were run separately or with the UVGI system in operation. Mycobacterium parafortuitum cells were generated in the test chamber such that their numbers and physiologic state were comparable both with and without UVGI and filtration. Results showed that airborne bacteria removal rates varied from 0.3–12 1/h depending on the PAC and from 17–27 1/h when using portable air cleaners in combination with UVGI.

2D1o1 Factors relating to the release of *Stachybotrys chartarum* spores from contaminated sources
KK Foarde and MY Menetrez

Although traditionally, fungi as building contaminants have primarily been viewed as allergens, adverse health effects resulting from inhalation of fungal spores are likely due to multiple factors. One factor is the mycotoxins produced by some fungi. This paper describes the preliminary results of a research project to determine the factors that control the release of *S. chartarum* spores from a contaminated source and test ways to reduce spore release and thus exposure. As anticipated, *S. chartarum* spore emissions from gypsum board at low flow are directly proportional to airflow and indirectly proportional to relative humidity and support our previous observations with *Penicillium* and *Aspergillus*. The relationship between the culturable colony-forming units (CFUs) and total spores varied over time and needs further investigation, but suggests one reason that correlation between airborne field measurements (usually only of culturable organisms) and possible exposure is so difficult.

2D1o2 Dynamics and ventilation effects on airborne microbes at air-conditioned office buildings in Taiwan
PC Wu, HJ Su, YY Li, CY Huang and CM Chiang

Our study conducts serial environmental measurements in 6 large office buildings with 2 different mechanical ventilation designs to obtain the patterns of airborne microbial exposure in typical office buildings, and to examine the effects of ventilation type and air-exchange rate on the distribution of airborne microbes. Duplicate samples of airborne fungi and bacteria were collected. All measurements were taken three times a day and continued for at least one week at every investigated building. The air-exchange rates were estimated by tracer gas concentration decay method, and measured by continuous Multi-Gas monitor in every test space. High levels of airborne microbes seemed to be more easily observed in buildings with Fan Coil Unit (FCU) system than in buildings with Air Handling Unit (AHU) system. Higher air-exchange rate might increase the indoor *Cladosporium* concentrations by infiltration, but could reduce those Yeast exposures of indoor origin.

2D1o3 Transport of fungal spores from crawl space to indoors
M Matilainen and P Pasanen

A mechanical exhaust ventilation system is typical in apartment buildings in Finland. In most cases the base floor has leakages, and as the apartment building has lower pressure than crawl space, thus air and fungal spores may flow from the crawl space to the apartment. Usually the concentration of fungal spores is clearly higher in the crawl space than inside the building. In this study, in most cases for the same species, the size distribution of fungal spores was similar in shape in the crawl space and indoors. The size distribution of fungal spores varied depending on the fungal species. Correlation between the fungal spores in the crawl space and indoors depended on microbe species. Some species have sources inside the building, which makes the correlation more complicated. However, some species like *Acremonium* do not normally have a source indoors, and the concentration of *Acremonium* in the crawl space correlated to the indoor concentration.

2D1o4 Mould propagation resulting from air pressure differences across the building envelope
T Lee and T Stooke

A common mitigation strategy for indoor air contaminants is ventilation. Typically mitigation measures provide additional general exhaust to remove the indoor air contaminants, or increase supply air to dilute the contaminants. Unbalanced air pressure will result in moisture within the building envelope, caused either by drawing moisture into the wall or from condensation. A historic courthouse in Calgary and a large high school in Halifax had a history of indoor air quality complaints. The mechanical engineers believed that bringing in outside air (courthouse) or exhaust (high school) would relieve the air quality problems. Occupant symptoms abated for about three days, and then more intense symptoms resumed. Toxigenic fungi (*Stachybotrys*, etc.) grew on/in the wall surfaces. Both buildings were abandoned, causing much disruption. This paper discusses two IAQ investigations where problems identified resulted from the inappropriate mitigation measures and illustrates the inherent need for trans-disciplinary approaches to IAQ investigations.

2D1o5 Use of fungal detectors to monitor drying of water damaged buildings
P Morey, K Abe, E Horner, and B Ligman

Fungal detectors (biosensors) were used in three water damaged buildings at various stages of restoration to determine if moisture remaining in building assemblies was still sufficient for fungal growth. Alternaria alternata, Eurotium herbariorium, and *Aspergillus penicilloides* were used as sensor fungi in the detectors. In one building where the relative humidity (RH) varied from 80 to 98%, all three sensor species germinated and grew. In the crawl space of another building where the RH was in the 73 to 79% range, only the xerophilic *Eurotium* species grew. In a wall cavity of a third building with the RH fluctuating between 45 and 70%, none of the sensor fungi germinated. The use of fungal detectors during building restoration provides a direct means of determining if residual moisture in a microenvironment is sufficient to cause fungal growth.

2D1p1 Development of an investigation method for evaluation of microbiological indoor air quality
S Sampò, S Bonetta, S Bonetta, S Mosso and E Carraro

An investigation method to evaluate microbiological air quality has been developed; it involved a compiling building inspections checklist and occupants questionnaires, choosing sites, sampling frequency and analysis procedures. This method has been applied in a representative building with HVAC system and open-space offices. Air samples and microclimate parameters were collected at the same time. Airborne microorganisms levels ranged from 50 CFU m^{-3} to 500 CFU m^{-3}. A high fungal concentration (>1000 CFU m^{-3}) was found associated with a winter flood event. Statistical analysis showed a significant seasonal and daily variation of airborne microorganisms. Staphylococcus and Micrococcus were the most common bacterial genera and *Penicillium* was the most widespread fungal genus. Samples collected at HVAC system levels demonstrated an overall good microbiological removal efficiency of the device, except for unusual events (flood). This study highlights the importance, for air quality control, of a preventive approach based on microbiological risk analysis and critical point control.

2D1p2 Release of fungal propagules from contaminated surfaces by vibration
RL Górny, T Reponen, SA Grinshpun, SH Cho and K Willeke

The effect of vibration on the release of fungal propagules from ceiling tile surfaces was investigated. The experiments prove that vibration is an important mechanism affecting the number of fungal fragments and spores released into indoor air environments. Vibrations of 1 Hz/14 W released the highest number of fungal propagules. The morphology of the fungal colonies was found to play an important role in the release process. Increased release rates of fungal propagules due to vibration should be taken into account in indoor exposure assessments and data interpretations.

2D1p3 Negative influence on IAQ by air movement from mould contaminated constructions into buildings
J Mattsson, OE Carlson and IB Engh

Mould is frequently occurring in crawl spaces under buildings. Such damages are normally regarded to have lower impact on the IAQ than if the damages are situated in rooms where people live. However, due to ordinary use of the buildings, e.g., using fireplace, mechanical ventilation or even just by opening windows, air can be transported from the crawl space and up into the building due to the negative pressure effect. Building surveys and field experiments in Norway have shown that this transport of mould-contaminated air has a significant influence on the IAQ. The same problems are shown to be present in cases with mould damages in thermal insulated basements walls, attics and various roof constructions. Normal procedure for building survey does not detect these problems, and many damaged buildings are thus regarded as “healthy”, even if the contamination can be of considerable negative impact on the IAQ.

2D1p4 Size relationship between airborne viable bacteria and particulates in a controlled indoor environment study
KW Tham and ZM Sultan

The relationship between airborne viable bacterial concentrations (predominantly of human origin) and particle counts of different sizes in controlled environmental chamber focusing on the effect of temperature setting is investigated. At each temperature setting, 6 subjects performed simulated office work for two and half hours, and the particulate and total bacteria concentrations were measured at 20 minutes’ intervals. The study revealed that in the absence of other sources, the main contributor of viable bacteria is humans. Results obtained indicated that viable bacteria concentrations at 20 C is higher than that at 26 C for sizes 1.0 m>X>2.0 mm while there is no statistical difference in particulates concentrations between the two temperature settings for other sizes. Viability of bacteria due to human contributions is shown to be affected by thermal effects. The percentages of particulates that are viable bacteria at the different sizes were all found to be very low (<<1%).

2D1p5 Study of moisture transport across interface between building materials
X Qiu, F Haghighat and K Kumaran

Accurately predicting moisture transport in multi-layered building materials depends on properly understanding the moisture transport across an interface. This paper studied influences of the presence of air voids on the moisture transport across bonded and natural contact interfaces. In addition, this paper also investigated influences of the rate of moisture flow reaching an interface on moisture transport across the interface. The experimental results showed that the presence of air voids can significantly resist moisture transport across an interface and thereby, the interface is imperfect for moisture transport when one or both composing materials contain a high percentage of air voids. This is valid for both bonded and natural contact interfaces. It was also found that the rate of moisture flow reaching an interface has no obvious influence on the imperfection of hydraulic contact.

2D1p6 Exterior moisture creates indoor humidity, dewpoint & bioaerosol increases in healthy buildings
TJ Ryan, LW Whitehead, TH Connor and KD Burau

Indoor environmental parameters and bioaerosols were studied in relation to exterior moisture events in healthy buildings. Significant differences between both relative humidity and dewpoint were observed when paired samples from wet and dry climatological conditions were compared ($p<0.001$). Relative humidity averaged almost 20 percent (7.2 scale points) higher indoors following rainfall. Bioaerosols determined during these climatological conditions were observed to remain elevated up to three days following heavy rainfall periods in building locations exhibiting increased humidity. Results indicate that heavy rainfalls can produce sustained indoor bioaerosol increases in healthy buildings. HVAC systems cannot control such high level, short-lived exterior moisture. These findings are discussed relative to HVAC system limitations, and bioaerosol concentration implications, in hot and humid climates.

2D2o1 Toward comprehensive federal guidelines for school environmental health
B Axelrad and B Jones

More than 55 million people in the United States spend a significant portion of each day in 117,000 K-12 schools. More than half of these schools report roof leaks, ventilation issues or other environmental problems (GAO, 1995). Most schools lack the expertise and funding to address environmental hazards and many are not convinced such issues are important due to the dearth of data linking student performance with environmental exposures. Federal, state and local programs to address indoor environmental issues in new and existing schools are not well coordinated, making access to reliable information difficult at best. Federal agencies are now exploring ways to expand cooperation through a newly created Schools Workgroup of the President's Task Force on Children's Environmental Health and Safety Risks. The paper highlights existing programs and resources, identifies significant knowledge gaps, and provides a framework for a long term strategy to improve school environmental health programs.

2D2o2 The EFA project: indoor air quality in European schools
P Carrer, Y Bruinen de Bruin, M Franchi and E Valovirta

The objectives of the EFA project 'Indoor Air Pollution in Schools' were to collect information on indoor air quality (IAQ) in European schools, to review the related policies and preventive programs and to formulate recommendations aimed at providing a healthy school environment. IAQ in schools should be recognized as a priority topic for public health. School buildings are used by a large number of people for a long time but its IAQ has been much less studied than in other buildings. Schools frequently have serious indoor problems because of poor building construction, maintenance, cleaning and ventilation; high levels of VOCs and allergens are reported. The IAQ in schools can cause various short- and long-term negative health effects and discomfort, particularly in subjects with allergy. Nowadays only a very few European countries have guidelines aimed at improving IAQ. A multidisciplinary European program aimed at improving the IAQ in schools is needed.

2D2o3 Education, indoor environment and HVAC solutions in school buildings - consequences of differences in paradigm shifts
HL Hansen and SO Hanssen

This paper takes a retrospective approach to understand the setting of today's educational environments in school buildings. By investigating educational methods, school architecture and the choice of HVAC solutions in school buildings from different time eras, we have investigated whether there is a connection with respect to paradigm shifts. The paper also discusses the experience gained from the use of different HVAC solutions in school buildings, dealing with the school system in different time eras. By taking into account the limitations of different HVAC solutions, and the various maintenance requirements, one should be able to achieve a better educational environment. Many of today's school buildings were not planned to accommodate any dynamic changes of internal life or activities, and therefore performing the remedial actions can be a great

challenge. Finally, the environmental task becomes even more important with respect to a rapidly increasing number of sensitised pupils.

2D2o4 NJ IAQ tools for schools network: an innovative approach to achieving good IAQ
J Feola, M Hiester and M McGuinness

In response to a growing demand by schools for help in managing indoor air quality (IAQ), the U.S. Environmental Protection Agency (EPA) developed the IAQ Tools for Schools program featuring an IAQ management kit. The kit contains activities that, when completed, lead to better indoor environments. Despite its initial popularity and EPA's best efforts to promote IAQ Tools for Schools, it went virtually unused; schools could not implement the program without outside assistance. This was particularly true in New Jersey, where a unique set of barriers existed. In 1999, the IAQ Tools for Schools Network (the Network) was designed to overcome these barriers by offering specialized training, technical support, and incentives to New Jersey schools. Currently in its fourth year, the Network is a replicable model for providing hands-on guidance to schools, without placing unreasonable time and resource burdens on school and/or government program staff.

2D2o5 Clearing the air: a model for investigating indoor air quality in Texas schools
SA Petronella, R Thomas, JA Stone, RM Goldblum and EG Brooks

This pilot project focused on indoor air quality (IAQ) assessment at a local school, utilizing the U.S. Environmental Protection Agency's *Indoor Air Quality Tools for Schools* program, a low-cost, minimal involvement, primarily educational approach. We compared findings from this approach with an air-sampling program to determine if use of *Tools for Schools* was sufficient to identify conditions related to adverse health effects. Data were gathered for formaldehyde and other volatile organic compounds (VOCs), ozone, particulate matter (PM_{10}), mold, relative humidity, and temperature. Levels of ozone and PM_{10} and all VOC levels except formaldehyde were found to be within federal standards, American Conference of Governmental Industrial Hygienists recommendations, and Texas Natural Resource Conservation Commission's effects screening levels. Mold, however, was widespread, including those associated with allergy and asthma, e.g., *Aspergillus* and *Alternaria*. In general, *Tools for Schools* provides a solid foundation for a school IAQ program.

2D2o6 The relationship between humidity and indoor air quality in schools
CW Bayer, RJ Hendry, SA Crow, and JC Fischer

Indoor air quality differences were investigated among five schools with and five schools without active humidity control systems. The active humidity systems provided approximately 15 cfm/person of ventilation air, while the schools without the active humidity control systems averaged less than five cfm/person. The space humidity levels in varying widely without active humidity control, and rose to unacceptable levels during summer shut-down periods. Field data and modeling showed that if the schools without active humidity control systems were operated at ventilation rates above five cfm/person, >70% relative humidity levels might occur for extended time periods. This research showed the importance humidity control and adequate ventilation in schools for contaminant control, comfort, and energy savings.

2D2p1 School indoor air quality assessment and program implementation
R Prill, D Blake and D Hales

156 schools in the states of Washington and Idaho adopted individualized indoor air quality (IAQ) programs during the 2000-2001 school year. An experienced IAQ/building science specialist conducted walk-through assessments at each school. These assessments documented deficiencies and served as an on-site training opportunity for the school's facilities and administration staff. Schools used the assessment findings, along with guidance from the specialist, to adopt indoor air quality practices and procedures from a "menu" of options. At least 22 options were selected by all schools, with most schools adopting more - up to as many as 58. The findings from the assessments and the specific options selected were compiled into a database to be used by school officials and agencies. A survey of schools was conducted to evaluate the effectiveness of the program and usefulness of the specific options.

2D3o1 Potential for natural ventilation in urban context: an assessment method
C-A Roulet, M Germano, F Allard and C Ghiaus

The natural ventilation potential (NVP) is the possibility to ensure an acceptable indoor air quality by natural ventilation only. The passive cooling potential (PCP) is the possibility to ensure an acceptable summer comfort using natural ventilation. NVP and PCP hang on many conditions depending on the site (outdoor air quality, outdoor air temperature and moisture, outdoor noise, local winds or global wind and urban structure, etc.) or on the building (indoor pollutant sources, indoor heat sources and stored heat, indoor air quality requirements, position and size of ventilation openings, indoor temperature, orientation of building, internal air path distribution, etc.) These potentials are expressed as a list of quantitative and qualitative

characteristics of the site or the building, based on available input data. No detailed modelling is required for this assessment. The contribution presents the method developed to assess the NVP, and to represent it using geographically referenced information.

2D3o2 An approach to the design of natural and hybrid ventilation systems for cooling buildings
J Axley, S Emmerich, S Dols, and G Walton

This paper presents an approach to the design of natural and hybrid ventilation systems that accounts for specific climatic and operational conditions and is organized to serve the building designer at each distinct phase of design – predesign analysis, preliminary design, design development, and design performance evaluation. The approach makes use of: a) a *climate suitability analysis* method, presented in a companion paper, that establishes design ventilation rates needed for preliminary design calculations; b) the *loop equation design method* to estimate preliminary sizes of system components and control and operational strategies; and c) detailed *multizone coupled thermal-airflow analysis*, using CONTAM97R, for design development and, ultimately, system performance evaluation. A representative application, limitations of the approach, and research needed to support the approach will be briefly outlined.

2D3o3 Natural ventilation in office buildings - the do's and don'ts
AK Raue, PG Luscuere and AC Boerstra

As part of a graduation research, six case studies were carried out to assess the validity of 10 often heard assumed disadvantages of natural ventilation in offices, including poor IAQ and thermal discomfort. The case studies included a methodic comparison of six buildings based on literature, interviews, field measurements and re-analysis of reports by others. Thus the preconditions for natural ventilation of office buildings and the most important design features could be determined in order to meet the performance standards as in use in the Netherlands. One important finding is that the indoor environment in naturally ventilated buildings is especially sensitive for occupant behavior. A low tech and a high tech approach can be distinguished to deal with this.

2D3o4 Impact of CO_2 concentration, temperature and relative humidity of air on the health and sense of well-being of employees in air-conditioned and naturally ventilated offices
S Muhi and V Butala

The current sense of wellbeing and health of employees engaged in similar types of activities in both air-conditioned (AC) and naturally ventilated (NV) buildings were analysed using an IAQ assessment, measurement of thermal comfort parameters, and a survey of employees. A questionnaire concerning the current sense of wellbeing was given while concurrently measuring CO_2 concentration, air temperature and relative humidity in the given building. Suitable statistical methods and models were used. The employees in both analysed buildings connect most of their health problems and current unpleasant feelings to the indoor environment, although more so in the AC than in the NV building. Statistically significant connections between CO_2 concentration and current sense of wellbeing parameters were found.

2D3o5 A method to assess the suitability of a climate for natural ventilation of commercial buildings
JW Axley and SJ Emmerich

Increasingly, European building designers have used natural ventilation to control air quality and cool commercial buildings to conserve energy compared to mechanical cooling and fan operation. These advanced natural and hybrid ventilation systems may be adapted to the North American context, but work is needed including consideration of the broader diversity of climates. An approach to the analysis of climate suitability is presented and applied to a number of North American climates. The climate suitability method presented offers an approach to predesign analysis for ventilative cooling that is climate specific and accounts for the expected level of internal and solar gains for a building. The climate suitability analysis also yields estimates of ventilation rates that are likely to be needed to achieve either a direct ventilative or night cooling design strategy

2D3p1 Passive modification of air temperature for thermal comfort in a courtyard building for Queensland
U Rajapaksha and R Hyde

The paper presents the effects of airflow access points on the passive modification of indoor air temperature in a partly roofed high-mass courtyard building found in moderate climate of southeast Queensland. Results of a field investigation reveal that despite sufficient shading within the courtyard, its air temperature and thus comfort levels depend greatly on the location of airflow access points in the building layout and section. Potential of courtyards for passive cooling (lowering of its air temperature than ambient) is seen when airflow access points for most frequent-easterly daytime summer breeze is integrated in immediate building microclimates where sufficient shading can be provided, in conjunction with nocturnal ventilation. Potential for passive heating (an elevation of courtyard air temperature above ambient) is seen if no airflow access points to the

most frequent south-westerly winter breeze are integrated but sufficient solar gain from northeast is allowed through building section.

2D3p2 Decentralized building automation and hybrid ventilation at ING HQ's
GA Jansen and PG Luscuere

In June 2002, 650 ING Group employees will move into their new HQ in Amsterdam; a building in which the (decentralized) control systems takes a prominent position. To emphasize the building's transparency it is entirely encased by a glass façade: the second skin façade. By means of a sophisticated balance between the architectural design and the HVAC-installations, office workers will experience an indoor climate that can be controlled individually by conventional HVAC-systems or by means of hybrid ventilation through floor-to-ceiling ventilation windows in the office areas. The conventional installations exists of locally installed panels for heating and cooling and a centralized installation for ventilation and humidification. The exterior climate condition is a tempered outdoor climate between building and second skin-façade. Automation of these systems is possible by means of a local operating network through which the integral system functionality can be realized at a decentralized (individual) level.

2D3p3 The evaluation of HVAC systems and indoor air quality of high-rise apartments
J-Y Sohn, H-D Ham, S-J Kang, N-H Kim

Although most of the apartments adopt state-of-the-art convenience facilities, since they have become the most popular housing type in Korea, they depend on natural ventilation for HVAC systems, as traditional floor heating systems (Ondol) are used. On the other hand, the indoor environments of the apartments have become more important, because people stay longer in a room and the room environment is polluted, because of various kinds of interior materials. Accordingly, some apartments apply air conditioning systems using AHU and ventilation systems using heat exchangers. However, there are few studies on indoor environments related to these. In this study we evaluated ventilation performance and the change in concentration of the pollutants, by measuring indoor environment of high-rise apartments with different ventilation systems to provide a method to maintain comfortable air conditions. From the study, it is proved that they cannot maintain indoor environment standards by natural ventilation and they need to introduce mechanical ventilation systems for ordinary ventilation.

2D3p4 Reducing the ingress of urban noise through ventilation openings
DJ Oldham, MH de Salis and S Sharples

For buildings in busy urban areas affected by high levels of noise from road traffic the potential to use natural ventilation can be limited by excessive noise entering through ventilation openings. This paper is concerned with techniques to reduce noise ingress into naturally ventilated buildings while minimizing airflow path resistance. A combined experimental and theoretical approach to the interaction of airflow and sound transmission through ventilators for natural ventilation applications is described. A key element of the investigation have been the development of testing facilities capable of measuring the airflow and sound transmission losses for a range of ventilation noise control strategies. A method is proposed for quantifying the acoustic performance of different strategies to enable comparisons and informed decisions to be model leading to the possibility of a design methodology for optimising the ventilation and acoustical performance of different strategies.

2D3p5 Natural ventilation performance in kitchens with transoms replaced with porous screens
CM Chiang, PC Chou, YY Li and CC Chen

This study was aimed to analyse the ventilation efficiency and indoor air quality in the conventional kitchens, when porous screens were installed on the transoms. Numerical simulations and laboratory full-scale experiments were carried out in the model kitchen in the Department of Architecture at National Cheng-Kung University. The influences of porous screens on the temperature fields, flow structures and ventilation rates were indicated. The “Tracer-gas Concentration Decay” method was conducted to measure the air exchange rate and the age of air in the model kitchen. Computational Fluid Dynamics (CFD) numerical simulations were also utilized to reveal the temperature and flow distributions in detail. It was found out the interrogatives and its relevant improvement strategies.

2D3p6 Optimising the design of ventilators for natural ventilation
S Sharples and N Chilengwe

The basic mechanism for natural ventilation in a building involves air flowing through purpose-made ventilator openings. These ventilators must be carefully designed as natural ventilation driving forces are weak compared to the dynamic forces created by mechanical systems. This paper describes a series of experimental parametric studies that investigated how components within a ventilator (in this case louvers and wire mesh screens) interacted. Airflow measurements through the individual louver and mesh components were compared to the airflow through mesh / louver combinations. Initial results

indicated that the airflow through a louver-mesh combination was always significantly less than the flow through an individual mesh or individual louver. At low pressure differences a louver with a small diameter mesh (insect screen) was experiencing airflow reductions of the order of 50%. For a large diameter mesh (bird and animal screens) the reductions were approximately 20%.

2D3z1 Barriers to improved ventilation in production housing
C. Dennis Barley

In addressing the goals of energy-efficiency and indoor air quality (IAQ) in homes, industry teams in the U.S. Department of Energy's Building America program are installing mechanical ventilation systems in tight homes. A variety of designs - some simple and inexpensive, some more sophisticated - have been demonstrated. The advanced designs provide more consistent ventilation over time, more uniform ventilation among rooms, and source control measures that reduce the air-change requirement. However, most homebuyers are not fully aware of IAQ issues and whole-house ventilation requirements, and are thus not willing to pay the incremental cost of improved systems. Because the applicable standards do not require these improvements, lower-performance systems are often installed despite the best intentions of the engineering teams. This paper describes the ventilation approaches used by the teams, shows test results that illustrate performance issues, and discusses obstacles that hinder more widespread application of improved systems.

2D4o1 Uncertainty of VOC and SVOC measurement - how reliable are results of chamber emission testing?
R Oppl and K Winkels

Emission tests of finishing materials and of furniture may decide on purchase, and even on the development and the production of a specific product. Therefore, accuracy and precision of such tests are key issues. With a given threshold limit for VOCs or for other parameters it might depend on the selection of the testing laboratory whether a product complies with the criteria or not. A round robin test for emissions of an adhesive showed a significant variation of results which was compared with earlier round robin tests. Variation of results is due to two factors: (1) the in-homogeneity of the material in test, and (2) different testing and analytical practice in the laboratories. The GEV label EMICODE considers this fact by classifying emissions in broad bands only (instead of comparing single test results). Additional round robin tests and random control analyses are additional consequences.

2D4o2 A comparative study of the FLEC and a small environmental chamber using a novel reference emitting material (REM)
S Rastan, T Brodie, D Bouchard, J Koziski, F Haghighat and JP Farant

Three different sizes of a novel Reference Emitting Material (REM) have been partially validated using five standard certified permeation tubes. The REM is designed and developed to mimic emissions of diffusion-controlled VOCs characterized by planar indoor building materials. It is used primarily as a Standard Reference Material (SRM) for parts per billion quantification of VOC emitting building materials. Three different sizes of REMs (REM-Small, REM-Medium, REM-Large) were specially designed and used for this study. The emitting surfaces are made of a specially selected membrane with surface areas of 7, 38, and 95 cm^2 respectively. Using both the FLEC and an ASTM-based 50 Liters environmental chamber, Toluene emission rates for the three REMs are estimated at 82, 441, and 979 ng/min, respectively. The REM provides researchers with a unique Standard Reference Material (SRM) for diffusion-controlled VOC emitting building materials.

2D4o3 Multiple headspace extraction gas chromatography for quantification of VOC's in concrete
T Hjellström, L Wadsö and J Kristenson

Concrete itself is not a source of VOC emissions of any importance. However, humid concrete is very alkaline and may cause degradation of organic materials. Concrete can also adsorb considerable amounts of volatile compounds, e.g. from degrading flooring materials. This together with the present trends in cement and concrete production (alternative fuels, new organic additives, waste materials) has made it interesting to develop rapid methods for quantification of VOCs in concrete. We have tested a multiple headspace extraction gas chromatography method to determine the VOC content of cement bound materials. The total VOC content of a sample may be calculated from repeated headspace injections. The sample incubation time and temperature were optimized for six organic compounds with different boiling points and polarity. The method is tested on samples with known additions of these six organic compounds. The method works well on relatively dry samples, but there are problems with over-pressure in the headspace vial from water vapor in humid samples.

2D4o4 Emission of flame retardants from consumer products and building materials
S Kemmlein, O Hahn, O Jann, S Kalus and D Stolle

The emission levels of high boiling brominated (BFR) and phosphoric (POC) flame retardants (FR) in different materials were examined. For the determination of the emission rate the tests were done in different emission test chambers and cells under standard conditions (23 C, 50% RH and fixed area specific air flow rates). Selected products, e.g. printed circuit boards, were investigated at elevated temperature (e.g. 60 C) to simulate working conditions. Applied analytical techniques for the air samples adsorbed on polyurethane foam (PUF) are soxhlet and ultrasonic extraction. Different conditions were used to analyse the FR via GC-MS. Based on the first results it could be demonstrated that the emission depends on material density and surface condition. The concentrations over time obtained for tris(3-chloropropyl)-phosphate, e.g., from emission test chamber and cell show a good correlation, partly the measured concentration are different. Sampling at elevated temperature gives higher concentrations.

2D4o5 Biocide emissions from materials into indoor air
W Horn, O Jann, M Burbiel, O Wilke and S Kalus

The European biocides directive (98/8/EG) demand the control of emissions into the envi-ronment like soil, water and air. In this study a method for measuring the input of biocides into the indoor air from materials should be developed. The emission of two products containing biocides (plastic foil, wool carpet) and six different types of biocide containing formulations applied on wood or ceramic tiles were investigated in 20 or 23 l glass emission chambers. Each chamber test was performed over a period of 100 up to 200 days. SVOC show totally different emission curves in chamber tests compared to volatile organic com-pounds (VOC). They reach their maximum value after some days or weeks. Thus a period of 3 months is sometimes necessary for exact measurements. Area specific emission rates (SERa in $\mu g/m^2h$) for permethrin (0.006), propiconazole (0.2), dichlofluanid (1.5), tolylfluanid (1.2), octylisothiazolinone (2.5) and for iodpropinylbutyl-carbamat (1.7) were determined.

2D4p1 Emission of phthalates from PVC flooring in two very different test chambers
PA Clausen, V Hansen, L Gunnarsen, A Afshari and P Wolkoff

PVC flooring containing ca. 17% (w/w) di-(2-ethylhexyl)phthalate (DEHP) as plasticizer has been emission tested in two FLECs (Field and Laboratory Emission Cell) and one CLIMPAQ (Chamber for Laboratory Investigations of Materials, Pollution and Air Quality) over a 300 days period. In spite of large differences in test conditions, the measured DEHP concentrations in all the chambers were comparable (~ 1 $\mu g/m^3$). However, the corresponding specific emission rates were 5-10 times higher in the FLECs. Furthermore, the time required to reach an expected constant concentration was unexpectedly long (~ 150 days) in all the chambers. There appears not to be problems with the sampling, the analysis or the background. Backpressure effect may explain the differences in the specific emission rates and sink effects may explain the long equilibration time.

2D4p2 A simple method to determine the sources of VOCs in indoor air
S Yoshizawa, Y Ezoe, S Goto, T Maeda, O Endo and I Watanabe

To determine the source of VOCs, usually the chamber and FLEC methods are used for building materials. In this study we modified the headspace method as a screening method for small household utensils. With this method, only an injection port attached to the GC/MS system is used to determine VOC. The material was kept in a gas-tight bottle and heated for 6 hours at 30ºC. Then the gas released from the material was taken by gas-tight syringe and dissolved in methanol, in another gas-tight bottle. The methanol solution was injected into the GC/MS system. The method produced a good chromatogram and the peaks were determined. From this method, it is clear that the absorbent is not necessary for sampling. This simple method is also economical.

2D4p3 Performance test of a small test chamber (ADPAC) for aldehydes and VOCs emission rates measurements
H Tanaka, S Tanabe and R Funaki

A small-scale chamber, ADPAC, was developed to measure chimerical emission rates from building materials and its performance characteristics were examined in this paper. Especially background condition and mass transfer coefficient in the chamber were measured and discussed. Background concentration in the supply air to ADPAC was confirmed to be pure enough for measurement. Emission rates of VOCs from EPS were not changed by the loading factor. However, emission rates of formaldehyde from MDF were changed according to the loading factor. For emission measurement of formaldehyde, loading factor should be fixed for comparisons to those of the other materials. Mass transfer coefficient in the chamber was calculated based on the water vapor evaporation. Mass transfer coefficient based on outlet humidity was derived at 4.96 kg/m^2h (kg/kg'). Air velocity at the surface of test material was estimated around 0.01~0.1m/s.

2D4p4 Study on measurement of semi volatile organic compounds (SVOCs) emitted from indoor materials and products using glass test chamber
K Hoshino, T Imanaka, T Iwasaki and S Kato

Indoor air can become contaminated with organic compounds emitted materials, and the accurate measurement of these compounds is important for clarifying the mechanism of indoor air contamination. Many reports have been published on the emission test chamber method for measuring volatile organic compounds (VOCs) emitted from materials. This method has also been adopted (standardized) by ASTM, ECA, and ENV. However, there are very few reports on the measurement of semi-volatile organic compounds (SVOCs). It is extremely difficult to apply the emission test chamber method to the accurate measurement of SVOCs emitted from materials indoors because SVOCs are adsorbed by the internal walls of the chamber. Therefore, the authors developed a new method for measuring SVOCs using a glass test chamber considering indoor environmental conditions.

2D4p5 Emission of organic acid esters into indoor
M Fujii, N Shinohara, ALS Siew, and Y Yanagisawa

Phthalate esters are estrogenic compounds that are used as plasticizer in many plastics. They are gradually emitted over time and so it is conceivable that they pose a significant health risk. This study aims to investigate the temperature dependence of the indoor emissions of various phthalate esters and to estimate the health risks of these emissions at various temperatures. Our study focused on 3 widely used plastic materials: synthetic leather, wallpaper and vinyl flooring. Our results show this temperature dependence is determined primarily by the type of phthalate ester and less so by the type of material.

2D4p6 New bottom part for the FLEC used to determine flow resistance of floorings to VOC
A Sjöberg

This paper describes a new bottom part for the Field and Laboratory Emission Cell (FLEC). This equipment can be used in combination with the FLEC to determine important properties for transport of VOC through sheets, e.g., flooring materials. In this investigation, the resistance to transmission of n-butanol and 2-ethylhexanol through two floorings, PVC and Linoleum, was measured with this equipment. There appear to be large variations in the measured values and the results are therefore uncertain. A explanation of this large variation may be that environmental conditions on the surface of the flooring change when the FLEC is placed on the specimens. A rough evaluation has been made of the flow resistance of PVC and linoleum flooring to degradation products from the adhesive. These are shown at the end of the paper.

2D5o1 Analysis of topics and trends in indoor environment research in Europe
C Aylward, PTC Harrison, RS Harris, and P Holmes

A database (IERIE) has been established that holds detailed information on indoor environment research projects across Europe, which is of potential value to both researchers and funders of research. This paper demonstrates how the database can be used to evaluate topic trends and patterns in indoor environment research. The illustrative analyses reveal, for example, the current interest in the study of particulates and the degree of multinational cooperation that this attracts, the high level of funding of asthma studies and the diverse sources of funding in this area, the focus of filtration/ventilation studies in Finland and the UK and the involvement of governmental organisations in funding these projects, and the important linkages between the study of humidity/dampness/moisture and fungi and respiratory disease. It is anticipated that as the database grows and develops it will be of increasing value to policy makers as well as to researchers and funding bodies.

2D5o2 Establishing indoor air quality research priorities
WJ Angell and DT Grimsrud

The US Environmental Protection Agency's program laboratory for indoor air quality (IAQ), the Radiation and Indoor Environments National Laboratory, initiated strategic planning to identify IAQ applied research priorities. Early in this planning, three priority research areas were identified: biocontaminants; particulate matter; and residential buildings. Based on these priorities, expert opinions concerning key IAQ studies that should be undertaken now and in the near future were elicited through a Nominal Group Technique. The identified studies showed considerable crossover among the three areas. The crossover revealed four core project areas that subsumed many of the highly ranked recommended studies: a residential baseline study; sampling and measurement methods development; guidelines development; and exposure studies.

2D5o3 Indoor air quality research in South Africa
N Gqaleni

This paper will describe research and activities carried out by the Africa Center for Indoor Air Quality. The Center serves in the areas of information management/dissemination, capacity development, and research and policy formulation on aspects of indoor air quality. The paper will also present results of more than 200 homes and buildings that have been monitored for indoor dampness and mold in Durban. Outdoor, indoor (air and surface) mold samples have been collected. Several fungal isolates have been identified to genus and species level. The results indicate that *Aspergilli*, *Cladosporia* and *Penicillia* predominate in indoor environments, constituting a high percentage of respirable material. These genera are well known for their ability to produce mycotoxins and possible pathogenicity.

2D5o4 A priority agenda for energy-related indoor environmental quality research
WJ Fisk, G Brager, M Brook, H Burge, J Cole, J Cummings, H Levin, V Loftness, T Logee, MJ Mendell, A Persily, S Taylor and J Zhang

A multidisciplinary team of IEQ and energy researchers is working together to define a program of priority energy-related IEQ research. This paper describes the methods employed, ten high priority broad research and development (R&D) goals, and 34 high priority R&D project areas linked to these goals.

2D5o5 The right to healthy indoor air: status by 2002
L Mølhave, M Krzyzanowski and Z Pan

One of the reasons for the inadequate quality of indoor air arises from the poor articulation, appreciation and understanding of basic principles underlying the policies and actions related to indoor air quality. A WHO Working Group derived nine statements on rights to healthy indoor air. The discussions and statements are available as a WHO report. It informs the individuals and groups responsible for healthy indoor air about their rights and obligations, and empowers the general public by making people familiar with those rights. One year after their publication the statements have been adopted as the base for future regulation and guidance. The Board of Directors of the International Society of Indoor Air Quality (ISIAQ) and the participants of two international conferences endorse the use of the statements. No opposition the statements have been registered. The statements have entered curricula of training courses and have been used in lawsuits.

2D5p1 The Swedish key action "the healthy building" - research results achieved during the first three-years period 1998-2000
E Abel, J V Andersson, N Dawidowicz, E Christophersen, S O Hanssen, A-L Lindén, T Lindvall and AL Pasanen

The first stage of The Swedish Healthy Building program has advanced the understanding of a number of hitherto unexplained building related health problems. Important insights have been achieved into the mechanisms and effects of biological agents indoors. New methodologies for assessing microbial emissions have been developed. The mechanisms of interaction between pollutant gases, building materials and room air are now better understood especially the mechanisms behind sorption and sink effects. In the indoor environment a large number of risk factors for adverse health effects are suspected. Some of these risk factors originate in misconduct in the design, construction and maintenance of buildings. Especially damp or humid buildings present increased risks but other factors also play a role.

2D5p2 Center for building and systems TNO-TU/e: a multi-disciplinary approach focused on well-being of people
PM Bluyssen, A de Geus, P Rutten and J Hensen

The Centre of Building and Systems is a cooperation agreement between TNO and TU/e in The Netherlands, in which several expertises were brought together for a large investigation on buildings and systems. The well-being of people (comfort and health) is the main focus. This multi-disciplinary approach has to result in innovative insights on lighting, indoor climate control, building acoustics, health and comfort, but also on sustainable energy. And, it has to result in knowledge to support the integral design process. This large and ambitious project will need approximately 12 MEuro in the first phase (2001- 2005). After 2005 the intention is to become an independent centre, without any additional investments of TNO and/or TU/e.

2D5p3 European project HOPE (health optimisation protocol for energy-efficient buildings)
PM Bluyssen

In January 2002, a new European project named HOPE (Health Optimisation Protocol for Energy-efficient Buildings) started with 14 participants from nine European countries. The final goal of the project is to provide the means to increase the number of energy-efficient buildings that are at the same time healthy, thus decreasing the energy use by buildings, and consequently, resulting in a reduction of CO_2 emissions from primary energy used for ventilation, heating and humidity control. The outcome

will comprise of a methodology for assessing the performance of buildings according to a set of health-energy integrated defined criteria, to improve unhealthy or low energy efficient buildings. This paper presents the background and the methods applied for this three-year European project.

2D5p4 Research and development of indoor air quality in China
GQ Zhang, YB yu and Y Zou

China is paying rapidly increasing attention to Indoor Air Quality (IAQ) issues in recent years. Different from the situation in developed countries, the basic source from which IAQ problems are generated is luxury decoration of residential apartment in urban area, when China is constructing the largest amount of residential buildings. In this paper, the source of pollution in these buildings in China is simply analyzed. The public concerns on IAQ and the relevant governmental regulating actions on identifying and controlling IAQ are presented. The contributions of Chinese researchers from different disciplines of IAQ research are reviewed, while the situation of knowledge transfer and education is described.

2D6o1 Air filtration system in an office building: from design to validation
M Jamriska and L Morawska

Provision of good IAQ in buildings located close to a busy road requires application of air filtration systems which are efficient for submicrometer and especially ultra fine particles, since traffic emissions are associated with particles in these size ranges. A study has been conducted in which a filtration system of an office building was designed according to measured outdoor air conditions and theoretically predicted indoor air conditions. The performance of the system was then validated by field measurements of particle concentration levels indoors and outdoors. The two-stage building filtration system consisted of a central outdoor air prefilter unit, and a set of secondary filtration units designated for each floor. The fractional and overall efficiency of each set of filters, as well as the efficiency of prefilter and secondary filtration units was measured in the size range 0.017 – 0.7 mm. The effect of electrostatic filters on ozone concentration indoors was also investigated.

2D6o2 Examination of the physical and chemical nature of used ventilation filters and collected particulate matter
CC Coffey, SB Martin, Jr., RB Lawrence, C Calvert, SP Berardinelli, Jr., PA Jensen, JD Pleil, JR Wells, and WG Jones

Maintenance workers expressed concern of a potential health hazard due to a strong odor from used ventilation filters during routine maintenance at a research facility. This prompted a thorough examination of the physical and chemical nature of the filters and collected particulate matter. Light and electron microscopy indicated a predominance of opaque small particles, mostly in the submicrometer range. Many were agglomerations of smaller, roughly spherical subunits, consistent with combustion aerosol. Headspace samples of filter portions were analyzed by gas chromatography-mass spectroscopy (GC-MS). Numerous volatile organic compounds were found on all samples at sub-ppm concentrations. Possible odor sources are: combustion aerosol containing adsorbed vapors, organics normally present in ambient environments concentrating on the particles, and/or microbial growth. The combined approach of GC-MS/microscopic examination proved useful in determining the vapor and solid collection history of ventilation filters. The concentrations of toxic substances were below levels at which adverse effects would be expected.

2D6o3 Effects of contaminated supply air filters on symptoms from the eyes and nose - a double-blind experimental study
G Smedje, D Norbäck, G Wieslander and R Wålinder

In buildings with mechanical ventilation, particles accumulate in the supply air filters. We conducted a field experiment in a school to investigate if such pollutants could affect the health of the pupils. In a school building we changed old and new supply air filters in the air handling units, with a cross over design of the study. Pupils answered a symptom questionnaire, and a subset of pupils was also examined by objective clinical methods. When there was an old supply air filter in the air handling unit, the pupils reported more symptoms from the eyes and throat, and the volume of the nose was smaller, compared to when the filter was new. Substantial microbial growth was found in the filters already after two months usage. Thus, supply air filters should be changed more often than is usually done.

2D6o4 Bioaerosol production from indoor air biofilters
J Mallany, A Darlington, and M Dixon

Several indoor air biofilters containing higher plants, mosses and microbes have been incorporated into functional offices, where they are a supplemental means of controlling indoor air quality through the removal of volatile organic compounds. In theory a rich microbial community indoors may in fact lower air quality through the production of microbial agents such as spores or aerial bacteria. Questions have arisen regarding the impact of an indoor air biofilter on ambient spore concentrations including the pathogen Legionella pneumophilia. This study presents empirical evidence which indicates that indoor air

biofilters do not increase the spore load of "treated" air under stable conditions and creates only minor increases when subjected to disturbance events.

2D6o5 Temperature and airflow influences indoor air biofiltration
DJ Llewellyn, AB Darlington and MA Dixon

Biofiltration is an alternative to ventilation for maintaining indoor air quality. Our biofilters were comprised of complex communities of plants which provides many ecological niches for microbial colonization while having strong aesthetic appeal. This study focused on the effects of temperature and airflow on biofiltration of volatile organic compounds (VOCs). Indoor biofilters typically function very well at ambient temperatures. However, some poorly degraded VOCs have low solubilities. Reduced biofilter temperatures may improve degradation by increasing contaminant solubility, however this may be offset by reduced microbiological activity. Another advantage of subambient temperatures is a reduction in humidity loading on the indoor air stream. Test biofilters were run at temperatures of 17 and 27 C. Ambient methylethylketone (MEK) and benzene concentrations ranged from 10 to 80 ppbv. Benzene removal was greater at 27 C suggesting microbially limiting conditions while MEK removal was higher at 17 C inferring substrate-limiting conditions.

2D6p1 Acclimation and nutrition of indoor air biofilters
AB Darlington and MA Dixon

Biofilters removed significant amounts of toluene and methylethylketone (MEK) present in parts per billion (by volume) concentrations from an indoor space. Two species of living moss (*Plagiomnium cuspidatum* and *Eurhynchium riparoides*) and coconut fibre were used as packing material. The moss biofilters removed significant amounts of MEK during the first diurnal cycle of operation and required approximately six days to reach maximal removal rates. All biofilters responded positively to the use of supplemental nutrients. *Plagiomnium cuspidatum* and coconut fibre biofilters were only able to remove toluene after the addition of nutrients. Once acclimated, the differences in the toluene removal efficiencies (percent removed per pass) for the moss biofilters could be attributed to the growth pattern of the mosses. There were no differences in the elimination capacity (removal per unit biofilter volume per unit time) of the different packing materials for toluene but the coconut fibre removed significantly more MEK.

2D6p2 Filter efficiency of selected HVAC filters
ES Moyer, MA Commodore, J Hayes, and SA Fotta

Air quality begins with good engineering air handling system (HVAC) controls. Air handler filters should remove the major particulate matter from incoming ambient air. A study of various NIOSH air handler bag filters was conducted to determine their filter efficiency against submicrometer particles (0.03-0.4 micrometers), since submicrometer particles are the most penetrating. Aerosol penetration measurements show an extremely large range of filter efficiency. New filter aerosol penetration ranged from less than one percent to greater than ten percent with penetration depending on flow rate, media surface area, and challenge agent particle size and state (liquid versus solid). Exposed filters (from air handler) showed a significant increase in submicrometer particle filter penetration and a shift in most penetrating aerosol particle size toward the larger particle size range. Both mechanical and electrostatic filters are used in HVAC applications. The electrostatic filters showed significant filter efficiency reduction over the filter's expected service lifetime.

2D6p3 Real-time HVAC filter efficiency testing using optical particle counters
SP Berardinelli, SA Fotta, J Hayes and ES Moyer

The National Institute for Occupational Safety and Health (NIOSH) has undertaken a long-term performance test of heating, ventilation, and air-conditioning (HVAC) system filters. This testing is being conducted at the NIOSH facility in Morgantown, WV in an air handling unit (AHU) that services the animal quarters. The six-pocket bag filters in this AHU have been replaced with higher efficiency mini-pleat V-Bank™ filters and have been monitored monthly for filtration efficiency. This study required the development of a method to determine the actual HVAC filtration efficiency using optical particle counters (OPCs) while the system was in operation. OPCs were used to collect particle counts in 15 different particle size ranges from 0.30-0.40 µm to >20 µm. Instruments are placed upstream and downstream of the filter bank and data were collected over several days. Filtration efficiency was determined for submicron to supermicron particles averaged over the sampling period.

2D6p4 Performance characteristics of soaked air filters
K Kovanen and R Holmberg

Several studies have shown that supply air filters in office buildings, schools etc. occasionally get wet due to weather impacts. The aim of this study was to investigate whether performance characteristics, such as pressure drop across the filter and filtration efficiency, change when two different kinds of air filters become soaked and dried. The filters used, were a fiberglass

bag filter and a plastic fiber bag filter, each of filter class F7. The study showed that the filter getting wet did not affect the shape of the dried filter material of plastic fibers. Therefore, neither the pressure drop nor filtration efficiency changed. Instead, the material of the fiberglass filter transformed its structure from wadding-like to papery. Hence its pressure drop clearly increased, but the filtration efficiency improved.

2D6p5 Particle filtration in a ventilated room
G Einberg and S Holmberg

Several studies based on analytical models and numerical simulations have shown that it is difficult to control airborne particle movements in a ventilated room. However, more knowledge and information on particle characteristics and particle movements, in combination with new numerical simulation tools, have recently made it easier to estimate particle patterns. In the present paper new information is used to evaluate the role of filtration and ventilation in the particle elimination process. Key parameters found include the particle aerodynamic diameter and the particle settling velocity governed by Stokes formula. Particle dispersion and settling are highly dependent on the ventilation airflow structure. Calculations with CFD (Computational Fluid Dynamics) show characteristic patterns of particle movements in rooms with displacement ventilation.

2D6p6 Laboratory determination of indoor air cleaner life span
A Ginestet, JH Salazar and S Laplanche

Indoor air cleaners are available on the market but a lot of them are not tested and their performances are not known. The main objective of our study was to develop a laboratory test method which allows to determine the life span of indoor air cleaners. Loading of the device is carried out with tobacco smoke which is an air pollutant that reflects real conditions. Fractional efficiency and air flow rate of the device are measured at the initial stage (clean device) and step by step as the device becomes loaded. Pressure difference of the device is maintained constant and equal to zero and variations of fractional efficiency, air flow rate and clean air delivery rate are expressed according to loading. Two different air cleaners using the two most popular filtration technologies (HEPA filter, electrostatic filter) have been tested according to the method and their life span have been determined.

2D6p7 Filter performance guidelines for good IAQ
T Nathanson, L Morawska and M Jamriska

Airborne particulates in the office environment can cause occupant health symptoms and discomfort as well as affect the performance of the HVAC system. To reduce particulate levels within a building, outdoor and return air is filtered. An experimental study was conducted to measure the performance of four filters; a 30 % dust-spot efficiency pleated filter and a 65, 85, and 95 % bag filter. Three types of challenge aerosols composed of a mixture of ultrafine, fine and coarse particulates were tested in the laboratory at different air velocities. The benefits and return on investment of using high efficiency (85 – 95 % dust-spot efficiency or MERV 13 – 15), in an office environment was confirmed by the Centre for Medical, Health and Environmental Physics at QUT, Brisbane (Jamriska, Morawska and Nathanson, 2002). This research was commissioned by Public Works and Government Services Canada (PWGSC) to develop filter selection guidelines.

3A1o1 Of microbes and men
A Nevalainen

The moisture accumulation, microbial ecology of the damage site and exposure to biological pollutants are all complex phenomena, and may result in various cases of indoor air pollution and health outcomes. Commonly reported are irritation symptoms, respiratory infections and general symptoms, but also diseases have been linked to mold, e.g., increased risk of asthma and clusters of hypersensitivity pneumonitis, pulmonary hemorrhage of infants and rheumatic diseases. Causal agents, still poorly known, may be linked to the complex interactions with the growth substrate and other microbes. Fungi and bacteria growing on building materials produce toxic secondary metabolites, and the material seems to have a critical effect on their production. Modern building technology has provided new ecological niches for microbes which readily exploit the faults in moisture control. In order to better describe the microbial exposures in buildings, current method development focuses on chemical markers of the biomass and PCR.

3A1o2 Asthma and indoor air
TAE Platts-Mills, N Custis, EA Erwin, R Sporik and JA Woodfolk

The role of the indoor environment in asthma is of major concern because (a) the disease has become more severe; (b) we spend >90% of our lives indoors; and (c) a large proportion of children and young adults with asthma are allergic to allergens found indoors. Recent evidence that children raised in a home with animals, i.e., indoor cat or dog, are less likely to become allergic has provided a great opportunity to understand mechanisms controlling the prevalence of allergic disease. In addition,

the results pose a challenge to many of the hypotheses about the reasons for the increase in asthma. The evidence that children or adults who make a modified Th2 response, i.e. IgG and IgG4 without IgE, are not at increased risk of asthma, strongly supports the role of IgE in asthma. Equally the results may define an important form of tolerance to environmental allergen.

3B1o1 An overview of the health effects due to mold exposure
M Shum

Several health studies have implicated mold as the cause of respiratory effects, asthma, central nervous system difficulties, and general malaise. Most of these studies have used self-reported data from questionnaires to obtain information on exposures and health outcomes Self-reported exposure is not well-correlated to airborne fungal concentrations, and self-reported symptoms or illnesses are limited in providing sufficient quality data for studying potential adverse health effects of mold. We reviewed those epidemiologic studies that attempted to use more objective measures for both exposure and health assessment. Among these studies, there appears to be a general consensus towards a positive association between mold exposure in indoor environments and respiratory effects. However, many of these studies are limited by small sample sizes, no demonstrations of dose-response relationships, exposure misclassification and other study limitations. Without better studies, a causal association cannot be confirmed at this time.

3B1o2 Health effects from *Stachybotrys* exposure in indoor air: a critical review
JS Weiss, and MK O'Neill

Increased public awareness and concern regarding exposure to fungal organisms, especially *Stachybotrys chartarum*, raises interesting challenges for the scientific community. Although exposure is probably widespread worldwide, the risk factors, temporal trends and natural history of illness caused by this organism are not well characterized. We critically reviewed the published epidemiological literature linking *Stachybotrys* and illness, summarizing the weight of the evidence. We also reviewed animal studies to consider the issue of biological plausibility. The studies were assessed using standard epidemiologic guidelines. All of the studies reviewed suffered from limitations, including lack of control groups, inadequate exposure data, non-standardized diagnosis and outcome assessments, potential for selection bias and comparison of risks based upon prevalence rather than incidence. Further studies, which improve upon the quality of previous work, should be performed in order to determine whether exposure to this mold in buildings causes adverse health effects.

3B1o3 Assessing health effects of bioaerosols measuring viable spores and microbial volatile organic compounds (MVOC) in residential air
CEW Herr, S Harpel, A zur Nieden, NI Stilianakis and TF Eikmann

This cross-sectional study in 1997 investigated influences of measurable outdoor residential bioaerosol pollution and annoying odors on next residents' reported health. Prevalence of health complaints during the past year, medical condition and residential odor annoyance were assessed in 214 residents by doctors. Bioaerosols (e.g. spores of *Aspergillus fumigatus*, actinomycetes and MVOC) were simultaneously measured in residential outdoor air. Bioaerosol pollution amounted to >105CFU thermophilic actinomycetes, molds and total bacteria m^{-3} air 200m away from the plant. 11 out of 16 MVOC were measured above detection limit. All concentrations were higher at 200m compared to 550m from the plant. Adjusted associations were found for 7 out of 17 respiratory complaints (OR>2.5) comparing residency at 150-200m to >400m-500m from the plant. Duration of residency >5 years was associated with 4 out of 17 respiratory complaints (OR>4.5). Odor annoyance did not confound these symptoms. Rates of medical diagnoses were not influenced.

3B1o4 Moisture damage and mold exposure in a hospital building - health effects and IgG-antibodies among personnel
T Husman, U Haverinen, J Koivisto, M Toivola and S Laitinen

In hospitals, moisture damage and microbial growth pose a health risk not only to the personnel but also to patients. In this study, the microbial risks in two moisture damaged hospital wards and a reference ward were estimated with special reference in bathroom construction. The health effects associated with microbial growth among personnel of the wards were measured with a questionnaire. In moisture-damaged wards, cough, hoarseness, nose bleeding and eye symptoms were more common than among workers in a reference ward. Headache, tiredness and other non-specific symptoms were more often complained in the damaged wards. Common cold with fever and sickness absence was more often observed among the exposed. Also microbe specific IgG-antibodies were detected for those microbes cultivated in the constructions. Moisture damage abatement is crucial in decreasing work-related morbidity among hospital personnel.

3B1o5 Bacterial strains from moldy building are highly potent inducers of inflammatory and cytotoxic effects
M-R Hirvonen, K Huttunen, J Jussila, T Murtoniemi, E Iivanainen, H Komulainen, A Nevalainen and M Roponen

Inflammatory responses and cytotoxicity induced by bacteria, isolated from moldy buildings, were evaluated in human and mouse cells and in a mouse. Human (28SC)- (SC) and mouse (RAW264.7) macrophage cell lines were exposed to the spores of *Streptomyces californicus* and bacterial cells of *Mycobacteriun terrae* at different doses *in vitro* and mice (NIH/S) were exposed by intratracheal instillation to the same microbes. The results show that *S. californicus* and *M. terrae* induce production of important inflammatory mediators i.e. nitric oxide (NO) and cytokines both in human and mouse macrophages *in vitro*, but mouse cells were more sensitive than human cells. In line with *in vitro* findings, these bacterial strains triggered *in vivo* dose- and time dependent production of the same inflammatory mediators in BAL and to caused injury cytotoxicity in the mouse lungs of the mice. Altogether, these results suggests that in indoor air streptomycetes and mycobacteria are highly potent inducers of inflammatory responses possibly related to adverse health effects of the inhabitants.

3B1p1 Health effects of indoor fungal bioaerosol exposure
F Fung and WG Hughson

Objective: To review current data on the health effects of indoor fungal bioaerosol exposure based on published studies. Methods: We conducted MEDLINE search and reviewed all English language studies on indoor mold exposure (visible survey or objective sampling) and human health effects published from 1966 to January 2002. Main findings of the studies are analyzed in conjunction with plausible association of health effects and fungal exposure. Results: Five case control studies, 16 cross-sectional surveys and 7 case reports met the selection criteria. Current evidence suggests that excessive moisture promotes mold growth and is associated with an increased prevalence of symptoms due to irritation, allergy, and infection. However, specific toxicity due to inhaled fungal toxins has not been scientifically established. Conclusions: Methods for assessing indoor bioaerosol exposure and health effects are not well standardized, making interpretation of existing data difficult. Additional studies are needed to document human exposure-disease and dose-response relationships.

3B1p2 Causal influences of airborne fungi and other factors on symptoms of respiratory allergies
D-W Li, B Kendrick and D Wyse

The aerospora indoors in 15 residences in Kitchener-Waterloo, ON, Canada was studied. Allergenco samplers were used in the study. The results showed that indoor total fungal spores, indoor *Aspergillus*/*Penicillium* and the age of the residences have significant effects on symptoms. Dampness, age of the patient, and cleanness have significant direct and indirect effects on symptoms. Dampness was the most important factor, showing a strong causal influence on symptoms. However, the exact role of dampness in relation to symptoms needs further research.

3B1p3 Actinomycetes in moist houses, the causative agent of rheumatoid symptoms?
W Lorenz, C Trautmann, R M Kroppenstedt, G Sigrist, E Stackebrandt, M Gareis, I Dill and L Virnich

Inhabitants of mouldy houses very often have respiratory complaints. Additionally, rheumatoid symptoms can be observed in some cases. The symptoms are almost reversible after disposing of the microbial damage or after moving out of the building. In these cases actinomycetes were detected in building materials. The following is a report of a case of a woman and her father who had moved to a newly built house. After a few months both acquired respiratory problems. The daughter also complained of headaches, severe rheumatoid symptoms and skin problems. In the building material and house dust we detected fungi and different actinomycetes. By a polyphasic taxonomic approach using morphological, chemotaxonomical and molecular biological methods, one group of the actinomycete isolates could be identified as members of the species Nocardia carnea, whereas the other isolates belong to new species of the genus *Nocardiopsis* and *Promicromonospora* respectively.

3B1p4 Comparison of nasal lavage and cell exposure methods in the assessment of inflammatory potential of the airborne particle material
M Roponen, M Toivola, S Alm, A Nevalainen, J Jussila and M-R Hirvonen

Exposure in moisture and mould damaged indoor environment has been shown to be a potential health risk. We evaluated inflammatory potential of the airborne particle material by measuring the production of proinflammatory cytokines in nasal lavage (NAL) samples of the studied subjects and in cell culture medium of mouse RAW264.7 macrophages which were exposed to the combined extracts of the filter samples representing personal exposure and main microenvironments (home and working place) of the subjects. Cytokine levels in the NAL samples of subjects with high microbial exposure and in the cell culture medium of the macrophages exposed to their corresponding filter samples were increased, as compared to the values of the subjects with low exposure. In conclusion, both methods discriminate between subjects with high and low microbial exposure.

3B1p5 Indoor air bacteria induce more intense production of inflammatory mediators than fungal spores in mouse and human macrophages
K Huttunen, A Hyvärinen, A Nevalainen, H Komulainen and M-R Hirvonen

Currently it is not known which microbes are the most harmful ones among the mixed population present in moisture damaged buildings. In this study the biological activity of fungi *Aspergillus versicolor*, *Penicillium spinulosum* and *Stachybotrys chartarum*, and the bacteria *Bacillus cereus*, *Pseudomonas fluorescens* and *Streptomyces californicus* were compared in mouse RAW264.7 and human 28SC macrophages by measuring the production of selected inflammatory markers and cytotoxicity. All bacteria induced significant production of inflammatory markers in mouse macrophages, but only the spores of *Str. californicus* induced the production also in human cells. Instead, exposure to fungal spores did not markedly increase the production of inflammatory markers in the studied cell lines. On the basis of equivalent numbers of bacteria and spores of fungi, the overall biological activity of bacteria was higher compared to fungi. These data suggest that bacteria in water-damaged buildings should be considered as possible causative agents of adverse inflammatory effects.

3B1p6 The human IgE reactivity to components of the *Stachybotrys* fungus
P Raunio, M Kärkkäinen, E Johanning, J Rautiainen, and A-L Pasanen

Human IgE reactivity to S. *chartarum* components is demonstrated in this study with sera of 17 study subjects exposed to *Stachybotrys* and 15 control sera in the immunoblotting analyses. In addition, the effect of sugar moieties of the components on the antibody reactivity was investigated. Seventy-six percent of the sera from the study subjects and 20% of the control sera showed the strong IgE reactivity against the 50 kDa component of *S. chartarum*. Several other *S. chartarum* components also possessed reactivity, though not as frequently and intensively as the 50 kDa component. After the enzymatic removal of N- or O-glycan chains from glycoproteins, many components of *S. chartarum*, unlike the 50 kDa component, lost their antibody reactivity. The 50 kDa component, the most immunogenic component for *S. chartarum*, is a promising candidate for development of *S. chartarum* specific immunochemical methods.

3B1p7 Inflammatory rheumatic diseases and mouldy buildings - possible causal mechanisms?
M Seuri, R Myllykangas-Luosujärvi , T Husman and A Nevalainen

We have found (papers sent for publication) two cases of mould-damaged buildings with clusters of different inflammatory rheumatic diseases, various rheumatic symptoms and signs. So far, we have an association of these disease clusters with exposure in mouldy buildings with no causal link. In this paper we shortly describe the cases and discuss the possible causal mechanisms, which should be addressed in the further studies.

3B2o1 Using the Insta 800 cleaning quality standard for advancing cleaning
A-L Schjønning, T Schneider and J Kildesø

The INSTA 800 standard defines cleaning object groups, types of surface contaminants, inspection strategy, quality levels and compliance criteria. The standard is based on visual inspection, with instrument-based methods being optional. Examples are given how introduction and application of the standard by cleaning companies, cleaners and customers can be facilitated and some of the positive feedback received. Some limitations in the standard and use of visual assessment and possible solutions are discussed. Implementation of the standard will professionalize cleaning work and increase challenge and job satisfaction among cleaners and supervisors with the potential to improve quality of working life of cleaners. The standard provides an approach for quantifying and accumulating experience, linking types of rooms, room activities, used cleaning methods, and obtained quality levels. This know-how can be used for optimizing planning of cleaning and for improving cleaning methods and tools and for choice of cleaning solutions.

3B2o2 Indoor air quality and the adequacy of cleaning in 25 Finnish schools
T Pasanen, T Keskikuru, J Ridell and P Pasanen

Indoor air quality and the adequacy of cleaning were studied in 25 schools in a Finnish city. Methods included a questionnaire for teachers (Örebro MM-40-FIN) and measurements of ventilation rate, CO_2, temperature, particulate matter (PM) and surface dust in 56 classrooms. In most classrooms, ventilation rates did not fulfill the rate required by the Finnish building code. CO_2-concentrations were lowest in classrooms with mechanical ventilation and highest in classrooms with natural ventilation. Ventilation rates correlated with PM in all particle size groups except the smallest one. Total PM-levels exceeded the recommended values, and almost all classrooms were too warm. No correlation was found between PM and surface dust. According to the questionnaire (n=424 teachers), main problems in the working environment were dust, stuffy or dry air and noise. There was a statistically significant correlation between perceived indoor air quality and symptoms. The prevalence of symptoms did not explain dissatisfaction with work.

3B2o3 The effect of intensive vacuuming on indoor PM mass concentration
K White and P Dingle

A study was conducted in 36 carpeted homes over 14-weeks to investigate the impact intensive vacuuming has on indoor particulate levels. Intensive, high efficiency, vacuum cleaning, was carried out in 19 homes while 17 were monitored as controls. The intervention reduced airborne PM mass concentration by approximately 50% ($P<0.01$). PM_{10} and $PM_{2.5}$ mass concentration at the end of the intervention and monitoring program were similar to outdoor concentrations at approximately 21mg m^{-3} and 14mg m^{-3} respectively. PM mass concentration did not increase once vacuuming intensity (duration of cleaning event) was reduced. No significant changes were seen in the control group during the course of the monitoring period. The results suggest one intense clean (4 min m^{-2} carpet) followed by regular moderate intensity cleans (1 min m^{-2} carpet) can substantially reduce the amount of material entrained in carpet and reduce the potential for PM re-suspension resulting in near ambient airborne PM mass concentrations.

3B2o4 Health effects, attitudes and perceptions towards cleaning chemicals
P Dingle, R Tan and A Maynard

Little information on how people use cleaning chemicals is available or what their attitudes and perceptions are towards these chemicals. This is important as it determines their use patterns as well as problems which may arise such as their contribution to indoor air pollution and direct toxic effects. A survey was conducted of 800 Perth homes to investigate their cleaning behaviour and the occupants attitudes to cleaning. 19% of households reported someone in the house, most frequently it being the home carer, having been adversely affected by cleaning detergents with their normal use. The most common reported symptoms were respiratory and skin irritation. 84% perceived no or low risk with their use. Despite this they reported that they thought some of the toxic ingredients should be removed. The ingredients are not labeled in Australia although an overwhelming majority believed labeling of the ingredients should be compulsory.

3B2o5 Characterization of emission from mechanical polishing of PVC floors
O Bjørseth, JV Bakke, N Iversen and B Martens

Floor surface temperatures were measured by IR-technique during high-speed polishing of PVC floors, and found in general to be below 40 C at normal operating conditions. Intensive polishing of small areas could produce spot temperatures up to 100 C. The particle concentration in the outlet air from the high-speed machine was low. The outlet air from the attached vacuum cleaner, however, showed concentrations of up to 100 times the room air concentrations, and demonstrate that a HEPA filter is necessary if a vacuum cleaner is to be used. The VOC emission during high-speed polishing is low at normal operation. The negative health effects observed can be caused by the particle emission.

3B2p1 Cleaning methods in relation to particles and allergen at school
G Smedje

There is a need to investigate the effectiveness of cleaning methods in reducing the concentrations of dust and allergens at school. Two field experiments are presented. In one study, cleaning of classrooms with mops and cloths of micro-fibres were compared to equipment of conventional cotton. In a second study, three different cleaning methods were tested in the gymnasium of a school; wet mopping of the floor once a day, cleaning the floor once a day with a mop impregnated with a fluid containing rape seed oil, and using this special mop also after each lesson. Comparing different equipment, only minor differences in amount of particulates in the environment were found. However, when increasing the frequency of cleaning, dust and allergens were significantly reduced.

3B2p2 The effects of cleaning on concentrations of surface dust and airborne particles
E Pesonen-Leinonen

Dust decreases the aesthetic properties of surfaces and can cause adverse health effects. The purpose of this study was to determine dust build-up on surfaces during one week in buildings, and the influence of cleaning on airborne dust concentrations. Surface dust sampling was performed by the foil sampling method and the fluctuation of the number of airborne particles was measured using an optical particle counter. Occupant satisfaction with cleaning was investigated using a questionnaire. In each building the dust build-up on surfaces was lowest on the furniture surfaces. The greatest variation in surface dust concentration between the buildings was on the floors, with the lowest concentrations on well-polished floors. Cleaning activities increased the number of airborne particles with size > 1 μm. The surface dust concentration before and after cleaning, and occupant satisfaction with cleaning, provide practical information for developing cleaning programmes to fulfil the demand for cleanliness in buildings.

3B2p3 The study of hard floor surface cleaning practices and the effects on dust particulate levels in eight Perth homes
J Nastov, R Tan and P Dingle

Dust particulates were studied in eight Perth homes before, during and after cleaning with different hard floor cleaning methods to determine if there was a difference in the levels generated. The respirable and thoracic particulate concentrations significantly increased after cleaning with the broom and dustpan (method D) when used in house 6. Inhalable particulates increased from 33.5 mg/m^3 to 64.5 mg/m^3 and thoracic particulates increased from 21.0 mg/m^3 to 37.0 mg/m^3. In house 4 there was a significant difference in the PM_{10} concentrations generated during cleaning between the allpurpose fibre floor cleaner (method C) and method D. Method D generated PM_{10} concentrations of 105.25 mg/m^3 in the kitchen compared to method C (6.33 mg/m^3). In the living room method D generated PM_{10} concentrations of 83.75 mg/m^3 compared to method C (10.16 mg/m^3). When using the dust fibre floor cleaner the airborne particulate concentrations were similar to the wet cleaning methods tested (<20.00 mg/m^3).

3B2p4 Cleaning quality guidelines for carpets based on measurements of the potential re-suspension of dust
J Kildesø and T Schneider

Dust in carpets contaminates the air by resuspension. A simple instrument named STEPP tester (Surface Total Emission Potential of Particles tester) has previously been developed for measuring the potential resuspension of dust from carpets. The instrument resuspends dust by a falling weight and collects it on an adhesive foil. The amount of dust on the foil is quantified by a direct reading instrument. The instrument has been calibrated with regard to collection fraction of the resuspended dust as function of particle diameter. It was found to decrease above 15 µm and this will reduce the influence of particles with low residence times in air on the measurement result. With this instrument, 240 representative field measurements have been made in the Copenhagen area. The 25, 50 and 75 percentiles of the measured potential resuspension were taken to represent typical low, medium and high levels and are proposed as a guideline for assessing dust levels in carpets in relation to cleaning quality.

3B3o1 Comparison of methods for measuring concentrations of semi-volatile particulate matter
JJ Jetter, Z Guo, JA McBrian and MR Flynn

The purpose of this study was to compare methods for measuring concentrations of semivolatile particulate matter (PM) from indoor-environment, small, combustion sources. Particle concentration measurements were compared for methods using filters and a small electrostatic precipitator (ESP). Particle size distributions were measured using an electrical low-pressure impactor (ELPI). Semivolatile PM was produced from cigarette and incense smoke, and, for comparison, a relatively nonvolatile aerosol was produced from polyalphaolefin oil. Results showed that semivolatile PM concentrations measured using the ESP method were significantly higher than those measured using the filter method. The ESP method was shown to be a more effective means of measuring semivolatile PM under the test conditions.

3B3o2 A web-based occupant satisfaction survey for benchmarking building quality
C Huizenga, K Laeser and E Arens

Occupants remain a largely untapped source of information for facility managers interested in improving the performance of their buildings. An appropriate web-based environmental quality survey offers opportunities to broadly include occupants in a building performance feedback loop. We have developed a survey that can measure occupant satisfaction with indoor environments in a standardized manner while minimizing research costs and inconvenience to the survey participants. A standard set of core questions is used to measure satisfaction with environmental factors such as indoor air quality, thermal comfort, and acoustics. "Branching" questions are used to capture detail for diagnosing causes of perceived problems. The survey has been extensively tested and refined. It has been applied in a variety of research scenarios, three of which are presented in this paper: evaluating the effectiveness of a design intervention, informing the development of design guidelines for a new building, and benchmarking facility performance.

3B3o3 A sociological approach to validate a questionnaire for the assessment of symptoms and perception of indoor environment in dwellings
K Engvall, C Norrby1 and E Sandstedt

A standardised questionnaire for dwellings – the Stockholm Indoor Environment Questionnaire (SIEQ) was developed, based on sociological principles and test procedures for validation. The every day language describing the building and its function was first obtained by qualitative personal interviews, then by standardised questions. The interview questionnaire was transformed into a postal self- administered questionnaire. The questionnaire was reduced by correlation analysis. It was found that to obtain a good validity, general questions are not sufficient, but also questions on perception and observations are needed. Good test- retest agreement was found for a random sample when investigating the same area, and the same buildings.

3B3o4 Critical review of an AI-based screening tool to evaluate IAQ
KM Dilwali, JF McCarthy and R Foster

Building owners and facilities managers who recognize the importance of maintaining good Indoor Air Quality (IAQ) have identified the need for a screening tool to facilitate early detection of IAQ problems. Building investigation experts concur that a technology combining the elements of a professional inspection with monitoring data would be beneficial, especially with limited access to on-site industrial hygiene (IH). This paper describes a new approach to routine IAQ screening that integrates the technical experience of IH and engineering professionals with environmental data. It consists of a web-accessible expert system (with experiential knowledge of thousands of building IAQ investigations), linked to an eight-parameter monitor, that transmits building data for automatic analysis. The expert system provides a probabilistic diagnosis and recommends follow-up action. IAQ experts and building managers are reviewing this approach for its screening effectiveness. This paper provides a critical review using three building examples.

3B3o5 What do "real people" mean by indoor air quality?
GJ Raw, SKD Coward, CE Aizlewood, K Rathouse and DJ Wilde

Typically, IAQ questionnaires are based on researchers' concepts of IAQ. This study sought to determine the IAQ concepts that non-researchers use, and thus generate new questions to be added to a standard questionnaire. The original and revised questionnaires were compared in a survey of 13 office buildings during winter and summer. Including the new questions did not affect response to the existing questions. The analysis challenges some concepts that have been used by researchers, because: odour, as an overall concept, has a minor role compared with specific odour types; satisfaction with air quality is distinct from satisfactory air quality, and "annoying" air is a separate factor again; being warm or cold is thought of not as a continuum but as two distinct states; stuffy and stale air are separate concepts; satisfaction is only one aspect of air quality and is closely related to thermal conditions.

3B3p1 New tools to develop internet questionnaire for indoor air quality surveys
E Kähkönen, K Salmi and K Reijula

In the middle of 1990´s we developed an IAQ questionnaire which based on the World Wide Web and Internet network. The workers´ opinions and impressions on the indoor air quality, symptoms, health and psychosocial factors have been collected quickly and directly through the World Wide Web and Internet networks since 1996. In the late 1990´s new tools and survey software packages were published and online surveys are rapidly becoming the most popular data collection methods. Non-technical people can create, update and administer surveys. There are remarkable differences in administration features, system security and privacy. The objective for information security is to protect data everywhere, so we must design how to protect databases, network traffic, servers, remote access, workstations as far as health information of a worker is concerned.

3B3p2 Environmental assessment protocols for homes, schools, and child care
BH Turk, D Hadlich, T Brennan, A Duggan, R Shaughnessy, M Vogel, A Abend, S Galbraith, S Hills and M Miller

Assessment protocol and training program modules have been developed for environmental health and safety hazards found in occupied spaces and near outdoor areas where children spend most of their time: home, school, and child care. The home and child care modules contain customizable assessment checklists, mitigation action plans that emphasize low-cost and no-cost approaches, fact sheet handouts, and extensive training and reference materials. The assessment covers outdoor sources, tobacco smoking, mold and moisture, lead, dust, other common indoor air contaminants, and other hazards. The school module is based on the U.S. EPA's IAQ Tools for Schools, but adds supplemental checklists and materials on asthma, mold and moisture, air cleaning, cleaning management, and other topic areas. There is a special focus on allergy and asthma-related conditions. Dozens of Albuquerque homes and over 1,400 New Mexico child care providers have had environmental assessments performed or received training using these materials.

3B3p3 Testing indoor air products: one approach to developing widely accepted protocols
DL Franke, DS Ensor, JT Hanley and LE Sparks

RTI is a partner in the US EPA's Environmental Technology Verification (ETV) Program, with responsibility for evaluation of products intended to improve indoor air quality. The program objective is to further the development of self-supporting private environmental testing/certification programs for indoor air products by convening stakeholder groups and developing and verifying test protocols. The protocols have also been specified in public and private procurements. Two areas of emphasis have been low emitting (i.e., low offgassing) commercial furniture and general ventilation filters for removal of aerosol contaminants. These areas have been reported earlier. A third area of emphasis currently being pursued is the evaluation of in-

duct electronic air cleaners. While the ASHRAE 52.2 is a starting point for the test protocol, RTI has investigated conditioning and dust loading issues specific to electronic air cleaners. A companion paper at the conference discusses the laboratory results.

3B3p4 Passive methods for monitoring indoor air quality in museums
T Iwata, C Sano, M Hori, H Tsukahara and N Oba

The purpose of this study is to develop a small passive sampling kit which can be suitable as a way of measuring IAQ in museums. Test measurements were conducted in a 20-year old museum. As well as temperature and humidity, the concentrations of ammonia, formaldehyde, nitrogen dioxide, acetic and formic acids, TVOC, ozone, salt and acidity/alkalinity were also measured by a trial sampling kit. The concentrations of nitrogen dioxide in the display cases were lower than that in the rooms, while the concentrations of formaldehyde in the display cases were higher. The results of the pH paper showed non-uniform discoloration and implied that both alkaline and acidic pollutants existed. Since the concentration of ammonia was very low, it was expected that the other alkali also existed. The validity of the small sampling kit was shown to measure IAQ in museums without preventing visitors from appreciating art.

3B3p5 Development of a unique ultra-clean full-scale thermal and air quality research facility
JS Zhang, TJ Herrmann, Z Zhang and K Noble

This paper discusses the major design features, construction challenges, and preliminary results of performance testing of a unique full-scale research facility. The facility consists of an indoor environmental (IEQ) chamber, an outdoor climate chamber, and a replaceable "separation/test wall" that is shared by the two chambers. The IEQ chamber can simulate realistic indoor environments, while the climate chamber can simulate cold winter to hot summer weather conditions and outdoor air pollution. The "separation/test wall" can be used to physically model and study combined air, heat, moisture, and contaminant transport through building envelope assemblies. Construction challenges included obtaining low leakage rates, achieving a high quality surface finish and minimizing Volatile Organic Compound (VOC) contamination. Preliminary test results show that the facility can achieve original design objectives. The facility can be used to study various source control, ventilation and air cleaning methods for achieving optimal IEQ in an energy-efficient and cost-effective manner.

3B3p6 MARIA: an experimental tool at the service of indoor air quality in housing sector
J Ribéron and P O'Kelly

CSTB has built an experimental house MARIA: Mechanised house for Advanced Research on Indoor Air. The house is dedicated to study pollutants transfers, test ventilation systems, settle field investigation methods, and validate computational models. MARIA will be instrumented and automated according to pre-established scenario of operation reproducing parameters related to human presence and behaviour. The human presence is simulated with heat load and water vapour and pollutants emission. The operation of equipments such as doors and windows, domestic devices, will be automated. Indoor air quality parameters, meteorological parameters, outdoor pollutants and parameters related to house appliances will be measured. The control system of the house can manage both the measurement and automation systems. In this way, the experiments can be performed not only for pre-established scenario, but priority commands derived from measurements can be taken into account. Demand-controlled strategies based on measured environmental parameters can be studied.

3B4o1 Effect of ventilation rate on contaminant emission rates from diffusion-controlled materials
SS Cox, AT Hodgson, and JC Little

The contaminant emission rate is an important parameter describing the potential for materials to affect indoor air quality through the release of volatile organic compounds (VOCs). Emission rates have traditionally been inferred from gas-phase concentration measurements obtained through chamber studies. However, models suggest that the rate at which VOCs are emitted by diffusion-controlled materials may be influenced by ventilation rates. This study describes an emissions model developed for diffusion-controlled materials and shows how emission rates are theoretically related to ventilation rates. Small chamber experiments were conducted to experimentally determine the effect of ventilation rate on VOC emissions from vinyl flooring. A field study in a house also measured the effect of ventilation rate on VOC emissions. Both laboratory and field results show that an increase in ventilation rate causes an increase in VOC emission rates. The effect is not as pronounced at longer time periods or if the material/air partition coefficient for the specific VOC is small.

3B4o2 Emission of isocyanates from PUR-adhesives: time course of emission from curing PUR-adhesive
M Wirts and T Salthammer

The time course of isocyanate emission from curing PUR-adhesives was studied in an emission test chamber. The adhesives under investigation were commercial products for fixing of textile floor coverings and based on methylene -bisphenyl diisocyanate (MDI). Influence of the curing mechanism was studied by comparing the emission curves of one-component

adhesive (OCA) and two-component adhesive (TCA). For TCA the decrease in isocyanate emission was found to follow a two-step process during curing. In the first step the emission is dominated by surface evaporation and the decay of emission is mainly caused by the decrease in monomer content due to reaction. In the second step the release is limited by internal diffusion. The influence of monomer reactivity on the emission profile could be demonstrated for 2,4´- and 4,4´-MDI. The less reactive 2,4´-MDI caused prolonged emission.

3B4o3 Indoor chemical pollution and emission rates investigated in a real sized model room
S Tanabe, R Shirai, M Banno and Y Asai

Indoor air concentration of chemical pollutants in a real sized model room and their emission rates from floor, wall and ceiling were measured with FLEC to predict indoor concentration of chemical pollutants in long terms. For the factor affecting indoor concentration, the effect of temperature on indoor concentration and on emission rates of chemical pollutants from test pieces were examined. Just after remodeling, indoor concentration of formaldehyde and TVOC were 191 and 1190 mg/m^3, which are above guideline values for VOCs by the Ministry of Health, Labor and Welfare, but they were decreased under the guideline after one month. Both indoor concentrations of the model room and emission rates of building materials were larger in higher temperature. Emission rates from floor materials were similar to those measured in the model room and decreased as time passed.

3B4o4 Experimental surface mass transfer coefficients in a standard FLEC
J Niu, L Zhang, and TK Wan

FLEC (field and laboratory emission chamber) is becoming a standard method to characterize pollutant emissions from building materials. Up until now, only the emission rate profiles are obtained, which are useful for the comparison and ranking of emission strength from different materials. However, to use the chamber emission test data to model pollutant concentrations in real buildings, and also to evaluate the effects of various control strategies, mass transfer model is required. As the first step, surface convective mass transfer coefficients are essential. In this study, a first series of direct measurements of surface mass transfer coefficients using distilled water at 5 air flow conditions ranging from 186 ml/min to 509 ml/min in a standard FLEC is conducted. Mass transfer data inside the FLEC is correlated by a dimensionless equation.

3B4o5 Effects of measurement errors on regression results of the emission parameters of building materials
G He and X Yang

Diffusion coefficient and partition coefficient are two critical parameters that describe the emission characteristics of building materials. These parameters could be obtained from least-square regression by fitting the model predictions with the experiment data obtained by widely used small chamber tests. The chamber data quality is important to the reliability of the regression results. In this paper we studied the influence of the measurement errors of chamber data on the regression results using the diffusion controlled emission model. The cases studied include one degree, two degrees, and three degrees of freedom. As expected, the more variables to be determined by regression, the larger uncertainties the parameter regression results have. Results also show that missing the peak information in the chamber emission data will not cause significant regression error. The results of this study could be useful for guiding further regression work and establishing the requirements of chamber tests.

3B4p1 Modeling of VOCs emissions from a varnish
H Guo, SC Lee and N-H Kwok

To measure VOCs emission of building materials and construction products, an environmental test chamber with controlled temperature, relative humidity and airflow rate, was used. Emissions of VOCs from a type of varnish were qualified and quantified using GC-MSD. The emission data obtained through this method could be used to estimate population exposure to the VOCs emitted and to reduce the exposure through selection of appropriate indoor materials. In this study, temporal emissions of volatile organic compounds from the varnish were analyzed based on chamber tests. The thickness effect of varnish on VOCs emissions was also investigated. A first-order decay model was used to predict the emissions of individual VOCs. The correlation between chamber measurements and model-derived results was statistically evaluated by using both residual analysis and correlation techniques.

3B4p2 Building materials VOC emissions: a systematic parametric study
H Huang and F Haghighat

Mathematical models that are used to predict VOC emission of building materials require four basic parameters as input: VOC diffusion coefficient of the material (Dm), VOC partition coefficient (k), material thickness (H) and surface air velocity (v). This paper describes a four-factor simulation design and a statistical procedure for analyzing material VOC time (Y)

sensitivities with respect to these four parameters variations and their interaction effects. Omega squared (ω2) is used as an index to measure the factor effect magnitude. The statistical analysis involving the comparison of ω2 of the four parameters and their interactions indicates that two parameters, Dm and H, and their interaction, Dm´H, significantly affect the material VOC time. Other parameters (k, v) and interactions (D_m k, D_m v, k H, k v, H v, D_m k H, D_m k v, D_m H v, k H v, D_m k H v) have minor effects on the material VOC time.

3B4p3 Modeling the VOC emissions of solid/wet building material assembly and its assessment
C-S Lee, F Haghighat, and W Ghaly

This paper presents the theoretical investigation of the VOC emissions from the solid/wet material assembly. A mass transfer model was developed considering the diffusion and sorption within the solid, and the convection (i.e., airflow) over the solid material. The wet material was modeled as an emission source with a constant decay rate and a negligible thickness. The analytical solution was obtained using the integral transform technique. This proposed model was assessed by comparing its prediction to small-scaled chamber test data of carpet/adhesive assembly in the literature. The effect of air velocity (i.e., Reynolds number) on the emission of the assembly was studied. The emission rate increases as the air velocity increases; however, the effect of air velocity depends on the solid material properties.

3B4p4 The moisture content and emissions from floors subjected to a moisture load
L Wirtanen, J Eronen and V Penttala

The emission of volatile organic compounds (VOC), ammonia, and formaldehyde and the moisture behaviour of different floor structures subjected to a moisture load were studied under laboratory conditions with the aim of designating the least emitting structures. The emitting compounds were collected primarily using a Field and Laboratory Emission Cell (FLEC). Additional samples were taken from the indoor air and from inside the structures. The emission rate of the total amount of VOC (TVOC) was in general 80-100 mg/m²×h. It exceeded 200 mg/m²×h principally at the first measurement, i.e. one month after the installation, of vinyl carpet or mosaic parquet coatings. The external moisture load did not prominently influence the TVOC-values, but excess moisture caused changes in the emission rates of single compounds. The results indicated that it is important to choose low-emitting materials in order to guarantee low emission rates also during and after a possible moisture damage.

3B4p5 A universal model of volatile organic compounds in room
T Cheng, J Yi, Y Xu and Y Zhang

A universal mathematical model is proposed to account for emissions of volatile organic compounds (VOCs) from homogeneous dry materials. The model considers multi-emission sources and sinks together with air-cleaning device. The salient feature of the model is that all the parameters have clear physical meaning and can be either found from experimental data produced by chamber study in the literature or calculated using known theories and/or equations. The model can predict the emission rate of VOCs from dry materials into air. It is also able to determine the relationship of the emission rates of VOC sources, the bulk air concentration and its volumetric flow rate, the sorption rates of VOC sinks and the removing rate of VOCs of air cleaning device.

3B5o1 Integrated probabilistic and deterministic modeling techniques in estimating exposure to water-borne contaminants: Part 1: exposure modeling
CR Wilkes, JN Blancato, SC Hern, FW Power and SS Olin

The Total Exposure Model (TEM) uses deterministic and stochastic methods to estimate the exposure of a person performing daily activities of eating, drinking, showering, and bathing. There were 250 personal activity time histories generated for the three exposure routes (oral, dermal, and inhalation) for the chemicals trichloroethylene (TCE), trichloroacetic acid (TCA), and dichloroacetic acid (DCA). Uptake models were used to estimate the absorbed dose. In a second, related paper, these exposures were input to the physiologically based pharmacokinetic (PBPK) model, ERDEM (Exposure Related Dose Estimating Model).

3B5o2 Integrated probabilistic and deterministic modeling techniques in estimating exposure to water-borne contaminants: Part 2: pharmacokinetic modeling
JN Blancato, FW Power, CR Wilkes, AM Tsang, SC Hern, and SS Olin

The Total Exposure Model (TEM) uses deterministic and stochastic methods to estimate the exposure of a person performing daily activities of eating, drinking, showering, and bathing (see part 1). There were 250 time histories generated, by subject with activities, for the three exposure routes, oral, dermal, and inhalation, and these were input to the physiologically based pharmacokinetic (PBPK) model, via ERDEM (Exposure Related Dose Estimating model). The chemicals modeled were trichloroethylene (TCE), trichloroacetic acid (TCA), and dichloroacetic acid (DCA). Time histories of concentrations and

Areas Under the Curve (AUC) were determined for the liver, kidney, and venous blood. They were combined to determine the distribution at each time step and hence define the 5th, 50th and the 95th percentiles. The important pathways and the basis for their predominance are shown. Thus highly variable exposures can be related to actual dose to various organs of the human body.

3B5o3 Application of chemical mass balance modeling to indoor VOCs
D Won, CY Shaw, TA Biesenthal, , E Lusztyk, and RJ Magee

There have been several studies to measure the concentrations of volatile organic compounds (VOCs) indoors and to characterize their sources. However, the two tasks have often been done separately, and few attempts have been made to provide a direct link between the sources and the measured VOCs. Chemical mass balance (CMB) modeling was applied to the measurements of 24 VOCs in a newly constructed house. The results of CMB modeling show that wall adhesive, caulking, I-beam joist, and particleboard are the dominant sources. An attempt was also made to estimate the source contributions using mathematical transport modeling. Good agreement was obtained between the two results. The CMB model is shown to have good potential for identifying the dominant sources and helping develop control strategies for indoor VOCs. However, more research is needed for the collinearity problem associated with source signatures.

3B5o4 A multi-pollutant model for estimating the impact of pollutants on indoor air quality
LE Sparks

Most existing indoor air quality (IAQ) models are not well suited for analysis of the impacts of sources that emit several pollutants into the indoor environment. These models are also not well suited for the analysis of the impacts of particulate matter (PM) on the indoor environment because of the need to include particle size distribution in the analysis. The IAQ model RISK was rewritten to allow analysis of multiple pollutants and PM. The IAQ model includes several new source emission models developed from EPA's ongoing indoor source research program. For PM, the model allows analysis of the effects of: the building shell on the penetration of outdoor particles into the indoors, the deposition of particles to indoor surfaces, particle removal by air cleaners, and indoor particle sources. Model predictions are in good agreement with the experimental data from EPA's IAQ research house.

3B5p1 Analysis of household water-use behavior for use as IAQ model parameters
CR Wilkes, SC Hern, JN Blancato, AD Mason, and LL Niang

In assessing exposure to indoor air contaminants, the understanding of population water-use behavior for indoor water-use activities as a function of demographic characteristics is vital to obtaining realistic exposure estimates. In response to the need for more specific and usable population based water-use data for exposure modeling, new data sources have been analyzed. Frequencies, durations, volumes and flowrates of showers, baths, clothes washers, dishwashers, toilets and faucets are presented, derived from analyses of the National Human Activities Pattern Survey (NHAPS) database, the Residential End Uses of Water Study (REUWS) database, the Residential Energy Consumption Survey (RECS) as well as from current literature and manufacturer information. Distribution parameters for water use behaviors are identified for use as inputs for modeling exposure to water borne contaminants.

3B5p2 Prediction of indoor nitrogen oxides concentration
I Senitkova and S Vilcekova

Indoor air is mostly contaminated from the use of gas for heating and cooking appliances. It is well known that the oxide of nitrogen production in the combustion products is the process that not been exactly described so far on all variables which are connected with its production. The comprehensive analysis of indoor air nitrogen oxides pollution show that extent of indoor air level exposure varies with many factor mainly with different distribution conditions and burning activity. It seems to be necessary study and formulate mathematical model for indoor nitrogen oxides production. A mathematical model has been developed to describe the physical processes determining indoor nitrogen oxides concentration as a function of outdoor concentration, indoor emission rates and building characteristic. The model has been parameterized for typical Slovak residences. The base of this activities is presented in the paper with belief in the next continue future work.

3B5p3 Ventilation in kitchen - aerosol concentration and key components in the vapour
B Andrejs, J Fauss , M Weigl , P Rietschel

When frying, grilling and deep-frying in kitchens, vapours and aerosols are released into the surrounding air. The aerosol is air-born and can contain an array of noxious substances. The purpose of the work was to develop a simple method for calculating the loading resulting from kitchen vapours . Of the low-molecular aldehydes, the acrolein in the air contributed most to the load in the kitchen due to its pungent odor and toxic properties. In kitchens, aerosols and aldehydes (low molecular aldehydes) up to

trans–2-hexenal and unsaturated fatty aldehydes (decenal, decadienal, undecenal) form the main components of the extraneous substances in the air. The aerosols consist in part of ultra fine particles and are deposited in the lungs. Up to 90% of these consist of triglycerides and fatty acids. Other components include furans and polymer or oxidised triglycerides. The concentration of aldehydes and aerosols changes in the same ratio.

3B5p4 Prediction of VOC concentration profiles in a newly constructed house using small chamber data and an IAQ simulation program

RJ Magee, A Bodalal, TA Biesenthal, E Lusztyk, M Brouzes, and CY Shaw

The ability of the Material Emission Database and Indoor Air Quality simulation program ("MEDB-IAQ") to use small chamber test results to model volatile organic compound (VOC) profiles in a newly constructed 2-storey single family home was evaluated. Selected building materials used in the construction of the CCHT (Canadian Centre for Housing Technology) "Reference" house were collected and subjected to chamber testing. VOC emission rates were modeled from the results and entered into MEDB-IAQ. A simulation of the house construction and subsequent operation for an additional nine months was then run with the software package. Air exchange rate data from the house was also used as model input. Predicted VOC results were then compared with air samples taken from the house and analyzed by GC/MS. Prediction accuracy depended on source complexity, source identification and emitting area, and on sink effects. Trends in relative contributions of individual materials could be readily identified.

3B5p5 Literature review on micro-environmental modeling

MD Koontz and SS Cox

A literature survey was conducted to characterize the state-of-science of microenvironmental modeling, particularly as it pertains to predicting the breathing-zone concentrations of exposed individuals over time, and to identify areas where significant data gaps or research needs exist. A framework based on a mass-balance model for indoor air quality (IAQ) was used to guide the search of peer-reviewed literature, including proceedings from recent major conferences with an IAQ emphasis. The resultant database includes fields for author, title, year, abstract, and 17 topic areas (coded as "T" if the paper provided some coverage of the area, "F" if not). A summary was developed for each topic area on the types of research efforts that have been undertaken, noteworthy achievements, and areas of apparent strength or weakness.

3B5p6 Upscaling of material emissions: comparison of small and full-scale chamber results and evaluation of an IAQ simulation model

TA Biesenthal, RJ Magee, A Bodalal, E Lusztyk, M Brouzes, G Nong, and CY Shaw

The emission rates of selected volatile organic compounds (VOCs) were determined for a series of building materials. Those same building materials were used to construct scaled-down ("mock-up") versions of the primary emitting surfaces from a recently constructed research house. The mock-up version of the house materials (including a painted wall assembly and a flooring assembly) was assembled in a full-scale (55 m^3) stainless steel chamber and the VOC concentrations were measured under standard conditions. A single zone model was used to simulate the concentrations during the mock-up experiments, based on the emission rates determined from the small chamber tests. The agreement between the predicted and observed concentrations was examined in detail, and in most cases the deviations can be attributed to the effects of unquantified sinks and sometimes unquantified sources.

3B5p7 A model for estimating sub-lethal effects of irritant gases on egress time in home fire scenarios

T Thomas, S White, S Inkster, M Neily, A Lee and L Saltzman

CPSC staff, in partnership with the National Institute of Standards and Technology (NIST) and other organizations is completing a study into the efficacy of various smoke alarm technologies in different home environments . A part of the study involves quantifying the concentrations of irritant and asphyxiant gases in specific fire scenarios. CPSC staff has developed a model to estimate the severity of the physiological effect of each gas and approximate the delay in egress time resulting from the gas exposure.

3B5p8 Measurement and prediction of pollutant level in public taxi transport interchanges in Hong Kong

WZ Lu, XK Wang, WJ Wang, AYT Leung, ATP So and S M Lo

A study on pollutant dispersion and distribution inside public taxi transfer interchanges (TTI) is reported. The pollutant levels inside TTI are affected by many factors, e.g., taxi data, climatic conditions, human activities, and geometrical layout of TTI, etc. A site measurement of Respirable Suspended Particulate (RSP) level is carried out in a typical TTI in Hong Kong. After analyzing the effect of above factors on RSP level, we propose to use artificial neural networks (ANN) to study such phenomena. The recorded data within different time periods inside the selected TTIs are used as the test data set to train the proposed neural network model. The recovery performance of ANN model is analyzed and justified. In the study, we compare

the forecasting results and the measured data of RSP in morning and afternoon sessions respectively. The results show the feasibility and reliability of the proposed approach for forecasting pollutant levels inside TTI.

3B6o1 The revision of Standard 62: what a difference a decade makes
A Persily

The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) has been revising Standard 62,Ventilation for Acceptable Indoor Air Quality since 1991. The two primary motivations for this revision have been 1) to convert the document into minimum requirements in mandatory and enforceable language for adoption into building codes and 2) to incorporate the increased knowledge from research and practical experience since the bulk of the standard was last approved in 1989. A number of changes have been approved since the revision process began ten years ago, but many difficult issues remain. This paper provides a summary of the progress that has been made to date and the issues that remain to be resolved before a complete code-language version of the standard can be issued.

3B6o2 CO_2-based occupancy detection for on-line demand controlled ventilation systems
J Sowa

The paper presents part of the outcomes from the preliminary stage of the project set up by Polish Committee for Scientific Research and devoted to development of the recommended control strategies for DCV systems in Poland. The performance of three CO_2-based occupancy detection algorithms for on-line demand controlled ventilation systems has been studied. Additionally, the analysis covers three different procedures of adjusting ventilation rates according to the following ventilation standards: ASHRAE 62-2001, CEN CR 1752 and Polish standard PN-83/B-03430. Computer simulation was used to present the accuracy of analyzed algorithms.

3B6o3 Review of ventilation system control strategies and effectiveness
PH Raymer

The optimum ventilation system would only operate when ventilation was “needed”, it would remove only the bad air, and it wouldn’t interfere with any other naturally aspirated household system. Running the ventilation system all the time at a low flow rate, a rate sufficient to match the ASHRAE recommended .35 ACH is a crude control approach to this optimum system. Conditions in a house are not constant. On average, a constant flow rate ventilation system will work reasonably well, but there are more effective approaches. Optimizing the ventilation control system is a way to meet the airflow requirements while minimizing the operating cost. This paper considers much of the previous work that has been done and then relates the results of a test of six different ventilation control approaches, considering what to use as a “marker” of ventilation system effectiveness.

3B6o4 Assessing the energy impact of ventilation and infiltration in multi-unit residential buildings
B Phillips and D Hill

Multi-unit residential building (MURB) corridor ventilation systems supply conditioned outdoor air directly to corridors, indirectly ventilating suites. Their impacts on infiltration and heating season energy use were not fully understood. A straightforward and inexpensive field test protocol was developed to assess these impacts and applied to five MURBs in Winnipeg, Canada. Analyses of field data revealed that operating corridor ventilation systems increased whole-building energy use by an amount equal to 60 to 90% of the energy used directly by the corridor ventilation system. The increases were considerably more than anticipated, indicating that corridor ventilation systems do not displace as much infiltration as expected. This paper describes the field test protocol and presents the field test results and their implications. The test protocol will be useful to energy auditors, building services engineers and other building professionals who must assess the energy implications of ventilation system operation in multi-unit residential buildings.

3B6p1 Optimal design of all-air systems
A Jönsson

Formulas for optimal design of all-air systems have been derived, where benefit is balanced against costs. This paper gives the numerical calculations of the optimum outdoor air rates in offices. The optimal outdoor air rate during the hot period is lower than during the lowest temperature since the price of heating capacity is lower than the price of cooling capacity and the hot period is shorter than the period with the lowest temperatures. The full heating and cooling capacity should be used during the lowest and hot period. The use of optimal outdoor air rates will increase the outdoor air rates during the low and lowest temperatures and improve the indoor air quality compared to the economizer cycle.

3B6p2 Outdoor and return airflow mixing with parallel dampers
C Sun, F Finaish and HJ Sauer

Thermal mixing of two airstreams with dissimilar temperatures and velocities entering a mixing chamber, equipped with parallel air dampers, is studied experimentally. The thermal mixing for outdoor airflow ratios in the range between 15% and 45% was examined at several stations in the mixing chamber. At each flow ratio, the return airflow damper was kept fully open while the outdoor air damper angle was changed from 30 to 90 . The results show that as the two streams flow into the mixing chamber and proceed downstream of the dampers-controlled inlets, most of the mixing occurs within a downstream distance equal to one height of the chamber. Furthermore, the results suggest that directing the two streams toward each other by altering the outdoor dampers from the fully to partially open position leads to improved mixing in the entrance region. However, this influence diminishes downstream of the dampers.

3B6p3 Advantageousness comparison of air ventilation systems
A Saari

The ventilation of a group of six apartment buildings was implemented in two different ways. Alternative A was used in three buildings where supply air came in through vents in the external walls. Exhaust air was removed mechanically. In Alternative B, the heat of the exhaust air was recovered to heat supply air. In both alternatives, the occupant can regulate the rate of exhaust air removal within certain limits by a regulator in the dwelling. The study analysed the merits of these two alternatives on the basis of the Negative Index. The Negative Index tells the disadvantages of the compared products in relation to the constant reference level. The Negative Index value is affected by life cycle costs (Variable 1) and environmental impact (Variable 2). Global warming potential is considered an environmental impact.

3B6p4 Effects of continuous ventilation on indoor air quality (IAQ)
J Wempen

Space-conditioning system operation affects energy use and indoor air quality (IAQ) in houses. This study assessed the IAQ implications of continuous versus cyclic system operation with and without whole-house ventilation. A calibrated multizone airflow and contaminant transport model was constructed and used to evaluate the effectiveness of seven system operation and ventilation schemes for controlling distributed and point source contaminants over a day. The multizone simulations show that continuous air-handler operation can significantly lower both the peak and average concentrations for both point source and distributed source contaminants, and can reduce room-to-room variability, regardless of mechanical ventilation strategy. Mechanical ventilation with cyclic air-handler operation can also lower the average concentration of both point source and distributed source contaminants, but can produce unacceptably high peak concentrations from point sources. Further research is necessary to evaluate these issues over a wider range of residential floor plans, ventilation system configurations, and weather

3B6p5 Effects of HVAC ventilation efficiency on the concentrations of formaldehyde and total volatile organic compounds in office buildings
Y-Y Li, P-C Wu, H-J Su, P-C Chou, C-M Chiang

Potential sources for emitting formaldehyde and volatile organic compounds are abundant in office buildings. Exposure to the above compounds may result in short-term, long-term, or carcinogenic effects at concentrations often measured. Our study conducts field measurements on six typical office buildings with different HVAC systems to evaluate the effects of ventilation efficiency on the concentration of formaldehyde and total volatile organic compounds (TVOC). Formaldehyde and TVOC concentrations were measured by continuous photo-acoustic Multi-Gas monitor. The air-change rates were estimated by tracer gas concentration decay method in every test space. Air Exchange Efficiency (AEE) and Effective Ventilation Rate (EACH) were also calculated to characterize the ventilation pattern and mixing factor. Our results show that the increase of effective ventilation could reduce formaldehyde and TVOC in office buildings. We therefore suggest that increasing ventilation efficiency appears to be a plausible solution to diminish both formaldehyde and TVOC concentrations in office buildings.

3B6p6 Estimation of air infiltration of buildings based on the degree of air tightness and climatic data
A Binamu and R Lindberg

This study presents a simple method, developed for estimating annual air infiltration rates in single-family detached houses. The input data to this technique are: measured building air tightness, wind speeds, and the indoor-outdoors temperatures. Six test buildings of the same size, constructed of different building materials were involved in the study. The air tightness of these buildings was determined by using pressurisation method at 50 Pa pressure difference. Infiltration air change rates were measured by using tracer gas – concentration decay method and also calculated by using the developed technique. In addition, four other infiltration models were used to predict the air infiltration namely: LBL, Kronvall, ASHRAE, and CEN models.

Measured and calculated/predicted infiltration results were compared. A very close correlation between the measured and the calculated results, obtained by using the developed technique and the other infiltration models was observed.

3B6p8 Analysis of ventilation rates for the BASE study: assessment of measurement uncertainty and comparison with ASHRAE 62-1999
JF Ludwig, BJ Baker and JF McCarthy

Ventilation is essential for providing safe and comfortable indoor environments. EPA's Building Assessment Survey and Evaluation (BASE) Study was designed to collect relevant baseline air quality data on a broad cross-section of office buildings across the United States. These include techniques that utilize traditional air balance measurements and naturally occurring tracer gases in buildings (CO_2). The paper describes the methods used in characterizing ventilation in 100 BASE buildings, summarizes the results, and reviews the accuracy and limitations of these techniques. These data indicate that, in most cases, ventilation rates determined using the CO_2 tracer gas method were shown to best represent the ventilation rate. A comparison of the BASE building ventilation rate results to current outdoor air ventilation rates recommended by the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE) is also discussed. Analysis shows that 11% had average outside air ventilation rates below current ASHRAE recommendations.

3C1o1 Moulds and health - an epidemiological study
HW Meyer, H Würtz, O Valbjørn, T Sigsgaard and F Gyntelberg

The objective was to test the hypothesis that building related symptoms (BRS) in adolescent school children were associated with mould growth in school buildings. In the questionnaire study including eight "wet" and seven "dry" schools sufficient responses were returned from 1,053 adolescent pupils of 8th and 9th grade. At the end of a working day dust was sampled from floors of the class rooms of these pupils, and analysed for culturable fungi. When dividing the buildings into "dry", "intermediate" and "wet" a surprising tendency towards higher prevalences of BRS in "dry" buildings was seen, though a significant trend was only found for eye irritation. Significantly higher prevalences of eye irritation, throat irritation, headache, concentration problems, and dizziness were seen with increasing levels of viable total moulds in collected floor dust.

3C1o2 The "healthy pet-keeping effect:" Pet-keeping in early childhood as a risk or a protection against allergic symptoms later in life
CG Bornehag, J Sundell, L Hägerhed, and S Janson

It is discussed whether exposure to pets during childhood is a risk or a protective factor for sensitization and allergic symptoms. The aim of this study was to investigate the association between pet-keeping and allergic symptoms among young children in Sweden. A questionnaire was sent to 14,077 children (1-6 y) with focus on health, home environment and other background factors. It was showed that pet-keeping is negatively associated with allergic symptoms. However, the prevalence for all allergic symptoms studied was significantly highest in the group of children where the families have had pets at the time of the child's birth, or later, but not current. This shows that the distribution of pet-keeping in the population is confounded by active avoidance of pets, i.e. those that have pets are those that can stand them, meaning a "Healthy pet-keeping effect".

3C1o3 Comparison of the perceived indoor climate and symptoms reported by students and personnel in 16 senior high schools in Sweden
K Andersson, G Stridh, I Fagerlund, W Aslaksen and S Rudblad

In school investigations the prevalens of complaints and symptoms often differ between the school personnel and students. To study this 1,023 personnel and 8,853 students from 16 senior high schools answered the same questions about the perceived indoor climate and SBS symptoms. Both personnel and students reported high prevalence of annoying indoor air quality, dust and dirt and temperature problems. The symptom prevalence was strongly related to sex and allergic constitution. The students reported much higher prevalence of general symptoms compared to the personnel, while the personnel reported somewhat higher prevalence of mucous membrane irritations and skin symptoms. In conclusion it is important to be aware of all factors influencing the results from a questionnaire study to do a correct interpretation. Proper use of relevant reference values is essential.

3C1o4 Microbial exposure and mold specific serum IgG levels of symptomatic schoolchildren
A Hyvärinen, T Husman, S Laitinen T Meklin, T Taskinen, M Korppi and A Nevalainen

The association between serum mold-specific IgG levels of 181 primary schoolchildren with asthma or wheezing or cough symptoms and the microbial exposure were determined. The study was conducted in a school with mold damage and in another without such damage. Microbial exposure was characterized with environmental sampling. Serum IgG antibody concentrations to 20 microbial strains were determined with ELISA. There was an association between elevated serum IgG levels to

Penicillium notatum and moisture damage in the school. In addition, moisture damage when present both in school and at home was associated with elevated IgG levels to *Penicillium notatum* and *Eurotium amstelodami*. These observations were in concordance with microbial findings in the index school. No other positive associations between IgG antibodies and microbial findings of the school buildings were observed; in fact, the microbe-specific IgG levels of children were often higher in the reference school.

3C1o5 Current asthma, respiratory infections and hypersensitivity to moulds in pupils in Shanghai, China, in relation to microbial components in the classrooms
D Norbäck, Y-H Mi, L Larsson, L Wady, J Tao and Y-L Mi

Thirty classrooms in 10 schools in Shanghai (China) were investigated. Dust was collected by vacuum cleaning, analysed for ergosterol, muramic acid, and 3-hydroxy fatty acids (LPS; endotoxin) by tandem mass spectrometry (GC-MSMS). Airborne microorganisms were measured by CAMNEA. The pupils received a questionnaire, 1414 participated (99%). The mean age was 13 y, 45% reported respiratory infections, 5.4% mould allergy, and 3.1% current asthma. Respiratory infections were positively associated with viable moulds in air ($p=0.04$), viable bacteria ($p=0.02$), 3-methylfuran ($p=0.04$), and negatively associated with LPS ($p=0.01$). Current asthma was positively associated with 1-octen-3-ol ($p=0.047$), and negatively associated with LPS ($p=0.05$). Mould allergy/intolerance was positively associated with total moulds ($p=0.002$) and muramic acid ($p<0.001$). Respiratory health and intolerance was associated with microbial components in the schools. LPS in settled dust seems to be protective, while muramic acid, viable bacteria, viable and total moulds, and MVOC were associated with adverse health effects.

3C1p1 Effects of moisture damage repair on microbial exposure and health effects in schools
T Meklin, T Husman, J Pekkanen, A Hyvärinen, M-R Hirvonen and A Nevalainen

This intervention study was designed to show the effects of the renovation of moisture and mold damaged school building on the schoolchildren's health and exposure. Microbial sampling from indoor air of the school and a health questionnaire study were performed before and after renovation. The results were compared to those from non-damaged reference school. The effect of a thorough renovation in the damaged school was seen as decreased concentrations of airborne fungi and decreased diversity of mycoflora. There was a significant decrease in the prevalence of the respiratory symptoms among schoolchildren after the renovation. The results show that the symptoms are associated with the moisture damage and that the increased symptom levels can be normalized with proper repair measures.

3C1p2 Moulds in the dust collector and health - children aged 7-10
T Sigsgaard, K Plesner, A. Høst, HW Meyer and H Würtz

This study tested if respiratory symptoms in 7-9 year old school children were associated with mould growth in schools. Eight "wet" and seven "dry" schools including 330 children were studied by means of an interview, spirometry, skin prick test and a "free running test". At each classroom a dust collector was placed for collection of dust for 140 days at app. 1.5 meters height. When dividing the classrooms into quartiles of dust concentration a positive trend was found with increasing quartiles of dust for "sensitisation to moulds" and "nasal symptoms" (Kendal's Tau b [KT]; $p < .05$). For mould exposure we found a positive association between increasing number of moulds and "headache at least once a week" (KT; $p < .05$). These results indicate that the dust collector method for collection of dust is probably a reasonable tool for exposure measurements that are related to health outcomes

3C1p3 Evaluating effects of moisture damage repairs on students' health using questionnaires
U Haverinen, J Pekkanen, A Nevalainen and T Husman

Symptom questionnaire responses were collected from upper secondary and high school students (n=245) before comprehensive repairs of moisture damage in the school unit. The questionnaire study was repeated one year (n=227) and three years (n=256) after the repairs. The data was analyzed both cross-sectionally including all respondents, and longitudinally including paired observations for those individuals who had responded both before and after the repairs. Compared to the situation before the repairs, the situation after the repairs was significantly improved in most of the 20 symptoms studied among the whole population. However, the improvement was not so clear in the paired analysis and regression analysis among the students who had responded to all three questionnaires. The results indicate that the repairs succeeded in terms of that new cases of symptomatic students were no longer expected. However, the situation of the group of exposed individuals may need to be considered separately.

3C1p4 Dampness in buildings and health. Dampness at home as a risk factor for symptoms among 10,851 Swedish children (DBH-step 1)
CG Bornehag, J Sundell, L Hägerhed, S Janson

With the overall aim of identifying health-relevant exposures in "damp" buildings an interdisciplinary epidemiological study started in Sweden in 1999, namely "Dampness in Buildings and Health" (DBH). The first step of the study (carried out during spring 2000) included a cross-sectional questionnaire study on 14,077 children (1-6 years) focusing on their health and their home environmental conditions (investigated by questionnaires). There were strong and consistent analysis showed significant associations between different "dampness"-indicators problems and symptoms among children. The combination of floor moisture problems and PVC as flooring material significantly increased the risk for symptoms.

3C2o1 Relationship of SBS-symptoms and ventilation system type in office buildings
O Seppänen and WJ Fisk

This paper provides a summary of current knowledge about the associations of ventilation types in office buildings with sick building syndrome symptoms. Most studies completed to date indicate that relative to natural ventilation, air conditioning, with or without humidification, was consistently associated with a statistically significant increase in the prevalence of one or more SBS symptoms, by approximately 30% to 200%. In two of three analyses from a single study, symptom prevalences were also significantly higher in air-conditioned buildings than in buildings with simple mechanical ventilation and no humidification. The available data also suggest, with less consistency, an increase in risk of symptoms with simple mechanical ventilation relative to natural ventilation. The statistically significant associations of mechanical ventilation and air conditioning with SBS symptoms are much more frequent than expected from chance and also not likely to be a consequence of confounding by several potential personal, job, or building-related confounders.

3C2o2 Indoor carbon dioxide concentrations and sick building syndrome symptoms in the BASE study revisited: analyses of the 100 building dataset
CA Erdmann, KC Steiner, and MG Apte

In previously published analyses of the 41-building 1994-1996 USEPA Building Assessment Survey and Evaluation (BASE) dataset, higher workday time-averaged indoor minus outdoor CO_2 concentrations (d CO_2), were associated with increased prevalence of certain mucous membrane and lower respiratory sick building syndrome (SBS) symptoms, even at peak d CO_2 concentrations below 1,000 ppm. For this paper, similar analyses were performed using the larger 100-building 1994-1998 BASE dataset. Multivariate logistic regression analyses quantified the associations between d CO_2 and the SBS symptoms, adjusting for age, sex, smoking status, presence of carpet in workspace, thermal exposure, and a marker for entrained automobile exhaust. Adjusted d CO_2 prevalence odds ratios for sore throat and wheeze were 1.17 and 1.20 per 100-ppm increase in d CO_2 ($p < 0.05$), respectively. These new analyses generally support our prior findings. Regional differences in climate and building design and operation may account for some of the differences observed in analyses of the two datasets.

3C2o3 Call-centre occupant response to new and used filters at two outdoor air supply rates
P Wargocki, DP Wyon, JB Nielsen and PO Fanger

A 2x2 replicated field intervention experiment was conducted in a call-centre providing a public telephone directory service: Outdoor air supply rate was 8% or 80% of the total airflow of 430 L/s providing 3.5 h^{-1}; and the supply air filters were either new or used (i.e., used in place for 6 months). Each of these 4 conditions was maintained for a full working week at a time. Room temperature and humidity averaged 24 C and 27% RH. The 26 operators were blind to conditions and assessed perceived air quality (PAQ), the intensity of Sick Building Syndrome (SBS) symptoms and self-estimated performance. Increasing the outdoor air supply rate with a new filter in place significantly alleviated many symptoms, as did changing from used to new supply air filters at the low outdoor air supply rate, but filter condition made little difference at the high outdoor air supply rate.

3C2o4 Sick building syndrome (SBS) in relation to energy conservation, and reconstruction in older multi-family houses in Stockholm, Sweden
K Engvall, C Norrby and D Norbäck

The aim was to study relationships between symptoms compatible with the sick building syndrome (SBS) and type of heating system and energy saving reconstruction's in older dwellings. In Stockholm, 231 multi-family buildings built before 1961, with 4,815 dwellings were randomly selected. The response rate of the questionnaire was 77%. Independent information on building characteristics and energy saving measures during the latest 10 years was gathered from the building owners. Multiple logistic regression was applied, calculating adjusted odds ratios (OR) adjusting for age, gender, hay fever, smoking, population density, type of ventilation, type of heating system, and ownership of the building. Electric radiators, heat pumps, and some

specific energy saving measures were associated with an increase of SBS-symptoms. The study did not support the view that energy saving in general is a risk factor for SBS, but major reconstruction of older dwellings may be associated with an increase of SBS.

3C2o5 Do building-related complaints reflect expectations?
W Bischof, S Brasche, B Kruppa and M Bullinger

Expectations confound the interaction between environment and human perception. Assuming expectations have an important impact on well-being and behaviour, identifying predictors of expectations might be a needful task concerning prevention. Thus, data of 4,596 office workers investigated in phase I of the ProKlimA project have been analysed by multiple logistic regression to find associations between expectations and potential impact variables. Women, subjects working in buildings with air conditioning and employees identified as SBS cases are characterised by consistently higher expectations towards indoor humidity, temperature, air velocity and ventilation quality. Adjusted odds ratios (OR) for 'SBS cases' range between 1.61 and 2.52. The risk of having higher expectations ranges between 1.45 and 1.93 for office workers in spaces with air conditioning compared to naturally ventilated rooms. With OR from 1.45 to 1.78, women report higher expectations than men. Building design and facility management should consider related expectations.

3C2p1 Sick building syndrome symptoms and performance in a field laboratory study at different levels of temperature and humidity
L Fang, DP Wyon, G Clausen and PO Fanger

Thirty female subjects were exposed for 280 minutes to four conditions in balanced order of presentation: to 20 C/40%, 23 C/50%, 26 C/60% RH at10 L/s/p outside air, and to 20 C/40% RH at 3.5 L/s/p. They performed simulated office work throughout each exposure and repeatedly marked a set of visual-analogue scales to indicate their perception of environmental conditions and of the intensity of SBS symptoms at the time. They were repeatedly reminded to adjust their clothing so as to remain in thermal comfort, and succeeded in doing so. Although perceived air quality improved at lower indoor air temperature and humidity and at the higher ventilation rate, this could not be shown to be associated with any effects on task performance. However, subjects reported significantly more intense SBS symptoms associated with decreased productivity, including fatigue, headache and difficulty in thinking clearly, when they were exposed to raised levels of temperature and humidity.

3C2p2 An intervention study of the relationships between indoor air-related health problems, productivity and cleanliness in an office setting
SK Nilsen, P Blom, J Rydock, J Nersveen and KI Fostervold

An intervention study was conducted in an office building to examine the effect of improved cleaning quality on perceived indoor air quality, health and productivity. Effects of a controlled increase in cleaning quality were studied by questionnaires, registration of sickness absence, psychological tests, measurements of air quality, and visual and instrumental measurements of cleaning quality as described in the internordic standard INSTA 800. The intervention (blind) included introduction of a quality based cleaning programme including all interior surfaces on 2 floors. The intervention led to reduced dust load on furniture and fixtures. INSTA 800 proved to be a good tool to assess cleaning quality. No correlations were found between the two methods used for measuring cleaning quality. Instrumental measurements should be chosen if low dust loads on surfaces are desired. The results indicated that improved cleaning quality may reduce SBS symptoms, improve productivity and reduce short time sickness absence.

3C2p3 What are "office workers" in Estonia and what do they complain?
A Soon and E Indermitte

Several alternative approaches were used in order to get a sample of offices and office workers that are not influenced by investigator's interests. Data were gathered by self-administered questionnaire with concurrent survey on technical characteristics of buildings that were obtained from building managers and data from visual inspection of buildings. Also, package of environmental measurements was done. Buildings surveyed were at different age and with various maintenance facilities. "Office workers" as presumed doing certain work tasks in rooms equipped with "classical" office tools were rather various group of workers performing a list of different tasks and spending in office rooms 3 to 13 hours a day. Most frequent complaints were those related to poor thermal environment. Few associations between complaints and measured indoor environment can be demonstrated. Results of current study suggest that thermal environment is an important factor for office workers' comfort.

3C2p4 Indoor climate complaints among employees at geriatric hospitals
HT Smedbold, D Norbäck, and B Hilt

The aim of this investigation was to assess the prevalence of symptoms associated with the Sick-Building Syndrome, and to elucidate a possible relation between such symptoms and work characteristics. The investigation encountered all employees (n=1,449) at 14 public geriatric hospitals in the municipality of Trondheim, Norway. The prevalence of general complaints was 24%, of mucous membrane irritation it was 25%, and of skin complaints it was 15%. The proportion of subjects with one or more of such symptoms was 44%. Our results indicate that shift work, working with nursing, dissatisfaction with cleaning, and workplace vicinity to heavy traffickated roads might increase the risk of having symptoms. When controlling for type of work, females did not have a higher prevalence of symptoms than males. We conclude therefore that workforce characteristics, type of work, hygienic standards, and vicinity of the hospitals might play a role as predictors for symptoms related to SBS.

3C2p5 A case of sick building syndrome caused by incorrect ventilation design of the tight building
J Wang, J-l Li and C-y Zhao

In a newly opened office high-rise in downtown Beijing, most occupants were reportedly feeling uncomfortable everyday. It was a tight building of which the central ventilation system provided mechanic air supply but natural exhaust. A survey was conducted, which included a questionnaire to occupants and detection of indoor air pollutants. Results of the questionnaire indicated that 98.7 % of occupants had sick building syndrome, and that their symptoms were more severe in the afternoon than in the morning. Results of pollutant detection showed that the concentration of carbon dioxide in some rooms was as high as 700 to 1000 ppm. In most rooms, carbon dioxide and radon levels were higher in the afternoon than in the morning. These data suggest that insufficient ventilation, likely as a result of the lack of exhaust duct system, causes accumulation of indoor pollutants that are associated with sick building syndrome.

3C2p6 Sick building syndrome (SBS) among school employees in the county of Uppsala, Sweden
B Sahlberg, G Smedje and D Norbäck

Sick building syndrome (SBS) in school employees was investigated in 38 randomly selected schools in mid-Sweden. A questionnaire was mailed in 1993, with follow-up questionnaires in 1995 and 1997. Exposure was measured in 98 classrooms in 1993, and 101 in 1995. In 1993, 1410 employees participated (85%). The prevalence of weekly ocular, dermal, upper-respiratory, and general symptoms in 1993 was 8%, 13%, 26%, 28%, respectively. General symptoms were more prevalent at higher temperature. Eye symptoms and tiredness were more common at lower lightning effect. Tiredness was more common at lower illuminance. Headache was more common at less daylight. Eye symptoms were related to total air concentration of bacteria. A relationship between observed building dampness and SBS-symptoms was found, but only in schools with an air exchange rate below the median value (<1.8 ach). The study indicates that bacteria, building dampness, temperature and illumination in schools, are associated with SBS.

3C3o1 Experiments probing the influence of air exchange rates on particles generated by indoor chemistry
CJ Weschler and HC Shields

Investigators have recently reported increases in the concentrations of airborne particles as a consequence of ozone/terpene reactions in indoor settings. The present study was designed to probe the influence of ventilation on these increases in particle concentration as well as on the resulting particle size distributions when both reactants originate indoors. The experiments were performed in two comparable offices. Each contained limonene sources, but only one contained an ozone generator. There was no statistically significant difference in particle concentrations between the offices when the ozone generator was on and the air exchange rate was high (> 10 h^{-1}). However, as the air exchange rate decreased, particle number concentrations in the room containing ozone increased. Furthermore, particulate mass was shifted from smaller sizes into the 0.3-0.5 µm size range. Such changes are of interest since size partially determines where particles deposit in the human respiratory tract. These results illustrate still another way in which ventilation affects health and well being.

3C3o2 The significance of secondary organic aerosol formation and growth in buildings: experimental and computational evidence
G Sarwar, R Corsi, D Allen, and C Weschler

Experiments were conducted in an 11 m^3 environmental chamber to investigate secondary particles resulting from homogeneous reactions between ozone and a-pinene. Experimental results indicate that rapid fine particle growth occurs due to homogeneous reactions between ozone and a-pinene, and subsequent gas-to-particle partitioning of the products. A new indoor air quality model was used to predict dynamic particle mass concentrations based on detailed homogeneous chemical mechanisms and partitioning of semi-volatile products to particles. Chamber particle mass concentrations were estimated from measured particle size distributions and were in good agreement with results predicted from the model. Both experimental and

model results indicate that secondary particle number and mass concentrations increase substantially with lower air exchange rates. This is an interesting result given a continuing trend toward more energy efficient buildings. Secondary particle mass concentrations also increase with lower indoor temperatures.

3C3o3 Effect of gaseous ammonia on nicotine sorption
AM Webb, BC Singer, and WW Nazaroff

Nicotine is a major constituent of environmental tobacco smoke. Sorptive interactions of nicotine with indoor surfaces can substantially alter indoor concentrations. The phenomenon is poorly understood, including whether sorption is fully reversible or partially irreversible. We hypothesize that acid-base chemistry on indoor surfaces might contribute to the apparent irreversibility of nicotine sorption under some circumstances. Specifically, we suggest that nicotine may become protonated on surfaces, markedly reducing its vapor pressure. If so, subsequent exposure of the surface to gaseous ammonia, a common base, could raise the surface pH, causing deprotonation and desorption of nicotine from surfaces. A series of experiments was conducted to explore the effect of ammonia on nicotine sorption to and reemission from surfaces. Our results indicate that, under some conditions, exposure to gaseous ammonia can substantially increase the rate of desorption of previously sorbed nicotine from common indoor surface materials.

3C3o4 An evaluation of how NO_2, NO, O_3 and relative humidity interacts in the oxidation of terpenes
L Pommer, J Fick, B Andersson and C Nilsson

Δ3-carene and a-pinene were injected into a 6-12 meter long simulated ventilation tube (teflon tube i.d. 25 mm) together with the two oxidants ozone and nitrogen dioxide. The levels of the oxidants, reaction time and relative air humidity were varied according to an experimental de-sign. The amount of terpene reacted in the tube varied between 2.7-12.9% and 0.2-13.3% for Δ3-carene and α-pinene, respectively. Reaction time and ozone level were the parameters that influenced the amount of terpene reacted the most. The influence of relative air humidity was negative. Several interaction terms were identified (e.g., NO_2-RH, NO-reaction time, O_3-reaction time), which demonstrate the complexity of the gas-phase chemistry. Theoretical models, simulating the chemistry in the teflon tube, were calculated and compared to experimental data. These models underestimated the amount of terpene reacted with 11.8% for both of the terpenes.

3C3o5 Rapid measurements of indoor mass-transfer coefficients
GC Morrison, M Ongwandee, H Chang, and J Portman

Some air pollutants react rapidly at surfaces (e.g. ozone on carpet), causing indoor concentrations to be lower than outdoors. To characterize the mass-transport to surfaces, we are developing a new method of rapidly and directly measuring compound fluxes from indoor surfaces. From this measurement, we can evaluate the mass-transport limited deposition velocity, vt. We coat a small microbalance sensor with a pure hydrocarbon. The flux (or evaporation rate) of the hydrocarbon into a room is quantified by the rate of mass loss on the microbalance. The mass-transport limited deposition velocity is then calculated by combining these measurements with the estimated vapor pressure of the hydrocarbon. In an office, the sensor was able to detect changes in conditions such as occupancy, activities and ventilation. At present, the results are in “order of magnitude” agreement with previously reported indoor mass-transfer coefficients.

3C3p1 CFD analysis of chemically reactive pollutants in 2D test room
K Ito, S Kato, Q Zhu and S Murakami

Recently, theoretical analyses have begun to evaluate some free radicals and other products that are generated by chemical reactions. Especially, the products of ozone / terpene reactions cause greater airway irritation in mice than would be predicted based on the known response of mice to ozone or terpenes. This paper presents an analysis of chemically reactive pollutants in indoor air. We have used CFD technique to simulate bimolecular reactions occurring indoors. In this research, the Second Order Rate Constant model which is a simple and fundamental model reproducing bimolecular Reaction is adopted. In order to demonstrate the performance of the Rate Constant models, CFD simulations are carried out for a 2D test room. Three sets of chemical compounds, ozone / terpene, are used in this study. The quantity of production substance Cprod through the chemical reaction is proportional to the concentration of source substances (Ozone and terpene).

3C3p2 Experimental design as a tool to study gas-phase reactions in ventilation ducts
J Fick, L Pommer, B Andersson and C Nilsson

The gas-phase ozonolysis of monoterpenes, have been investigated at ppb levels in a model of a ventilation duct and the impact of the ozone level, relative air humidity, and time have been studied using experimental design. The designs were able to describe almost all the variation in the experimental data and were also successful in predicting omitted values. The results

clearly shows that the experimental designs was a useful tool to study reactions in a setting with unknown parameters, e.g. a ventilation duct.

3C3p3 Measurements of emission and sink effects for wall covering materials by using a small chamber ADPAC
R Funaki, H Tanaka, and S Tanabe

In this study, aldehydes and VOCs emission rates and sink effects for wall covering materials were investigated by using a small-scale chamber ADPAC (Advanced Pollution and Air quality Chamber). First, the measurements of emission rates were carried out for nine types of wall covering materials. Measurements were repeated after 1, 7 and 14 days. Emission rate of formaldehyde form a PVC wall covering was 42 $\mu g/m^2h$ after one day. Emission rates of wall coverings were equally decreased after 7 days, but they were increased again after 14 days. It may be supposed that some chemical substances were adsorbed on the wall coverings. Therefore, sink effects of wall covering materials were investigated for formaldehyde and toluene. Polluted air with given concentration was used. Span gas was used for experiments. By comparing the inlet and outlet concentration of the chamber, effect of adsorption on wall covering was investigated for formaldehyde and toluene.

3C3p4 VOC sorption of activity related contaminants - influence of boundary layer diffusion
P Hansson and H Stymne

The most pronounced consequences of the sink-effect occur when room air concentrations change quickly. This happens for example when chemicals are released during activities indoors. Simulations with a simple mathematical model show that air concentrations in a hypothetical room finished with a porous sorbing material are influenced by boundary layer diffusion variations. The effect is most pronounced when the sorption capacity of the material significantly increases the hold-up time for the contaminant. Moreover, the ratio between the amount of VOC sorbed onto the surface of the material and the amount sorbed in the interior of the material is an important aspect for the sink-effect. Simulations show that materials with high surface adsorption capacity influence room air concentrations during a short release of VOC, to a higher extent than materials with low surface adsorption capacity. This indicates that models for the sink-effect should include surface sorption as well as interior sorption.

3C3p5 Lumped parameter model for predicting the sink effect of volatile organic compounds in indoor environment
D Sambinello and S Piva

A lumped parameter model describes the concentration of Volatile Organic Compounds (VOCs) in indoor environments taking into account the sink effect (adsorption and desorption of pollutants due to the surfaces). The concentration of a pollutant is calculated by solving a dimensionless mass balance equation in a room where there are VOC sources, a ventilation system and adsorbing/desorbing surfaces. Adsorption and desorption are supposed to act independently and the sink effect is supposed to be a diffusion process, typically described by exponential functions. In order to validate the model, concentration data taken from the literature are used. These data refer to experiments in a text chamber where different adsorbing materials are exposed to constant emissions of a pollutant.

3C3p6 Characterization of the sink effect of VOCs on building materials, with specific emphasis on painted surfaces
J Popa and F Haghighat

The objective of this research was to determine experimentally the adsorption and desorption parameters of a wide range of volatile organic compounds (VOCs) from building materials. Paint and painted gypsum board were chosen as testing materials due to their presence as large surface areas in the indoor environment. The pollutants used for adsorption testing were toluene and a mixture of six organic compounds. The specific objectives were to show the impact of pollutant concentration, thickness of paint and the type of material on sorption.

3C3p7 Investigating the influence of the wall materials and thickness on the reversible sink effect
A Damian, P Blondeau and AL Tiffonnet

The paper deals with a numerical study of the interactions between gaseous air pollutants and building materials. The model used is based on the assembly of elemental mass transfer models including boundary layer diffusion, diffusion in porous materials and sorption at the gas and solid interfaces. Adequate diffusion and sorption data was input in the model to dynamically calculate the room air acetone concentrations, the acetone concentrations in the pores of the materials, and the contaminant flow-rate at the room air and wall interface, for various configurations of contaminant sources and building walls. The temporal profiles observed clearly show the “buffer” effect of the wall and the strong analogy with conductive thermal transfer in buildings. A parametric study is then carried out to investigate the influence of the material thickness on the resulting room air concentrations. It shows that increasing the material thickness over a critical value doesn’t significantly change the indoor air concentration profile.

3C4o1 Barriers to reduce emission rates from diffusion-controlled materials
D Kumar and JC Little

A model is developed to predict the rate of mass transfer between a double layered building material and indoor air. A uniform initial material-phase concentration in both layers is considered. It is assumed that the two layers are flat homogeneous slabs, that internal mass transfer is governed by diffusion, and that the indoor air is well mixed. The six primary parameters that define model behavior are the diffusion coefficients of the volatile compound in the two material-phases, the partition coefficients for the material/air systems and the uniform initial material-phase concentrations. An analytical solution to the double-layer model is presented and used to demonstrate the potential for a thin surface barrier layer to reduce contaminant emission rates from diffusion-controlled sources. Decreasing the diffusion coefficient in the surface layer is more effective at reducing emissions than increasing the material/air partition coefficient.

3C4o2 Implementation of VOC source reduction practices in a manufactured house and in school classrooms
AT Hodgson, MG Apte, DG Shendell, D Beal and JER McIlvaine

Detailed studies of a new manufactured house and four new industrialized relocatable school classrooms were conducted to determine the emission sources of formaldehyde and other VOCs and to identify and implement source reduction practices. Procedures were developed to generate VOC emission factors that allowed reasonably accurate predictions of indoor air VOC concentrations. Based on the identified sources of formaldehyde and other aldehydes, practices were developed to reduce the concentrations of these compounds in new house construction. An alternate ceiling panel reduced formaldehyde concentrations in the classrooms. Overall, the classrooms had relatively low VOC concentrations.

3C4o3 Controlling odorous emissions from office furniture
MS Black , DR Cortes, and BK Ligman

Volatile organic compounds (VOCs) and odors associated with interior construction materials and furnishings can result in human complaints including mucous membrane irritation and headaches. These nonspecific complaints can result in Building Related Symptoms (BRS) within an office building, leading to occupant discomfort and loss of productivity. Independent studies of two large multi-story office buildings indicated the presence of objectionable odors resulting from the installation of new office furniture within the past six months. Sources of these odors were identified as trimethylamine (TMA) and butyric acid, respectively, emitting from the acoustical panels. Sources of these chemicals were identified as fiber glass insulation for TMA and an internal structural septum made of cardboard for the butyric acid. In an effort to control these emissions and resulting odors from finished furniture, material specifications were established to allow no greater product emission levels than 10 $\mu g/m^2$ hr for TMA and 2.5 $\mu g/m^2$ hr for butyric acid.

3C4o4 Experiences from the emission classification of building materials in Finland
E Kukkonen, K Saarela and P Neuvonen

A renewed version of the Finnish guidelines "Classification of Indoor Climate, Construction and Building Materials" was released 2001. The classification consists of three parts; requirements for the IAQ, guidelines for construction works and classification of building materials. This third part is described here. More than 500 different building materials have already got the best M 1 labelling and it has had a positive effect on the emissions from the building materials in Finland. The classification will of course only guarantee lower levels of such chemicals, which are measured in the tests, but all stinky emissions are detected by the complementary sensory tests. The chemical testing methods are mainly basing on international standards. The sensory tests are carried out by untrained sensory panels using the acceptability scale. The reliability of the classification tests is also shortly presented.

3C4p1 Results from house appliance safety and depressurization tests conducted on single family houses undergoing sound insulation
DL Bohac

Extensive house appliance safety and depressurization tests have been conducted on houses before and after they have received acoustic treatments as part of an airport sound insulation program. Results show that 25% of the ovens do not initially meet the program carbon monoxide standard of 150 ppm. Only 3% of the natural draft water heaters and 8% of the furnaces exceed the program standard of 100 ppm. For furnaces the failure rate doubles when the test is performed under down-draft conditions. Combustion spillage tests have shown that about 20% of natural draft water heaters and 10% of furnaces fail a worst-case spillage test. About half of the failures appear to be the result of excessive depressurization and the other half to deficient combustion vent systems. Twelve percent of the houses have a measured depressurization greater than the guideline for the combustion appliances in the house.

3C4p2 It's time to sound the alarm regarding high capacity exhaust devices
JC Haysom, PH Huelman and D Fugler

There are more high capacity exhaust appliances coming on the market. These appliances, unless installed with provision for fan-supplied make-up air, can severely depressurize modern houses. This can lead to problems with venting of combustion products, soil gas infiltration and infiltration of carbon monoxide attached garages. Where these appliances are installed in a new building, the industry may find it difficult to comply with code requirements for fan-supplied make-up air if the appliances have not been designed with provision for inter-connection. Of more serious concern is the situation where the owner of an existing house simply purchases and installs one of these appliances and is unaware of the potential problems such appliances can create. The appliance industry does not seem very aware of the problems these devices can create in even a moderately tight house. This paper reviews the technical issues involved and discusses possible means of addressing them.

3C4p3 House depressurization and backdrafting: follow-up survey and standardization
NL Nagda and MD Koontz

Furnaces and water heaters in nine houses were monitored continuously for backdrafting and spillage over periods as long as seven months. This intensive monitoring followed initial surveys in 42 houses (from which the nine were selected) in the Omaha, NE, and Washington, DC, areas. The initial surveys indicated that the correspondence between short-term tests (less than 2 hours) and long-term monitoring (one week or longer) was poor. Parameters for continuous monitoring in the follow-up study included appliance vent pressure differentials, carbon monoxide, carbon dioxide, and appliance on/off status. Sequential 15-second averages were recorded on a data logger in each residence. Results indicated that backdrafting/spillage events were relatively rare and short in duration. Nearly all such cases occurred during periods of warmer weather and were confined to water-heater spillage. The follow-up results add further confidence to the conclusion from initial surveys (based on limited continuous monitoring) that these houses are not spillage-prone.

3C4p4 Status of the indoor climate labeling scheme in Denmark
T Witterseh

The impartial Indoor Climate Labelling, ICL, originally introduced in Denmark to reduce emissions from building materials and products used in the indoor environment, is still developing and consolidating its position. The ICL benefits from an expansion of the product areas covered and a still increasing number of labelled products. The product area of furniture is now included, making a total of ten different product areas. Approximately 100 different groups of products are included, which individually covers a number of specific products. An increasing number of manufacturers apply for the Indoor Climate Label, due to a growing concern about the indoor environment among architects, consulting and planning engineers and private consumers. This shows that the concept is now working as originally intended. A goal for the ICL is to develop a method for labelling of the overall indoor environment in buildings. Work towards this goal is, however, only at its initial level.

3C4p5 A pre-study of HCHO and VOCs emissions from building materials for setting emission criteria
W-J Jo, H-S Kim, J-Y Cheon

Restriction of use of high emission materials is one of good ways for improving indoor air quality. KNHC has been preparing emission criteria of building materials to make indoor environment better. For the emission standard, emission tests from building materials were done with 27 general building materials(PVC floorings, wall coverings, paints, plaster boards, adhesives) and 7 environmentally friendly materials. HCHO and VOCs Samplings using FLEC were done with DNPH-cartridges and stainless tenax tubes. HCHO analysis was done by HPLC and VOCs was done by thermal desorption unit and GC-FID. The plaster board among solid apartment materials is the main HCHO emission source. Glues and adhesives had quite low HCHO EFs. While HCHO emissions from two environmentally friendly products were 6-10 times higher than general ones. In the case of VOCs, PVC floorings and wall coverings showed high emission rate.

3C4p6 What is behind TVOC in M1 -classified construction and finishing materials - VTT's experience
K Saarela, K Villberg and T Tirkkonen

The Finnish Classification of Indoor Climate, Construction and Finishing Materials was first published in 1995 revised in year 2000 (Classification of Indoor Climate 2000). One part of the requirements consists of Emission Classification of building materials. The aim of establishing the classification is to enhance the development and use of low-emitting building materials. TVOC was chosen as one criterion representing the whole group of VOC-emissions as the emission testing procedure should be simple, well defined for different building material categories, cost effective and fulfill the requirement of pre-defined, short testing time and cost. Up today 500 building materials have been granted M1 label. This study overviews how well the TVOC-concept covers the possible health- and comfort effects of the single VOC-emissions.

3C4p7 The apportionment of volatile organic compounds and the effect of remedial action at two indoor air problem sites
H Järnström and K Saarela

Indoor air and material emission measurements were performed in five apartments, where building related symptoms appeared among the inhabitants. Chemical analyses of VOCs (Volatile Organic Compounds), formaldehyde and ammonia were performed to determine the IAQ. The concentration of the ester compound TXIB (2,2,4-trimethyl-1,3-pentadiol-isobutyrate) in indoor air was higher in these apartments compared to the average value detected in "normal" indoor air cases according to the VTT indoor air database. The air exchange rates at all measurement sites exceeded the required values. The field and laboratory emission cell (FLEC)- technique was used to confirm the floor surface as the TXIB-emission source. As a renovation procedure the floor covering was changed to low emitting materials. Measurement data was collected during the floor renovation to define the level of VOC and to clarify the transfer of TXIB in the floor structure. The effect of the different renovation methods and materials used on indoor air quality is discussed.

3C4p8 Potential for reducing styrene exposures from copied paper through use of low-emitting toners
DB Henschel, RC Fortmann, NF Roache, and X Liu

Tests were conducted using 53 L chambers to determine styrene emission rates from freshly copied paper produced on a single photocopier, using two toners manufactured for the copier but having different styrene contents. Copied-paper styrene emissions with both toners could be represented by a power law or a 3rd-order decay model (R^2 = 0.94 to 0.99). The two toners resulted in copied paper having significantly different styrene emissions ($p<0.01$). Unit mass emissions of styrene ($\mu g/m^2$) over 1,000 h are predicted to be 9 times greater from paper with the higher-emitting toner. But even copied paper produced using a still-higher-emitting toner reported in the literature, is predicted to produce peak indoor styrene concentrations in a typical office only 0.3% of the estimated minimum concentration of concern to susceptible sub-populations. Thus, for the toners studied here, indoor styrene exposures from copied paper appear too limited to provide incentive for switching to the lower-emitting toner.

3C4z1 Room chamber assessment of pollutant emission properties of low-emission un-flued gas heaters
SK Brown, M Cheng and KJ Mahoney

Pollutant emissions from unflued gas heaters were assessed in CSIRO's Room Dynamic Environmental Chamber. This paper describes the assessment procedure and findings for major commercial "low-emission" heaters. The chamber was operated at controlled conditions of temperature, humidity, ventilation and air mixing, representative of those encountered in indoor environments. A fixed rate of heat removal from the chamber air ensured that the heaters operated at constant heating rates, typically ~6 MJ/h, simulating operation after warm-up in South-East Australian insulated dwellings. Pollutants assessed were nitrogen dioxide, carbon monoxide, formaldehyde, VOCs and respirable particulates. One heater was lower emitting for nitrogen dioxide, but emitted greater amounts of carbon monoxide and formaldehyde (the latter becoming significant to indoor air quality). When operated with low line pressure or slight misalignment of the gas burner, this heater became a hazardous source of these pollutants. Emissions from one heater changed little after continuous operation for three months.

3C5o1 Finnish classification of indoor climate 2000: revised target values
J Säteri

A voluntary classification of indoor air quality and climate in new construction has been in use in Finland since 1995. The voluntary approach has been proven to improve the IAQ in new buildings and to reduce emissions from building materials. An updated classification document was taken into use in 2001. The structure of the Finnish classification system is designed to help all parties in the con-struction process in the assurance of good IAQ. Included are target value specifications, de-sign guidelines, quality assurance procedures and requirements for building products. The main features in the updated document are revised target and design values; modified instruc-tions on how to achieve cleanliness at building site; a requirement for a moisture control plan; and new criteria for the cleanliness of ventilation systems and components. This paper de-scribes the structure of the updated classification document; and the revised target values for thermal comfort, IAQ and HVAC noise.

3C5o2 Development of guidelines for healthy home construction in the United States and challenges faced in the process
R Shaughnessy, T Brennan, J Lstiburek, and H Levin

In the past decade the general population in the USA has developed a heightened awareness on indoor air quality (IAQ) issues. As a result there is a significant demand by the public for housing provisions that offer not only a comfortable living environment, but also one that is more conducive to improved health afforded by the quality of the indoor air environment. The

American Lung Association (ALA) in the United States is responding to the needs of homeowners by undertaking the development of guidelines for builders, designers, and other members of the construction community, with the end-goal to provide guidance on construction practices for improved IAQ in residences. The guidelines are intended to address construction practices targeting homes for the general population and include a second tier of criteria for people with severe allergies or asthma. This paper details some of the issues and difficulties encountered in the formulation of the guidelines.

3C5o3 Indoor air quality legislation in South Africa
J Gansan, N Gqaleni and JE Ehiri

This paper assesses legislation in South Africa with respect to indoor air quality. It indicates that, although there is no specific law and comprehensive policy that deals, specifically with indoor air quality, there are several acts of parliament that safeguard health and address specific health matters, in which indoor air quality does not feature prominently. The paper will describe the role of the Constitution, Health Act, Atmospheric Pollution Prevention Act, Housing Act, Occupational Health and Safety Act as well as the National Building Regulations in making provisions for better indoor air quality.

3C5o4 Indoor air quality and energy efficiency in the design of building services systems for school classrooms
KL Tam

Efficient energy utilization and indoor air quality (IAQ) inside office premises and other public places have become issues of increasing concern in the Hong Kong Special Administrative Region (HKSAR). The Government of HKSAR has launched a territory wide consultation in 1999 on the proposed Indoor Air Quality Management Programme for offices and public places. This paper briefly introduces the proposed Indoor Air Quality Management Programme and its proposed target objectives. It also outlines the design approaches taken to tackle the issues both from maintaining good air quality and energy efficient usage in school classrooms. There are approximately 1,200 public sector primary and secondary schools in Hong Kong, and each year around 20 new schools will be added to the list. Achievements including indoor air quality, lighting, thermal comfort and energy efficiency in classrooms will be presented.

3C5o5 Sustainable building practices in California state buildings
L Alevantis, K Frevert, R Muller, H Levin, and A Sowell

The State of California, until recently, did not have a centralized, coordinated effort to define and integrate sustainable building practices in the State's capital outlay design and construction process. Efforts to define and implement these practices started in 1999, when the Legislature required the incorporation of sustainable building measures in a large state office building complex. These successful efforts led to the formation of a multi-agency task force to address sustainable issues for all state buildings. In response to an executive order issued by Governor Gray Davis, the task force prepared a report recommending strategies and action items necessary to incorporate sustainable practices in future state projects. The task force is also working on issues related to sustainable procurement practices. This paper describes how these efforts were originally envisioned, how they were developed and implemented, what barriers were encountered, and the lessons learned during this process.

3C5p1 Feelgoodbuilding: IEQ dissemination reinvented
AC Boerstra and AK Raue

In the 80's Sick Building Syndrome was the Buzzword, in the 90's it became more fashionable to use the more political correct 'Healthy Building'. Maybe it is time to start communicating more positively about comfort and health related to buildings and building service systems. High time we find a 'terminology' that actually is understood by those making the decisions in the building design process. The time has come to think and talk in terms of … not sick buildings…. not healthy buildings, but FEELGOODBUILDINGS. "First we shape our buildings, and then they shape us" (Winston Churchill).

3C5p2 Increasing the value of a building by addressing well being - the principal tools: thermal and olfactory comfort
D von Kempski

Until recently, cost has been the primary consideration in the management of real estate. Nowadays investors and users require that buildings are built and operated to a standard known as 'performance based building' (PeBBU). These buildings go well beyond traditional methods of addressing the well being of building occupants, resulting in enhanced productivity, reduced absenteeism and reduced health risks. Physiological and neurophysiological research shows that air quality, encompassing both olfactory and thermal comfort, plays an important role. The elimination of pollutants is far from being sufficient and does not significantly reduce the dissatisfaction rate of building occupants. This paper will demonstrate how the economic value added was increased in a Berlin office building as a result of improvements in the indoor air environment. These improvements are based on physiological and neurophysiological studies on the perception of air that have focused on olfactory comfort and its relation to thermal comfort.

3C5p3 What Chinese prefer for indoor air
N Zhu, J J Liu and Z Tian

To understand what people really like and want for their requirement of indoor air is important to design and control Indoor Climate. Through questionnaire, which 1204 persons involved in and test work, 198 persons involved in, and statistic analysis, this paper find that in China, people consider IAQ and thermal comfort are the two most important factors for their indoor air requirement. Compared to the results of Prof. Fanger's and others, the neutral temperature of the tested people is 24.7 ºC, higher than the expected temperature. And there is slight difference between neutral temperatures of Chinese male and female. The 80% satisfactory of thermal range of tested person is 21.1-27.5 ºC, about 1ºC lower than Fanger and Nevis's results. The up limitation of this test is 1.5ºC higher, compared with the thermal comfort range given in ASHRAE Standard 55-1992.

3C5p4 A pilot study of the predestined planning conditions and the indoor environment
U Hammargren

A pilot study has been conducted to find out if and how the building process influences the indoor air or the perception of the indoor air. As the first part of this investigation, a media study of what are considered to be healthy and unhealthy buildings was performed. From this media study two buildings were chosen and their building processes were examined more closely. This was carried out as a qualitative interview study with different people who had been involved in the building process. A tentative result of this interview study is that the degree to which the future tenants had been involved in the planning of the building was important for whether they regarded the building as healthy or not. This method for studying the problem seems to be a good way of finding possible weak links in the building process that may later cause indoor air problems.

3C5p5 Developing a method for labeling the indoor environment of a home
M Björck

The indoor environment of buildings affects our health and productivity. The purpose of this project, which was performed as a study of the literature and through dialogue with experts, has been to develop a method for labeling the indoor environment in new buildings. The project is divided into five stages, dealing with: the state of the art; defining a base level for the experience of a good indoor environment and assigning values to the factors that we believe to be most important for health, together with methods of measurement; developing an evaluation model for building materials; developing a system of aids for building investigation regarding the indoor environmental; and developing a method for labeling the indoor environment of a home. The project will be completed in 2005.

3C5p6 Residential indoor air quality investigator training in Canada
V Salares and K Ruest

Canada has developed a training program for residential indoor air quality investigators. The program is a building science-based inspection that uses the CMHC Residential IAQ Investigation Procedure. The training is structured into courses and fieldwork. Since the roll out of the program in November 1998, twenty individuals have completed the program and are now offering IAQ investigation services to homeowners.

3C5p7 Office building ministry of transport at Terneuzen, The Netherlands: low energy, high thermal comfort and high sustainability in one concept
A van der Aa, HHEW Eijdems, and JJM Cauberg

The new office building of the Ministry of Transport at Terneuzen in the Netherlands is a sustainable and energy efficient building with a good indoor environment. The building is constructed of sustainable materials, well insulated, utilises maximum daylight and is equipped with a minimum of building services. Passive and natural sources have been utilised as much as possible. An advanced natural ventilation system provides fresh air and controls the thermal comfort in summer. A heat pump on canal water as heat source delivers heat supply for the low temperature wall and floor heating system. DHW is produced by a solar collector system and 54 m2 of PV cells generate part of the electricity. Measurements are carried out to analyse the performance of the building and the building services.

3C6o1 Calculation of thermal comfort from CFD-simulation results
H Koskela and J Heikkinen

Thermal comfort in ventilated spaces depends mainly on air temperature, air speed and turbulence intensity. The indices for assessing thermal comfort, such as PMV and Draught rating, are based on measurements of the time-averaged mean air speed with omnidirectional hot sphere sensors. At present, thermal comfort is often estimated computationally by CFD-simulations.

The mean air speed is not directly obtained from CFD-simulation and therefore the velocity vector magnitude is usually used instead. Since it is smaller than the mean air speed, this method may lead to underestimation of thermal discomfort. A correction method has been earlier proposed for calculating thermal comfort from CFD-simulation results. In this study, the correction method was implemented in CFD-software. Air speed and draught rating values were calculated for two simulated case examples and the effect of the turbulence correction was studied. The correction was found to be significant in room areas with high turbulence intensities.

3C6o2 Simulation study on the summer thermal performance of a typical Chinese traditional residential building Anhui residence
L Song, B Lin and Y Zhu

Traditional residential buildings in Anhui, Southern China, maintain comfortable indoor thermal conditions in the summer without any air-conditioning. To understand this phenomenon, the building thermal environment was simulated to study the physical principles for maintaining natural thermal comfort. Measured data such as outside temperatures, solar radiation intensities, the thermal characteristics of the structure, and the interior gain were used as the boundary conditions. Various natural ventilation modes were evaluated in the simulation to determine which mode resulted in the measured indoor temperature. The simulated results showed that the best mode was to limit natural ventilation during the day and promote it at night. Ventilation by the stack effect was the key to realize this ventilation mode. Other important factors are also discussed which are useful to the design of ecologically sound buildings and reduced energy use.

3C6o3 Prediction of global comfort in air conditioned building with a zonal model
E Rutman, C Inard , A Bailly and F Allard

This study presents a zonal model used for predicting a global approach to comfort in air conditioned buildings. This model is used to calculate different comfort indexes in the occupancy zone of an air conditioned environment. We used indexes devised by Fanger (Fanger 1970) as the Predicted Percentage of Dissatisfied (PPD) and the Draught Rating (DR). This model is also used to calculate the Noise Rating (NR) (ISO 1971). To calculate the mass air flow between zones, we distinguish driving zones and the current zones where the momentum is small. For the driving zones we used specific flow laws. Comparisons between experiments and numerical results were carried out. Using the results obtained we then calculated spatial statistical comfort indexes and obtained satisfactory results. Which enables us to consider the use of this model to predict the comfort performance of a real Heating Ventilation and Air Conditioning (HVAC) system.

3C6o4 Experiences of predicting transient surface temperatures
P Tuomaala, K Piira and J Piippo

The thermal performance of a building is closely related to both energy consumption and thermal sensation. Therefore, the thermal environment within a building is a key issue when assessing thermal comfort and dimensioning heating devices. Predicting transient surface temperatures requires physically reliable modeling, and integration of a heating device and heat transfer through building structures. A fireplace is selected as an example of a highly time-dependent heating device. Transient thermal behaviour of a test fireplace, and interaction between this heating device and building elements are modeled. All models are based on conservation of energy, and multi-mode heat transfer is allowed. Thermal radiation is taken into account by including surface net radiation components, and an improved progressive refinement method (IPRM) is applied to solve the surface radiosities in a room. The simulation results are presented in 3D graphics, and the results are compared with empirical data with quite good agreement

3C6o5 Simulation of a subway environment for evaluation of the thermal comfort
K Fukuyo, Y Shimoda and M Mizuno

We developed a subway-environment simulator based on a thermal-network model. This simulator partially uses the results of computational fluid dynamics simulations as a database. Flow rates calculated by this simulator agree well with measurements taken in an actual subway system. The simulator has an additional program for evaluating thermal comfort (based on index ET*). The result of this evaluation shows that index ET* depends on the air velocity at certain places in the subway system.

3C6p1 Study on the thermal environment in buildings with large-scale atriums and large area of glass surface
X Li, J Du and Z Jin

The control of thermal environment is complicated in buildings with glass-covered atriums. Numerical simulation can play an important role in the heating, ventilation, air-conditioning (HVAC) design of atriums. Many researches have developed various computational fluid dynamics (CFD) methods to accurately predict the thermal environment in atriums. However, a simple, reliable and fast method to deal with complex building construction is more suitable for building designers and engineers to

take as a routine assistant tool of HVAC design. In this paper, such numerical method is analyzed and summarized, which includes the composite grid method for solar radiation simulation, a new zero-equation model for airflow analysis, and Gebhart method for long-wave radiation calculation. The method is validated by compared with measurement data and applied to optimize the HVAC design of a practical project to demonstrate its application.

3C6p2 A tool for thermal analysis of conceptual design
JP den Hartog, PG Luscuere and EJ van Dijk

In contemporary architectural design, the indoor climate receives little attention. Most architects are not familiar with the typical problems and solutions involved in climate design. However, it is this relation that provides much control over the initial climate conditions and can prevent costly artificial solutions. As a result, many design decisions are made without insight into the consequences on the indoor climate. In order to educate architects and students of architecture in the effects of their design decisions in the area of thermal performance, we build a tool for temperature analysis of conceptual designs. This tool involves a new interface for the leading temperature overheating tool in the Netherlands (VA114). The interface concentrates primarily on architectural elements that have a large influence on thermal performance. Designers can input their design and receive predictions on the design's temperature profiles and energy use.

3C6p3 Interferometric modeling of temperature fields in ventilated and heated spaces
M Pavelek and E Janotkova

The interferometric modeling of temperature fields allows to visualize clearly the distribution of temperatures in typical centres of ventilated and warm air heated spaces and spaces heated using radiators and walls. For the visualization the Mach-Zehnder interferometer is applied and the research is realized on diminished models by means of the similarity theory application. This contribution contains some examples of visualized non-isothermal jets flowing into free space, visualized flow around some obstacles and visualized temperature fields in heated rooms at heating start and in a stable state. The visualization results comprise temperature fields pictures which provide both qualitative and quantitative information. From interferometric researches the conclusions for further investigation of monitored processes are deduced either using experimental or computer modeling methods. The results of the visualization contribute to an optimum solution of above ventilation and heating problems.

3C6p4 Room average velocity equation - a tool to improve design of thermal comfort conditions
K Hagström, O Hakkola and T Moilanen

For a long time PPD index defined in international ISO7730 standard has been a practical tool for evaluation of measured thermal comfort conditions in existing buildings. However, its usage has not yet been realized in design phase. One of the reasons is that there has not been any practical tool available to estimate average velocity conditions within the occupied zone. A kinetic energy model for calculation of the average room velocity has been presented in earlier paper. Current paper reports additional verification results of the kinetic energy model with different types of diffusers. The verified kinetic energy method has been applied together with other appropriate theories in development of design procedure and a software tool for designing of thermal comfort conditions according to ISO7730. Additionally, the design tool enables designer to evaluate maximum draft velocity conditions from the supply jet.

3C6p5 Numerical and experimental investigations of air flow and temperature patterns of a low velocity diffuser
M Cehlin and B Moshfegh

In this article, four turbulence models are studied to capture the flow and temperature behavior of the air close to a low-velocity diffuser for displacement ventilation. Turbulence is modeled by means of one zero-equation model and three different two-equation models, i.e. the LVEL, the RNG, the Standard k-e, and the Chen-Kim model. They are evaluated for their performance in predicting the air flow patterns and temperature profiles close to the diffuser. The models are validated with measurements performed both with traditional point measuring techniques and a whole-field measurement method. The prediction of the velocity and the temperature by the three two-equation models is generally satisfactory. The predictions from the RNG and the Chen-Kim model were almost the same and slightly different than the standard k-e model. The RNG model and the Standard k-e model are computationally much more stable than the Chen-Kim model.

3C6p6 Study on the thermal performance and air distribution of a displacement ventilation system for large space application
K Sakai, E Yamaguchi, O Ishihara and M Manabe

The purpose of this study is to clarify the usefulness of a displacement ventilation air-conditioning system introduced into a multipurpose hall after CFD simulation and measurement. In the multipurpose hall of Kurume City, a displacement ventilation

air-conditioning system equipped with a floor outlet had been adopted. A CFD simulation for the purpose of selecting an air condition system indicated the floor outlet system would be more effective for the design plan of the hall than a ceiling outlet system. Measurements for the purpose of determining the effectiveness and thermal performance of a displacement ventilation system were conducted after construction of the hall, and the obtained results for thermal performance and airflow distribution in the hall were consistent with the CFD simulation.

3C6p7 Research on the fluctuating characteristics of airflow in the naturally ventilated buildings
G Tan, L Song, andY Zhu

Natural ventilation's fluctuating airflow has impacts on the thermal comfort and VOCs transportation in the naturally ventilated buildings. Research about the fluctuating characteristics of the airflow in naturally ventilated buildings was carried on in this paper. A significant amount of data for airflow velocity of natural ventilation was recorded. Based on these simultaneously measured velocities of the indoor and outdoor airflow, the characteristic parameters, such as energy spectrum, turbulence intensity, and dimensional restructuring etc., of the airflow under naturally ventilated situation were analyzed. Not only the methods of statistical analysis but also the methods of turbulence theory, chaos theory and fractal theory were used to describe the structural characteristics of the fluctuating airflow of natural ventilation. The basic rules governing how the airflow fluctuating characteristics change when airflow goes through the building's openings or enters the building space were summarized in this paper.

4A1o1 Sustainability and indoor air quality
N Kohler

The different origins of sustainable development and its application to the built environment in the form of protection objectives are presented. Assessment methods of Indoor Air Quality and Sustainable development are compared (bottom up or top down). Economic, social and cultural aspects of indoor air quality, in particular odour and smell are related to a broader framework of sustainable development.

4A1o2 The global burden of disease from indoor air pollution: results from comparative risk assessment
KR Smith, S Mehta, and M Feuz

Recent estimates (organized and coordinated by WHO) of the global burden of disease for some two dozen risk factors by age, sex, and region include, inter alia, malnutrition, hypertension, tobacco use, obesity, unsafe sex, and several environmental risk factors, including lead, climate change, and indoor and outdoor air pollution. Only two categories of indoor pollution were deemed sufficiently well characterized regarding both exposure and risk to attempt to make global estimates: environmental tobacco smoke and combustion products from household use of solid fuels (biomass and coal). We summarize here the approaches used to estimate the health impacts from solid fuel use, including exposure modeling and meta-analyses for major disease endpoints. Although all the risk factor studies are not yet completed, the results seem to place indoor air pollution as a major risk factor worldwide, perhaps fifth after malnutrition, tobacco, HIV, and poor water/hygiene/sanitation in attributable burden.

4B1o1 Ventilation and moisture sources in apartments
L Gunnarsen and M Hjorslev Hansen

Moisture related problems, growth of fungi and an abundance of house dust mites harm the health. Suggested alleviating measures include increased ventilation, the use of biocides, improved moisture and temperature insulation, or reduction of humidity sources. This study was done to investigate the importance of user behavior; ventilation and construction details for humidity related problems. In a cross sectional study in Danish apartments air exchange rate, relative humidity and temperature of room air was logged during winter with average daily outside temperatures in the range –5 to 8 ^{o}C. Information on user behavior was obtained by questionnaires. A mass balance model based on humidity in room air, temperature and air change rate was used to show that moisture production is significant related to air change rates. Laundry drying was significant for humidity of room air. No significant relation between air change rates and humidity was found in the study.

4B1o2 Humidity states in the indoor air under the influence of the surrounding building elements
J Dreyer, T Bednar and C Hecht

This paper presents examples to decrease indoor air humidity and to avoid dangerous states by application of surface elements to walls, ceilings and floors. To demonstrate these effects a modeling of the moisture balance of the indoor air is carried out. The first example shows that interior plaster or lining boards decrease the indoor humidity peaks by diffusion and absorption. The second example deals with methods to calculate the time characteristic of the moisture content in wall and other elements after a retrofitting of the moisture protection. Furthermore the indoor air humidity of rooms, which suffer from high moisture

load by evaporation of wet elements, is investigated. Special surface systems, which allow diffusion and stop the capillary water transfer, decrease the evaporation rate and are able to reduce the indoor humidity. This paper helps to apply building materials with a good influence on formation of a good indoor climate.

4B1o3 Modeling moisture in residential buildings with a multi-zone IAQ program
SJ Emmerich, AK Persily, and SJ Nabinger

Although water vapor is not typically thought of as an indoor contaminant, multizone indoor air quality (IAQ) modeling can be used to predict water vapor concentrations in each zone by applying mass balance equations that incorporate water vapor sources and sinks. However, very few attempts have been made to model water vapor with a multizone IAQ program and such modeling presents unique issues including the appropriateness of model assumptions, the adequacy of moisture storage and generation models, availability of input data, and metrics for analysis. This paper describes measurements of humidity and other IAQ parameters in a single zone test house. Experiments included generation of water vapor with a humidifier during a variety of ambient conditions. Moisture storage and generation elements were then added to a previously validated airflow model of the building to evaluate the capability of the CONTAMW multizone IAQ model to predict indoor humidity levels.

4B1o4 Failure modes and effects analysis (FMEA) used on moisture problems
A Nielsen

Preventing "damp" buildings will give a better indoor climate and less risk of health problems for the inhabitants. Many industries use FMEA (failure modes and effect analysis) to reduce the risk. This method is new in the building sector. Part of an analysis of a building and the in-stallations is presented. The failure mode table gives the possible failure modes from free water. Based on the failure modes can the effects for each failure be found and prevention measures can be taken. Some modes are easy to see others are hidden and will first be seen if something else fails. In the future it should be possible to calculate the risk levels and com-pare different solutions. The FMEA analysis can be used in planning and building of new houses, but also as help in preventing failures in existing buildings.

4B1o5 A simulation tool for hygrothermal analysis
N Mendes

The software DOMUS has been developed to model coupled heat and moisture transfer in multi-zone buildings. It has also been conceived to be a very user-friendly software so that to stimulating a larger number of users to use building simulation software to investigate the effects of moisture content on IAQ. The models are able to predict temperature profiles within multi-layer walls for any time step and the temperature and relative humidity for each zone. In order to show some capabilities of the program, results in terms of moisture content profiles prediction are presented.

4B1p1 Inspector-reported and objective measurement of indoor moisture in homes of asthmatic children
P Lowenthal, K Mortimer, K Hammond, J Macher and I Tager

Epidemiological studies of indoor dampness and respiratory health frequently rely on survey-reported evidence or objective moisture measurements. In this investigation, the relationship between independent inspector reports and instrument measurements of moisture was assessed for 105 participants of the Fresno Asthmatic Children's Environment Study (FACES), a longitudinal cohort investigation of asthma and the environment. Only 4.8% of living rooms and 15.5% of bedrooms had inspector-reported signs of dampness. Homes with central or bedroom cooling systems had significantly lower moisture meter readings. There was no significant association between other housing characteristics and moisture readings, possibly due to the low frequency of "damp" homes in this population. Over the next several years, these homes will be resurveyed and additional homes will be inspected, allowing examination of multivariate associations between moisture, microbial contamination, dust mite and cockroach antigens, and short and long term measures of asthma morbidity.

4B1p2 Identifying water and moisture infiltration paths in building envelopes
LP Lazure and J Lavoie

In the past ten years, fungal contamination of buildings has been linked to many complaints related to indoor air quality. Three elements promote microbial growth in an indoor environment: a) a microbial source, b) nutrients, and c) water. Controlling the presence of water is generally the most effective means of limiting fungal colonization. The pervasiveness of microbes in our environment and the presence of many nutrient substrates limit the possibilities of rapid and effective intervention at these levels. In order to determine leakage sources and to perform an effective field investigation, the role of building components in preventing moisture intrusion and the mechanisms of moisture migration must be understood. Specialized techniques such as thermography and spray tests can be used to conduct the analysis and the assessment of the integrity of a building enclosure.

4B1p3 ORM (optimal removal of moisture from water damaged building constructions) - mould growth
J Mattsson, I Grønli, P Blom and OA Braathen

Mould growth occurs rapidly in water damages constructions. During the project ORM, critical moments were identified – both by laboratory studies and surveys in damaged buildings. Removing of water from damaged constructions is normally a slow process. During this time, the risk of mould growth is extremely high. Both in laboratory experiments and field surveys, it is proven that mould growth occurs in few days under optimal conditions. Different methods for drying out experimental constructions gave various degree of mould growth. Only in case of efficient drying conditions, growth of mould was avoided. A normal method for removal of moisture is either removal of damaged materials or drying by extra ventilation in the wet constructions. If mould fungi contaminate the materials, those measurements lead to spreading of spores and microbial contaminated dust to the surrounding areas. This has been shown to have significant impact to the indoor air quality.

4B1p4 Time-dependent moisture properties for plasterboard with surface coating
K Svennberg and L-E Harderup

The level and fluctuations of indoor humidity plays an important role for the indoor air qual-ity. The buffering effect of the internal surfaces in the building has been more emphasized lately. This study focus on the buffering effects for short time periods (hours, days) since the surface materials at this time scale may play a significant role. The objective is to determine the time-dependent moisture properties of plasterboard for indoor use and the different layers of a dispersion paint surface coating system. The effect of moistening and drying is studied in the interval RH 33–54% (+20 C). The surfaces step-response was determined through a gra-vimetrical method while the sample was in a well-defined relative humidity (RH). Calculated values for the moisture capacity, x, together with an evaluation of the experimental data are presented. The experimental results have a satisfying agreement compared with the calcula-tions.

4B1p5 A program of drying and microbial growth prevention in a hospital following an accidental water release
MS Smith, LR Lee, and LL Hilken

An accidental release of more than 2,000 gallons of domestic water from a construction project caused water damage on five floors of a high-rise hospital tower. Water extraction of wet carpets was initiated within hours of the release. At-risk patients were relocated to unaffected areas of the hospital. A desiccant drying system was connected in-line to the HVAC system and supplemented with air moving fans and portable dehumidifiers to dry the structure. Affected areas were isolated using physical barriers. Daily visual inspections, moisture measurements, and air monitoring for viable *Aspergillus* species and total fungi were conducted to monitor drying progress and identify fungal amplification sites. No visible mold growth was observed on building materials, and airborne concentrations of viable *Aspergillus* species ranged between none detected and 7 cfu/m^3 throughout the project. No cases of nosocomial aspergillosis were reported as a result of the water release and 60 days post restoration.

4B2o1 VOC-related sensory symptoms in office buildings
V Herzog, J Witthauer, S Brasche, W Bischof

The results of the ProKlimA project in which the indoor air of over 600 rooms in 14 office buildings was analysed, showed a significant association between the specific exposure to TVOC and SBS symptoms of the occupants. Therefore the aim of the present work was to identify single compounds and to specify the actual effect on eyes, skin, nose, mouth, throat, central nervous system and on the non-specific symptom complex “SBS”. For this detailed examination, multiple logistic regression analysis including adjustment for psychosocial factors such as gender, age, education and workplace variables was used. Results: In office workers a rise in limonene concentrations increased the odds for eye symptoms (OR 1.74, 95% CI 1.07-2.85). Elevated concentrations of aromatic hydrocarbons increased the risk of skin symptoms (OR 1.87, 95% CI 1.13-3.07), central nervous symptoms (OR 2.62, 95% CI 1.61-4.24) and the non-specific symptom complex “SBS” (OR 1.98, 95% CI 1.25-3.13).

4B2o2 Multivariate evaluation of VOCs in homes and office buildings with and without known SBS complaints
A-L Sunesson, J Gullberg, K Olsson-Köhler and G Blomquist

Volatile organic compounds (VOCs) were sampled in sixteen homes and nineteen office rooms in two pilot studies. In half of the homes/offices the inhabitants/workers suffered from sick building syndrome (SBS) symptoms and in the other buildings no such symptoms were reported. The samples were analysed by thermal desorption-gas chromatography, and all individual compounds were included as variables in evaluations using multivariate techniques. Homes with and without SBS problems and offices with and without known SBS problems could be separated in multivariate plots (Coomans’ plots and PLS-DA plots). This shows that multivariate evaluation of VOC data from buildings is a promising tool for separation of problem- and non-problem buildings. The TVOC values from problem buildings were not significantly different from TVOC values in non-problem buildings.

4B2o3 The indoor environmental index and its relationship with occupant symptoms
DJ Moschandreas and SC Sofuoglu

This paper reports an ongoing effort to associate a new index, the Indoor Environmental Index (IEI) and symptoms registered by occupants of the US EPA BASE study. This study modifies the structure used to calculate the Indoor Air Pollution Index (IAPI) and estimates the Indoor Comfort Index (ICI). The average of these two indices is the Indoor Environmental Index (IEI) that is calculated in selected areas of 100 office buildings. A symptom index was also developed to denote the Percent of Occupants with two, 2, or more Persistent Symptoms, POPS2. A simple linear regression was formulated to associate the IEI with corresponding values of a symptom index, the POPS2. The model explains 79% of the variation of the POPS2 with the variation of the IEI. In principle, a questionnaire and the model may be used to ascertain office buildings with elevated environmental index. The index may be used as an indoor air management tool.

4B2o4 Class separation of buildings with high and low prevalence of SBS by principal component analysis
L Pommer, J Fick, B Andersson, J Sundell, C Nilsson, M Sjöström and B Stenberg

This method was able to separate buildings with high and low prevalence of SBS in two different classes using principal component analysis (PCA). Data from the Northern Swedish Office Illness Study describing the presence and level of chemical compounds in outdoor, supply and room air, respectively, were evaluated together with information about the buildings. The most complex model was able to separate 71% of the high prevalence buildings from the low prevalence buildings. The most important variables that separate the high prevalence buildings from the low prevalence buildings was a more frequent occurrence or a higher concentration of terpenoid compounds and ketones in the high prevalence buildings. Relative air humidity in supply and room air, and TVOC in outdoor and supply air and 10 building variables also contributed to the separation of low and high prevalence buildings.

4B2o5 Women's chemical sensitivity and chemical exposures indoors and outdoors
B Berglund and L Zheng

Chemical sensitivity (CS) is a new phenomenon characterized by a variety of unpleasant, ambiguous symptoms attributed to low-level chemical exposure. Since more women are affected than men, a cross-sectional questionnaire study was conducted in a random sample of 6003 women (18-65 years old). The results were: (1) 27.6% prevalence of self-reported CS; (2) CS persons commonly attributetheir symptoms to household products and differ from non-CS persons regarding upper-airway and mucosal symptoms; (3) psychological tests show significant differences between non-CS and CS persons; CS persons' symptoms influence test outcome rather than the reverse; (4) demographic factors are not predictors of CS; (5) age-onset for allergies precedes CS which in turn precedes other environmental syndromes. Women's CS may be incited by environmental exposures, and in this process, many other physical, psychological and social factors may compromise their susceptibility.

4B2p1 TXIB-emission from floor structure as a marker of increased risk for some specific symptoms
P Metiäinen, H Mussalo-Rauhamaaand M Viinikka

Two small-scale studies were conducted in order to find out any connection between VOC-emissions from floor structure and symptoms of the residents. Three blocks of flats with PVC-carpet on concrete floor were studied. In all flats residents were asked to fill out a modified questionnaire based on Örebro and Tuohilampi questionnaires. Volatile organic compounds were measured by the GC/MSD system. Higher concentrations of 2,2,4-trimethyl-1,3-pentanediol di-isobutyrate (TXIB) in indoor air seem to increase the risk of symptoms like nose and eye irritation, throat symptoms and "heavy head". Health effects may be a direct effect of TXIB exposure. Alternatively TXIB may act as a marker for another PVC component. In the world TXIB has been or is widely used as plasticizer in many PVC-products. Results of this survey indicate that these findings are of potentially major public health importance.

4B2p2 Damaged flooring material and absenteeism in an office
E Palomäki, M Seuri, A Tuomainen and J Uitti

Flooring materials may break down if mounted on a damp concrete surface. There are some reports relating to upper respiratory and asthma symptoms caused by degradation by-products of polyvinyl chloride building materials. Here, we report increased number of upper respiratory, conjunctival and dermal symptoms among employees exposed to the degradation by-products of linoleum floor coverings. The number of sick leaves caused by respiratory symptoms and diseases rose simultaneously. The damaged flooring materials were removed and replaced by epoxy coating, which is not affected by moisture. After the repairs, the number of sick leaves due to respiratory symptoms and diseases decreased by 14%. It was calculated that the repair costs were paid back in two years in terms of decreased expenditures on the care of respiratory diseases and symptoms.

4B2p3 Field survey on indoor air quality and occupants' health conditions in sick houses
H Yoshino, K Amano, K Ikeda, A Nozaki, N Iida, K Kakuta, S Hojo and S Ishikawa

Indoor air quality of twenty-two houses in Sendai-city, Japan, where occupants are suspected of suffering from what are called Multiple Chemical Sensitivity (MCS) and Sick Building/House Syndrome (SBS/SHS), was investigated during the summer in 2000. The investigation included measurements of formaldehyde, volatile organic compounds (VOCs), questionnaire regarding subjective symptoms and medical examination of MCS. The measurement revealed that the formaldehyde concentration found in 38 rooms (63%) exceeded the criterion from the guideline, set 0.08 ppm, by the Ministry of Health, Labour and Welfare, Japan. Almost all occupants complained of subjective symptoms. The 88% of participants in medical examination were diagnosed with possible MCS. The relationship between the measurement result of indoor chemical substance concentrations and the subjective symptoms obtained from questionnaire suggested that the symptoms revealed more serious in higher chemical substance concentration houses, but even in lower chemical substance concentration houses, some occupants also suffered from symptoms.

4B2p4 The environment and multiple chemical sensitivity
RA Fox

In a sample of 100 patients who fulfilled the consensus criteria for multiple chemical sensitivity, MCS, 40 had no clear cut event associated with onset of illness. Seventeen had acute onset and attributed this to a single , significant environmental problem. Thirty five attributed onset to various environmental exposures from contaminated ambient air of childhood or adult life, from indoor air at home, from hobbies or from occupation. Eight patients linked acute onset to other events such as a motor vehicle accident, childbirth or viral illness. Thirty four worked in “tight buildings” and 22 reported an indoor air quality problem. If environmentally contaminating, manufactured chemicals are causally linked to the etiology of MCS then exposure is most likely long term and to low, so called “safe levels”, of complex mixtures. It is likely that environmental contaminants interact with host factors as part of a causal web.

4B2p5 Methods to "investigate a sick building"
T Hall and L-O Nilsson

With a properly undertaken damage investigation, it is often possible to find the cause of defects in buildings with SBS. The causality between ill health and measurable pollutants in the indoor environment is largely unclear. However, it has often been found that the sources of pollutants that are hazardous to health are emissions from surface finishes and building components. A practicable way of remedying defects in buildings with Sick Building Syndrome (SBS) may be to look for abnormal primary emissions or secondary emissions from damaged finishes and building constructions. Assessments should however be made with care and be preceded by a broad based and well-performed damage investigation. The experience of practicing Swedish Indoor Air Quality consultants shows that the causes of pollution in the indoor air can be found and traced to e.g. moisture damaged building materials or constructions. When these damaged building components are given remedial treatment, the symptoms decrease or vanish.

4B2p6 Comparison of personal VOC exposures of multiple chemical sensitivity patients and non-patients
N Shinohara and Y Yanagisawa

The number of Multiple Chemical Sensitivity (MCS) patients is rapidly increasing in US, EU and Japan, because of exposures to volatile organic chemicals in indoor environments. To identify the responsible chemicals of the hypersensitive symptoms, we applied passive and active sampling methods to 22 MCS patients. Besides the personal exposure levels of 76 non-MCS persons were measured. The mean ± SD of formaldehyde weekly exposure levels of non-MCS persons were 22.3 ± 11.7 ppb and that of all MCS patients were 16.4 ± 12.2 ppb. The weekly exposure levels of the responsible chemicals of each MCS patient were lower than the median of the weekly exposure levels of non-MCS persons. This indicated that MCS patients chose places where chemical levels were relatively low. According to the exposure levels that induced hypersensitive reactions, the patient’s symptoms are possible to be induced in general places around us.

4B3o1 PCB in indoor air and dust in buildings in Stockholm
R Corner, M Sundahl, L Rosell, B Ek-Olausson and M Tysklind

PCB levels in indoor air were low, (>50 ng/m^3) in 9 flats and 3 schools. In 15 flats levels varied more (23-270 ng/m^3). Sealant contained a less volatile high-chlorinated PCB-mixture except in one case. Levels were over 300 ng/m^3 in 2 flats analysed from passive samples, but were below this from active samples. The most toxic PCB congeners were very low. PCB in house dust varied considerably (0.01 - 5.4 µg/g) and was also found in buildings without PCB in sealant. Average PCB level in dust is of the same magnitude that one-gram of dust represents the average daily intake of PCB from food. Small children should not be

exposed to this dust. PCB levels in indoor air may correlate with ventilation, floor level and dust. More study is needed on dust and/or gas paths and exposure. Quality control of the indoor environment should be improved when dismantling PCB sealant and a safe-level needs to be established.

4B3o2 Characterization of polychlorinated biphenyls in building materials and exposures in the indoor environment
KM Coghlan, MP Chang, DS Jessup, MA Fragala, K McCrillis, and TM Lockhart

The accidental discovery of PCB contamination in a university office building triggered an extensive sampling program to define the nature and extent of the indoor contamination. PCBs were detected in air samples (111 – 393 ng/m^3) and in dust samples collected from the unit ventilators (<1 ppm – 81 ppm). Surface samples were at or below the limit of detection (2 ng/cm^2). Aroclor 1254 was the principle PCB mixture detected in all samples. While PCB concentrations remained below regulatory limits for air samples, source materials found in the building contained PCB concentrations well above the EPA approved limit of 50 ppm for non-liquid PCB products. Left in place, any of these sources of PCBs would continue to contribute to the low-level concentrations of PCBs found in environmental sampling. This data suggests the need for further study of potential PCB exposures and associated health implications for occupants in buildings constructed with PCB-containing products.

4B3o3 Small particles containing phthalic esters in the indoor environment - a pilot study
B Lundgren, C-G Bornehag, L Cedheim, L Rosell, and L Hägerhed

Many chemicals in polymeric materials have low vapour pressure. Hypothetically such chemicals are emitted and may stay as particles or be adsorbed onto dust particles and become air-borne. The aim of this pilot-study has been to validate the methods for measuring phthalates on particles in indoor environments. Sedimented dust from the child's bedroom in seventeen homes has been sampled using a Vacuu Mark sampler and a vacuum cleaner. The dust is collected on 90 millimetre cellulose filters, which are extracted and analysed by techniques such as HPLC and GCMS. First results have shown that phthalates and chemicals were extruded from the polymeric material. A co-variation between the amounts of the phthalate, DEHP on the filters and the type of interior decoration on walls and floors were found.

4B3o4 Role of dust analysis in complaint resolution of indoor air quality
DR Cortes, AG Worthan and MS Black

We report on two studies where the chemical analysis of dust was used to help resolve indoor air complaints. Dust was collected on a 0.45 mm polycarbonate cassette with a high-flow vacuum pump, and analyzed using thermal desorption – gas chromatography/mass spectrometry. Chemicals in the dust are identified and compared to published sensory irritation data. In addition, the use of the dust as an indicator of low-volatility airborne chemicals and as a record of past exposure is examined.

4B3o5 Indoor air principles applied to a legal case involving phenol poisoning
V Salares

A chemical spill occurred inside a car due to improper packaging of liquid phenol by a pharmacy. Two individuals were exposed to phenol vapors. This led to a lawsuit that remained unresolved for eight years. This paper describes the application of chemistry and indoor air principles to elucidate how phenol vapor got transported from the car to other sites. This paper is also an example of applying science in the pursuit of truth and justice.

4B3p1 Remediating PCB-containing building products; strategies and regulatory considerations
M Chang, K Coghlan, and J McCarthy

Following the discovery of building materials containing polychlorinated biphenyls (PCBs), a northeast university undertook a remediation and abatement program for the building. PCB-containing gaskets, caulking, and foamboard were found throughout the building. The PCB concentration in these materials were in excess of allowable limits of 50 parts per million (ppm) for non-liquid PCBs set by the U.S. EPA. In addition, these materials were thought to contribute to the PCB concentrations measured indoors. A comprehensive sampling strategy identified several PCB-containing products within the building envelope, as determined by sampling the building materials and researching the architectural drawings and plans. Federal, state, and local regulations and interests need to be addressed when dealing with the remediation work and disposal of PCB-containing materials. Specifically, complying with current TSCA requirements can create significant operational and economic challenges.

4B3p2 Phthalate diester levels in personal air samples during pregnancy in two urban populations
J Adibi, R Whyatt, D Camann, K Peki, W Jedrychowski, and F Perera

There is growing concern over the widespread exposures to phthalates detected in the U.S. population. Phthalates have been shown to be hepatic, reproductive and developmental toxicants. Certain phthalates are elevated in women of reproductive age, resulting in implications for the health of the developing fetus. In the current study, we assess the presence of phthalates in personal air samples of pregnant women subjects in prospective cohorts in Northern Manhattan and Krakow, Poland. Phthalates were detected in 100% of samples. Diethyl phthalate (DEP) (range 1,447-7,123 ng/m^3) and dibutyl phthalate (DBP) (range 755-14,763 ng/m^3) were present at the highest levels in Northern Manhattan and Krakow respectively. Dicyclohexyl phthalate (DCHP), butylbenzyl phthalate (BBzP), diethylhexyl phthalate (DEHP), and disobutyl phthalate (DIBP) were present in ascending order. Demographic characteristics of study subjects are presented to identify possible risk factors. Comparison data are presented for 4 phthalate isomers to assess the significance of these levels.

4B3p3 Development of a microanalysis method of phthalate esters in indoor air and its application to practical measurement
T Matsumura, M Hamada, T Imanaka and S Muramatsu

The authors have developed a microanalysis method for the purpose of elucidating the actual form(particulate or gaseous) of phthalate esters(P.E.) present in indoor air and the particle size distribution and individual exposure amounts. In this study, a method of sampling was used layering 2 sheets of filter material different in collecting property and the method of analysis by GC/MS was established. The technique was applied to the measurement of indoor air it became clear that the P.E. were always present in both the particulate form and gaseous form. And, it was also made clear that in the particle size distribution the concentration of micro particles not more than 2.5 mm tended to be high.

4B3p4 Measurement technique for particulate phthalate ester in indoor air
T Imanaka,T Iwasaki, K Hoshino and T Matsumura

Recently, phthalate ester has been shown to be a kind of endocrine disruptor (Takahashi, 1998), however there is still much that is unknown about phthalate esters, such as their behavior in indoor air. In this work, high-sensitivity measuring method was studied in order to clarify concentration fluctuation of phthalate esters in a day. The 5-10 minute sample air (at a flow rate of 10 liter per minute) is collected using the quartz fiber. The thermal desorption was carried out at Disk-Chamber, and the measurement was carried out in GC/MS in respect of phthalate esters on the quartz fiber. The lower detection limit value of phthalate esters was 0.5 nanogram/m^3. As a result of applying this measuring method to indoor air, that the effect of the ventilation was received in phthalate esters in which vapor pressure is low clarified.

4B3p5 LC/MS method to determine plasticizers in indoor dust
R Nagorka, C Scheller, D Ullrich and B Seifert

The analysis of a broad range of plasticizers in indoor dust is necessary due to their widespread use, their ubiquitous occurrence in environmental media and their toxicological properties. Since commonly used GC methods are less suited to analyse compounds of low volatility a HPLC method has been developed. The method covers phthalates (up to C10-alkylated), adipates, an azelate and a trimellitate and is suitable for compounds of even higher molecular weight. A mass spectrometer with atmospheric pressure chemical ionisation (APCI) was used as a detector, which yields mass spectra of low and specific fragmentation. Typical performance characteristics of this analytical method are: recovery of 105% to 130 %, limits of determination from 150 mg/g down to 1 mg/g (based on a 50 mg dust sample, depending on blank value), repetitive RSD from 3 % to 16 %.

4B4o1 Simulation of contaminant transport in large-scale zonal models of complex building envelopes
CE Hickox, JE Brockmann, F Gelbard, RO Griffith, TJ Heames, and KK Murata

Computational strategies, developed at Sandia National Laboratories (SNL), are applied to the numerical simulation of contaminant transport within a zonal model (or equivalently, a multizone model) of a building envelope. This is accomplished through a three-step process that involves (1) partially automated model construction, (2) thermal-hydraulic simulation, and (3) contaminant transport. The zonal representation of the building envelope and the associated interconnections are constructed by a procedure based on the application of commercially available solid modeling software plus meshing and data handling software developed at SNL. The transient thermal-hydraulic response and transient contaminant transport for the zonal building model are simulated with the SNL code KCNBC. The simulation procedure is demonstrated by application to a two-storied building that includes architectural features typical of office and administration buildings. The results of the simulations are used to demonstrate the effects of contaminant release location, doorway openings, leakage, filtration, and HVAC system operation and to evaluate mitigation strategies.

4B4o2 Contributions to simplified modeling of building airborne pollutant removal
G Carrilho da Graca and PF Linden

This paper presents two contributions to simplified modeling of airborne pollutant removal in multi-zone cross-ventilated buildings, applicable on two scales: inter-room flows and in-room pollutant concentration. On the first scale we present an improved cross-ventilation model, obtained by introducing a momentum conservation term in the equation that relates pressure variations to flow through apertures. On the room scale we present an analytical model to predict pollutant levels in two main regions: inlet jet flow and recirculation. The predictions of the model combining these two approaches are compared with CFD simulations of pollutant removal in a multi-zone building. The model retains most of the simplicity of current multi-zone, single node per zone models and can calculate the flow through offset outlet openings, correctly predicting the variation in the flow rates with offset geometry. The predicted airflow and pollutant removal rates display the sensitivity of pollutant concentration to building geometry.

4B4o3 Rapidly locating sources and predicting contaminant dispersion in buildings
MD Sohn, P Reynolds, AJ Gadgil and RG Sextro

Contaminant releases in or near a building can lead to significant human exposures unless prompt response measures are taken. However, selecting the proper response depends in part on knowing the source locations, the amounts released, and the dispersion characteristics of the pollutants. We present an approach that estimates this information in real time. It uses Bayesian statistics to interpret measurements from sensors placed in the building yielding best estimates and uncertainties for the release conditions, including the operating state of the building. Because the method is fast, it continuously updates the estimates as measurements stream in from the sensors. We show preliminary results for characterizing a gas release in a three-floor, multi-room building at the Dugway Proving Grounds, Utah, USA.

4B4o4 Modeling transient contaminant transport in HVAC systems and buildings
CC Federspiel, H Li, DM Auslander, D Lorenzetti and AJ Gadgil

A mathematical model of the contaminant transport in HVAC systems and buildings is described. The model accounts for transients introduced by control elements such as fans and control dampers. The contaminant transport equations are coupled to momentum equations and mass continuity equations of the air. To avoid modeling variable transport delays directly, ducts are divided into a large number of small sections. Perfect mixing is assumed in each section. Contaminant transport equations are integrated with momentum equations in a way that guarantees mass continuity by using two non-negative velocities for computing the mass transport between elements. Computer simulations illustrate how the model may be used to analyze and design control systems that respond to a sudden release of a toxic contaminant near a building. By coupling transient flow prediction with transient contaminant prediction, the model overcomes a number of problems with existing contaminant transport codes.

4B4o5 Mixing of a point-source indoor pollutant: numerical predictions and comparison with experiments
C Lobscheid and AJ Gadgil

In most practical estimates of indoor pollutant exposures, it is common to assume that the pollutant is uniformly and instantaneously mixed in the indoor space. It is also commonly known that this assumption is simplistic, particularly for point sources, and for short-term or localized indoor exposures. We report computational fluid dynamics (CFD) predictions of mixing time of a point-pulse release of a pollutant in an unventilated mechanically mixed isothermal room. We aimed to determine the adequacy of the standard RANS two-equation (k-ε) turbulence model to predict the mixing times under these conditions. The predictions were made for the twelve mixing time experiments performed by Drescher et al. (1995). We paid attention to adequate grid resolution, suppression of numerical diffusion, and careful simulation of the mechanical blowers used in the experiments. We found that the predictions are in good agreement with experimental measurements.

4B4o6 Mixing characteristics of a continuously emitting point source in a room
W Ott, S McBride and P Switzer

Previous research on a continuously emitting source in a room has observed a "proximity effect," or higher concentrations near the source. The pollutant is transported from the source throughout the room on thin, rapidly moving strands called "microplumes." In 12 experiments in a home, we used a combustion source (a cigarette or an incense stick) near the center of the room with two nephelometers located at 5 m on opposite sides of the source to measure light scattering at 2-second intervals to determine the arrival time of the first elevated concentration (the "first hit" time). With calm indoor air (< 0.2 m/s), turbulence caused the microplumes to reach the outer edges of the room rapidly, and "first hit" times at 5 m ranged from 1.7 to

17 min, averaging 4.9 min (or approximately 0.017 m/s). The paper discusses the implications for personal exposure research and for indoor air quality modeling.

4B4p1 Study of food odour concentration and dispersion in an atrium
F Wang and M Tait

A computer modelling investigation was carried out to test three mechanical ventilation options for an office building with an atrium at its centre. The ventilation system is proposed to supply serviced air to the offices and the atrium and remove the food smell generated from a restaurant and its food area on the ground floor of the atrium. The options were assessed by the effectiveness of keeping odour concentration low on the two open plane offices on the two top floors. The objective of this study is to determine which of the three options of a proposed mechanical system would give the best ventilation. The paper reports the back-ground to a specific challenge, the design and modelling approach used and the outcome of the study.

4B4p2 Developing new scales of indoor air quality for assessing the contribution of pollutant sources
T Kim, S Kato and S Murakami

The locations of pollutant sources in a room have a great responsibility for pollutant distribution in the air. The concentration of the point concerned depends on the each pollutant source and the room air distribution. The concentration of that point can be considered as the sum of the contribution ratios of sources. To controlling and designing the indoor air quality efficiently, it is very important to know the contribution ratio of pollutant sources in a room. In this paper, the new scales of indoor air quality for assessing the contribution of pollutant sources, termed CRIAQs (Contribution Ratio of Indoor Air Qualities), were developed. These scales are all calculated using the CFD (Computational Fluid Dynamics) method, which accurately analyzes the velocity, temperature, and pollution distribution. Using the CRIAQs, the contribution ratio of pollutant sources of the model room was analyzed. The CRIAQs were found to be very useful in this study.

4B4p3 Numerical prediction of contaminant distribution in a food processing clean room
O Rouaud, M Havet and C Solliec

In order to assess the efficiency of pollutant elimination in a pilot scale clean room, a numerical study is carried out, which permits to quantify contaminant dispersion in several configurations. The results are presented for several Air Change rate (ACH) usually recommended in such clean rooms and we call for the ventilation effectiveness concept to evaluate the ambiance quality. The contaminant removal effectiveness appears to be strongly related to the contaminant source position and does not vary significantly as the ACH decreases from 80.2 h^{-1} to 20.1 h^{-1}. Moreover, even if the mean concentration of pollutant in the room increases with the reduction of the supply air velocity, the cleanliness class can remain unchanged in working areas, primarily because the contaminants are not evenly distributed in the whole room. These numerical results corroborate previous experimental observations and can lead to new recommendations.

4B5o1 IAQ, energy, and cost implications of underfloor air distribution systems
R Brahme,V Loftness, M Mondazzi, E Vineyard, and M MacDonald

A recent comprehensive review of underfloor air distribution (UAD) systems literature and interviews with engineers (who have a significant number of completed projects using these systems) has shown that the use of UAD system results in measurable improvements in thermal comfort, indoor air quality, and user satisfaction. These systems support changing space layouts with continued levels of HVAC delivery, and provide high level of user control. Frequently, the UAD systems show first-cost savings over more conventional ceiling systems, churn-cost savings ranging from $10 - $50 per square meter per move, and savings of 5-35% in energy consumption. Finally, facility management costs are often reduced. In this paper, we discuss the findings from the above-mentioned review in the context of different UAD system approaches, comparing their performance to traditional ceiling-based systems. Specifically, we discuss the reasons for better air quality, reduction in peak and operational energy use, and lower first and life cycle costs of these systems.

4B5o2 Thermal stratification performance of underfloor air distribution (UFAD) systems
TL Webster, FS Bauman, J Reese and M Shi

Tests were conducted to determine the impact of room airflow and supply air temperature (SAT) on the thermal stratification in interior spaces, and the effect of blinds in perimeter spaces for UFAD systems. Room airflow was varied over the range of 0.7-5.1 (L/s)/m^2 (0.3-1.0 cfm/ft^2) and SATs over 15-19 C (60-67 F) for constant nominal interior heat input of 55-59 W/m^2 (5.2-5.5 W/ft^2). Results show that spaces can be highly stratified when the airflow is reduced for a given load. When SAT is varied, the shape of the temperature profile does not change; it only moves to higher or lower temperatures. Perimeter space tests conducted at a heat load of 116 W/m^2 (10.7 W/ft^2) and constant room airflow of 5.1 (L/s)/m^2 (1.0 cfm/ft^2) with blinds opened

or closed showed that room load is reduced when blinds are closed due to bypassing of window gains directly to the ceiling return via a convective plume.

4B5o3 Computer modeling of underfloor air supply system
JJ Kim, JD Chang, and JC Park

An underfloor air supply system is considered to provide better thermal distribution than a conventional overhead air supply system. A computer model of an environmental chamber under construction was developed to investigate the performance of these two systems. Computational fluid dynamics (CFD) was applied in this research to compare the temperature and air speed distribution patterns of both systems under different supply air grill locations. The CFD modeling has shown the underfloor air supply system to provide improved temperature distribution over the conventional overhead system. Under identical conditions, an underfloor air system can achieve lower air temperatures within the seated zone above the floor than possible with an overhead system leading to the possibility of energy savings. Initial results also indicated less air turbulence with an underfloor system.

4B5o4 Antipodal ventilation - a conceptual introduction
Z Lin, T T Chow and Y Li

This paper proposes a new mode of ventilation for indoor airflow. Computational results show that with properly designed supplied air velocity and volume, locations of diffusers and exhausts, the proposed system should be able to maintain better thermal comfort with a smaller temperature difference between the head and foot level, and possibly lower energy consumption, if compared with conventional systems. It looks promising that better indoor air quality (IAQ) in the breathing zone could also be achieved but that further work is needed to determine if IAQ benefits are significant.

4B5o5 Improving indoor air quality in schools by utilizing displacement ventilation system
D Holland and A Livchak

The study conducted by the Government Accounting Office in 1995 says that 25 % of the nation's schools are plagued by IAQ problems, even higher percentage of schools having IAQ problems is reported by the Environmental Protection Agency (Johnston and Davis 2001). Most of these IAQ problems can me contributed to poor ventilation. This paper will summarize the experience of 15 schools equipped with Displacement Ventilation (DV) system. It will illustrate how DV system improves the IAQ in schools and reduces system annual energy consumption by having higher supply temperature compared to traditional mixing ventilation system. Special attention will be contributed to the moisture control.

4B5p1 Experimental comparison of characteristics between ceiling-based system and floor-based system using CAV HVAC system in cooling period
Y-T Chae, H-J Moon, B-W Ahn and J-Y Sohn

During the last few years, a new displacement air supply system using Access Floor has been introduced into office buildings in Korea. The present paper evaluates indoor thermal environment, cooling efficiency and energy consumption between a floor-based system and a ceiling-based system using a mock-up model in cooling period. The experimental chamber has a UFAC, underfloor air conditioning, system and a ceiling-based system. And the experiments are set with practical internal load conditions including occupants, lighting units, and heat sources (office automation equipment). The following were compared and evaluated; 1) the vertical and horizontal temperature distribution, 2) vertical temperature gradient in occupied zone, 3) PD, predicted percentage of dissatisfied due to draft, at occupied area, and 4) electrical energy consumptions in each experimental conditions. As the results, floor-based system is more effective to make design thermal conditions with lower electric energy consumption than ceiling-based system.

4B5p2 Study of an innovative partition-type personal modulation air-conditioning system
H Chiang, CC Su, CS Pan and FH Tsau

This paper proposes a new personal air-conditioning system, which modifies a common partition used in offices to a partition-type fan-coil unit (PFCU) with inlets and outlets on its surfaces. Chilled water is supplied as the cooling energy, and is delivered to the partitions by pipelines incorporated into the structure. Hence, conventional air conditioning systems using ceiling-based air diffusers for open-plan offices may be dispatched into several small individual systems controlled by the occupants. Another advantage of the new system is that a raised floor system is not required, so the applicability to retrofit buildings is very convenient. In this study, the transient variations of room temperature distribution and the skin temperature of a thermal manikin were measured in a real-scale climatic chamber. The preliminary test results of a prototype system have shown that the PFCU system has many promising features and deserves further development.

4B5p3 Façade-integrated ventilation units with heat recovery - energy efficiency and indoor air quality
FD Heidt, S Höptner and V Kalender

This contribution reports on investigations about the performance of decentralised ventilation units with heat recovery. Such units can be easily installed in individual rooms and therefore offer an interesting alternative to central ventilation units. Nevertheless these units exhibit some problems. Experimental examinations of two commercial decentralised units showed that the real effectiveness of heat recovery was always below 50 % and that considerable leakage between the air ducts can result in poor indoor air quality. Additional investigations have been performed to measure air flow patterns and local age of air within a test chamber. The obtained measurements have been compared with CFD simulations and showed rather good agreement. This verification of simulation results allows for further numerical studies of indoor air quality under several conditions.

4B5p4 Experimental and numerical studies on local high efficiency air conditioning system for office buildings
I Izuhara, R Kuwahara and K Mizutani

The effects of an air conditioning system for office buildings were studied experimentally and computationally. A displacement ventilation system was used as the main air-conditioning system, and a partition with a built-in circular fan was used to deliver the air-conditioned clean air near the floor supplied by the main displacement system to the occupant in the office directly. Experimental model tests and computational analysis that used the large eddy simulation (LES) have been carried out to obtain local air exchange efficiency, air temperature and air velocity distributions in a test chamber. The measured and simulated air velocities were compared. The results show that the partition's built-in circular fan has a great impact on the local air exchange efficiency in the immediate vicinity of the occupant. However, the thermal comfort of the occupant should be examined in more thoroughly.

4B5p5 Geoexchange & low exergy buildings
P Platell, D Schmidt and G Jóhannesson

A large part of the non-renewable energy resources worldwide is today used for space conditioning where the temperature requirement is about 20 C. By adopting a so called Low Exergy approach for heating and cooling of the Building and employing the ground as a thermal energy storage by installing special ground heat exchangers it seems possible to realise cost effective and comfortable indoor climate which is mainly relying on solar energy and ground cooling. The current paper describes a so called Geoexchange & Low Exergy system developed on and off since the 70's and at present at KTH, Stockholm. The paper summarize earlier work and recent work carried out at KTH involving computer simulation of a double-gap building envelope implying interesting synergies with the special ground heat exchangers.

4B5p6 Customised environment - an holistic clean air solution
R Kohonen, J Valkenburg, D J C Gill, P-O Danielsson and L Bartek

Poor indoor air quality causes huge economic losses in terms of occupant discomfort, illness or lower productivity. Recent studies have proven that even incremental improvements of the indoor environment can result in lower risk of sick building syndrome and improvement in occupant productivity. In other segments like health care the impact of a poor indoor environment can be more severe, it being reported that numerous hospital acquired infection cases have airborne contamination as the root cause. The challenge of ventilation solutions is to break the links of transmission of infection and infection agents amongst occupants. A jointly developed a system, Customised Environment™ (CE), is an integrated approach combining advanced air filter and air distribution technologies. The system creates new flexibility in ventilation systems as well as clean zones in the occupied zones of rooms. The paper outlines the key results from laboratory and CFD analysis that verify the designed system performanc

4C1o1 Microorganisms, MVOCs and the health complaints
B Wessén, J Honkanen and B Mälarstig

In Scandinavian buildings, moisture related problems are the dominating factor in explaining "sick buildings". In this study 420 buildings with pronounced health complaints of the occupants were investigated. The results showed that there were prevailing moisture problems in 65% of the buildings. These moisture problems resulted in vivid microbial growth, with microbial/chemical emissions of building material and microbial metabolites. The other buildings (35%) could be explained by historical moisture damages, which were backdated several years in time. IAQ complaints were investigated through questionnaires. Microbial biomass was determined as viable (CFU) and non-viable microorganisms as direct count of acridine orange stained microbial cells. Through the technique of direct-count, the dried-out microbial damages could be detected. The use of direct-count alone made it possible to explain the cause of 147 problem buildings out of 420. These buildings had otherwise not been able to remediate in a proper way.

4C1o2 Two unusual clusters of joint symptoms associated with sewer gases, mold exposure and atypical mycobacteria
T Husman, E Iivanainen, S Rautiala and A Tuomainen

Although the causes for rheumatoid arthritis and autoimmune diseases remain obscure, previous epidemiological studies have shown that rheumatoid arthritis is associated with age, female sex, smoking and certain occupational exposures. A few unusual clusters of autoimmune diseases have been found in association with moisture damaged buildings. In this paper, clustering of joint symptoms is described in a school building and a day care center in a rural Finnish town. Both buildings have prolonged indoor air problems associated with moisture damage, microbial growth in construction, insufficient ventilation and unpleasant odors of sewer gases. In microbial samples, high concentrations of moisture damage indicative microbes were detected in material samples and additionally, atypical mycobacteria were found in indoor air and material samples. A questionnaire study showed a high proportion of workers with muscle and joint pain and relatively high number of workers with doctor diagnosed rheumatoid arthritis or other type of collagenosis.

4C1p1 An analysis of outdoor air reference samples collected in the Mid-Atlantic region of the United States
M McGuinness, P McGuinness, M Dieda, M Yuran, D Wieller and A Warner

A seasonal outdoor air reference sample for the Mid-Atlantic region of the United States was ascertained in this study. *Cladosporium* spores and basidiospores were the dominant or sub-dominant fungi identified in countable fungal samples. *Cladosporium* species were also the dominant fungi identified outdoors on culture plates. The goal of the research was to approximate the types of species and measured levels present in the outdoor environment in the Mid-Atlantic Region of the United States. In essence, we tried to define what constitutes “normal” or “usual” microbiological conditions. Once we have defined “usual” conditions, it becomes simpler to determine “unusual” conditions when evaluating indoor environments for fungal exposures. We believe reference to this data may assist interpretation of sample results from indoor environments and assist risk assessment activities related to building assessments and clearance sampling activities following mold remediation projects.

4C1p2 MVOC emissions from fungi in HVAC systems
JS Park and K Ikeda

The purpose of this research was to investigate MVOC emissions from microorganisms in HVAC systems, and also to survey their effect on indoor air quality. MVOC emissions from fungi sampled in HVAC systems were analyzed in the laboratory. 2-methyl-2-Propanol, 2-Pentanone, methyl isobutyl Ketone and others MVOC were emitted from *Cladosporium*, *Aspergillus*, *Penicillium* and *Alternaria* which were detected in HVAC systems of five buildings. MVOC emission rates of four species were greatly varied according to species, though some MVOCs were emitted from all species. And it was found from the field measurement that MVOC thought to be from fungi, such as 2-methyl-1-Propanol, 2-Pentanone and methyl isobutyl ketone, were emitted by some HVAC systems. For these results, it is suggested that MVOC emissions from fungi in HVAC system became one of the indoor pollution sources.

4C1p3 Practical experiences with MVOC as an indicator for microbial growth
W Lorenz, T Diederich and M Conrad

The detection of hidden microbial growth in buildings by measuring airborne microbial particles is in many cases not successful. An alternative method is the measurement of microbial VOC, the volatile metabolism products of microorganisms, called MVOC. Fungi and bacteria emit MVOC during nearly all phases of their growth. The investigation of about 2000 buildings by measuring MVOC showed good results. An estimation scheme based on that and on additional measurements in emission chambers was developed, which can be used with very good reliability in practice under certain assumptions.

4C1p4 Microbial analysis of deposit dust on surfaces in buildings offices equipped with central air-conditioning installations: proposed microbial practical values with a new standardized method
C Chasseur, S Gofflot and N Nolard

A method for monitoring the microbiological composition of deposit dust in buildings equipped with HVACs (Heating, Ventilation, and Air Conditioning) is described. A piece of glass, firstly washed with an alcohol solution was placed on furniture for 7 days. Afterwards, 5 RODAC plates, were applied to the glass, and incubated at appropriate temperatures. From July 1999 to August 2000, more than 180 samples were made in 19 buildings for bacteria and in 24 buildings for moulds. Total bacteria and total moulds were counted. Main moulds were identified. Values situated between centile 50 and 75 were considered as a good practical range of values to determine the "average conditions" of different taxa: 18 to 34 CFU/plate for mesophilic environmental bacteria (25 C), and 14 to 28 CFU/plate for mesophilic human-source bacteria (37 C), 12 to 23 CFU/plate for mesophilic moulds. Thermophilic moulds (45 C), and thermophilic Actinomycetes (52 C) were rarely isolated.

4C1p5 Concentrations of airborne bacteria in 100 U.S. Office buildings
FC Tsai, JM Macher and Y-Y Hung

This paper presents preliminary summary statistics of airborne bacteria from the US Environmental Protection Agency (USEPA) Building Assessment Survey and Evaluation (BASE) study. Air samples were collected with a single-stage agar impactor in 100 large office buildings from 1994 to 1998. Five groups of culturable bacteria were identified at two incubation temperatures: (1) Gram-positive rods, separately actinomycetes and Bacillus species, (2) Gram-positive cocci, (3) Gram-negative rods, (4) Gram-negative cocci, and (5) unknown bacteria. Bacterial concentrations were compared by: (1) incubation temperature (30 C and 55 C, respectively, for mesophilic and thermophilic bacteria), (2) sampling location (indoors and outdoors), and (3) season (summer and winter). Mesophilic bacteria accounted for more than 80% of total culturable bacteria, both indoors and outdoors. Total bacterial concentrations generally were higher and more variable outdoors but similar in summer and winter. Indoor concentrations showed more seasonal difference and Gram-positive cocci were somewhat higher in summer.

4C1p6 Concentrations of cat and dust mite allergens in 93 U.S. Office buildings
JM Macher, FC Tsai, LE Burton and K-S Liu

The concentrations of cat (*Fel d*1) and dust mite (*Der f*1 and *Der p*1) allergens were measured in 93 of 100 BASE buildings. Sample mass ranged from 0.005–0.65 g (Median: 0.17 g) and was similar for all floor types and in summer and winter. *Fel d*1 was detected in 235 samples (94%) [Range: below detection limit (<DL)–19 µg/g; Median: 0.3 µg/g] but exceeded 8 µg/g (a sensitization threshold) in only two buildings. *Der f*1 and *Der p*1 were found in 113 (45%) and 128 (51%) samples (Ranges: <DL–53 µg/g and <DL–25 µg/g; Medians: <DL and 0.01 µg/g). Mite allergen exceeded 2 µg/g (a sensitization threshold) in five buildings and 10 µg/g (a symptom threshold) in three of those buildings. Mean *Fel d*1 concentrations were significantly higher in summer. No consistent patterns were observed between allergen concentrations and summer or winter temperature, summer humidity, building age, cleaning practices, or occupancy.

4C1p7 Correlations of particles, allergens, fungi and bacteria in air and chair dust in a hospital setting
CY Rao and JM Cox-Ganser

An environmental survey was conducted in two hospital buildings, one of which had a history of water incursion on the top floors and a cluster of work-related asthma. Sampling focused on air measurements for ultrafine particles (<1 µm), culturable fungi, culturable bacteria, fungal spores, endotoxin and latex allergen. Chair dust was analyzed for culturable fungi, culturable bacteria, endotoxin, mouse urinary protein, and latex, cat, dust mite, and cockroach allergens. In general, air concentrations were higher and chair concentrations were lower in the health complaint building. The air measurements for total fungal spores, total culturable fungi, ultrafine particles, and airborne endotoxin were significantly correlated with each other. Endotoxin concentration in chair dust was significantly correlated with total culturable fungi. No significant correlations were found between air and chair measurements. Our data suggest that exposure ranges both within and between buildings require consideration when investigating associations between health effects and environmental measures.

4C1p8 *Aspergillus* air pollution in operating theatres
N Vescia, D D'Alessandro, E De Simoni, M Fabiani and O Maggi

Aim of this paper is to present the results of a survey, performed in a teaching hospital of Rome, in order to evaluate the fungal air pollution of operating theatres (OTs) in which also high risk patients underwent an operation. The study was performed in 14 OTs. In each OT, 9 air samples were collected, using an active sampler SAS-PBI. Rodac plates with Sabouraud cloramphenicol and nutrient agar were used; the CFU were counted after incubation for 48h at 37 . Eight (57%) OTs showed at least one sample positive for *Aspergillus*. 12 (9,5%) of the 126 samples collected were positive. 33,4% of positive samples were collected near the air conditioning system outlet (*A. fumigatus*, *A. flavus, A. niger*) and a further 33,4% near the surgical table (*A. niger, A fumigatus, A. nidulans, A. flavus*). The remaining strains were isolated away from such critical places. All *Aspergilli* isolated were thermo-resistant.

4C1p9 Exposure of workers to mites in Finnish stores
A Harju, T Husman, K Immonen, R Merikoski and S Pennanen

We assessed the mite exposure of workers in Finnish stores by collecting samples of settled dust in six different stores. Mites were counted and identified microscopically. Mite allergen (*Der p* 1 and *Der f* 1) content of dust was analyzed with two-site ELISA. Mites were found in 18% to 100% of the samples, both from the storage and salesrooms. Seven samples (8%) contained more than 100 mites per gram dust and five additional samples (6%) more than 500 mites per gram dust, the suggested limits for mite sensitization and acute allergic symptoms, respectively. Most of the mites were storage mites

belonging to Astigmata (Acaridae, Glycyphagidae) or Prostigmata (tarsonemids). House dust mites were found only occasionally. Two dust samples out of 19 contained *Der p* 1 and none contained *Der f* 1.

4C2o1 Self-reported eye complaints and measurements of the superficial lipid layer of the tear film - comparison of risk factor profiles

S Brasche, M Bullinger, A Petrovitch, E Mayer, H Gebhardt, V Herzog and W Bischof

Profiles of impact factors on self-reported eye complaints and on objectively determined thickness of the superficial lipid layer of the tear film have been examined and compared using data for 817 office workers. Multiple logistic regression analysis reveals significantly increased risks for female gender, use of contact lenses and health deficits on the subjective perception of eye symptoms. Relating to a thin lipid layer (indication of dry eyes) significantly increased risks are detected for high particle load, high endotoxin concentration and female gender. A thick lipid layer (indication of inflamed eyes) is significantly associated with a low educational level. The risk factor profiles agree on a few points. Only the objectively examined thin lipid layer is significantly affected by indoor environmental variables. Therefore we conclude that there is a need for the development and application of objective clinical methods for field monitoring parallel to questioning.

4C2o2 Eye trigeminal sensitivity, tear film stability, and conjunctival epithelium damage in 182 non-allergic, non-smoking Danes

SK Kjærgaard, A Hempel-Jørgensen, L Mølhave, K Andersson, J-E Juto and G Stridh

The distribution of CO_2 induced irritation sensitivity in the eyes (COI), breakup time (BUT), and epithelium damage (ED) and the relations within these and with age, gender, eye irritation, and perceived environment was assessed in 182 non-allergic non-smoking persons from a random sample. BUT, COI at 16% CO_2 and ED was non-normally distributed. COI- average was normally distributed. BUT decreased, the threshold to CO_2 increased, and the irritation intensity at COI decreased with increasing age. ED was highest among women. The three physiological measures were not correlated, but BUT was lower among subjects rating exposure to dust, electrostatic fields, and dry air. ED was increased with experiences of high temperatures. COI increased with perceived draught, dry air, and noise exposure. The results may be used as reference data after controlling for age and gender. The relation to environment should be interpreted with reservation, but may generate new hypotheses.

4C2o3 Effects of low humidity on sensation of eye dryness caused by using different type of contact lenses in summer season

H Tsutsumi, A Toyota, T Akimoto, S Tanabe and T Suzuki

In order to clarify the effects of low humidity caused by the use of different types of contact lenses, the subjective experiments were carried out during the summer season, 2000 in a climate chamber. A total of 37 college-aged subjects, namely 10 ones with naked eyes, 7 with hard contact lenses, 10 with soft contact lenses and 10 with glasses, were exposed for 180 minutes. They were exposed at 4 different conditions. In all conditions, SET*(Standard Effective Temperature) was constant at 25.2 C. As the results of experiments, effects of low humidity on the sensations of eye dryness and discomfort caused by contact lenses were observed. The general dryness sensation was associated with the eye dryness. Break up time of hard contact lenses wearers was significantly shorter than that with naked eyes, while the environmental humidity did not affect on their break up time.

4C2o4 Limiting criteria for human exposure to low humidity indoors

DP Wyon, L Fang, HW Meyer, J Sundell, CG Weirsøe, N Sederberg-Olsen, H Tsutsumi, T Agner and PO Fanger

Thirty subjects (17 female) were exposed for 5 hours to clean air at 5%, 15%, 25% and 35% RH at 22 °C. Another 30 subjects (15 female) were similarly exposed to air polluted by carpet and linoleum at 18, 22 and 26 °C with humidity 2.4 g/kg dry air (=15% RH at 22 °C), and at 22 °C, 35% RH. The subjects performed simulated office work throughout each exposure. Building Related Symptom (BRS) intensity was reported on visual-analogue scales. Tests of eye, nose and skin function were applied. In these short exposures subjective discomfort, though significantly increased by low humidity, was very moderate even at 5% RH. However, tear film quality as indicated by the Mucous Ferning Test deteriorated significantly at RH<25% and at T>22 °C, significantly more rapid blink rates were observed at 5% than at 35% RH, and skin became significantly more dry at 15% than at 35% RH.

4C2o5 Recall, information and ascertainment bias - fatal methodological flaws in studies of indoor air quality and adverse health
JS Weiss, and MK O'Neill

This paper examines factors that influence the reliability of ascribing a causal relationship between subjective symptoms identified by questionnaire and the attribution of these complaints to particular problems observed in the indoor environment. Studies, both from the medical literature as well as independently commissioned by building owners were used to demonstrate common limitations in study design. Of the many sources of bias that may be introduced, the ones with the most influence to adversely impact the outcome of a study are ascertainment bias, recall bias and information bias.

4C2p1 The relationship between indoor climate and salt concentration in the soup
T Sasaki, M Uozumi, M Sugawara and M Hayashi

The rate of the attacks of cerebral apoplexy is high in the north of Tohoku District in Japan. Although the cause is considered to be the coldness in residences in winter, the relationship has not been proved yet. The authors have made a survey on 18 residences in Tohoku District. The temperature distribution and the salt concentration in the soup of a meal were measured. The results show that positive correlation was clearly seen between the maximum difference of indoor temperature and the salt concentration in the soup the residents usually eat. Temperature difference in a residence is thought to be a main factor in the people's taste for salty meals because of their physiological need for salt. Salt is a factor to raise blood pressure, and if a person with hypertension moves rapidly to a place that has a large temperature difference, the risk of apoplexy attack increases.

4C2p2 Individual and environmental variables in relation to indoor air symptoms among office employees
K Skyberg, K Skulberg, W Eduard, K Kruse1, E Skåret, F Levy and H Kjuus

We report a screening questionnaire study in 11 companies without previously recognised indoor air problems. 4556 personal questionnaires were returned from office employees. Individual factors, workload, perceived physical work environment, allergy and symptoms were asked for. Engineers filled in a technical questionnaire on building characteristics, floor surface materials, ventilation, cleaning procedures, heating and cooling, covering 3562 employees. Frequent symptoms were feeling fatigue or heavy-headed, eye irritation and dry facial skin. Women reported symptoms more frequently than men. Employees with allergy had a 1.7 – 2.5 times risk of general symptoms, skin symptoms and mucosal symptoms. The risk of a high symptoms score increased with daily VDU work time. Passive smoking and psychosocial load were also relatively strong predictors of symptoms. Weekly cleaning as compared to a frequency of cleaning 2-4 times a week increased the risk of symptoms. A high ventilation flow and long daily ventilation time was not associated with few symptoms.

4C2p3 Psychological factors influencing SBS symptom reporting
A Gidlöf Gunnarsson and B Berglund

In health studies, self-reported somatic symptoms are consistently associated with psychological factors (attention and attribution processes, mood, somatization). Few empirical SBS studies have focused specifically on this relationship. A case-control questionnaire study was conducted in which both cases and matched controls were apartment-building areas comprising between 80-300 apartments. For the cases, but not for the controls, the buildings had been renovated during the last 10 years because of suspected SBS or other indoor air problems. Since no significant case-control differences were found, the data were pooled to one sample and submitted to a multiple regression analysis. Number of SBS-symptoms was associated with perceptions of indoor-environmental factors, somatization, symptom attribution, worries of indoor-environment health effects, female gender, negative affectivity, and sensitivity to chemical products. The findings are discussed in relation to symptom-reporting theories involving mental models, attribution, and personality characteristics.

4C2p4 Individual differences in sensitivity to indoor air complaints: physical or psychological?
JL Leyten and AC Boerstra

An overview of three relevant and comparatively methodologically strong studies indicates that individual differences in proneness to experience indoor air complaints are not of a psychological nature. That means that they are not caused by differences in expectations or differences in general proneness to complain. However more research is needed.

4C2p5 Personal and environmental characteristics, occupational factors and psychosocial correlates of sick building syndrome
K Heslop

The relationship between personal and environmental characteristics, occupational factors and psychosocial correlates of sick building syndrome was investigated among 348 employees occupying two buildings in South Africa. One building was

characterized as 'sick', whilst the other was not a known sick building. There was a significant relationship between several personal characteristics, environmental characteristics, occupational factors and the total number of symptoms reported. Respondents in the 'sick' building had a propensity to remain absent from work for significantly more days, and experienced greater productivity decrements.

4C3o1 Prevalence of potential sources of indoor air pollution in U.S. Office buildings
JR Girman, BJ Baker and LE Burton

As part of its effort to collect baseline information about office buildings, the U.S. Environmental Protection Agency collected information on the prevalence of sources in or near 100 randomly selected office buildings in the USA. Indoor sources surveyed included special use areas (e.g., kitchenettes, parking garage, laboratories, print shops), cleaning product and pesticide use, renovation activities, water damage, and storage. Outdoor sources surveyed included nearby construction, heavy traffic, power plants, industrial stacks, emergency generators and trash dumpsters. For some sources, the frequency of use is also presented. These data can be used by as model inputs to estimate concentrations and exposure as well as be used to assist policy makers making decisions about which sources deserve attention.

4C3o2 The Hokkaido healthy housing (H3) study: study design and baseline findings
S Nakai, M Takeda, K Nishiyama, N Shinohara, K Kumagai and Y Yanagisawa

In the past several years, the insulation efficiency of houses in Japan has been much improved, but new indoor environment problems (e.g., indoor air pollution emitted from building materials, condensation, etc.) have become a concern. Residents usually live in the same house for many years. It is important to investigate indoor environments longitudinally. In order to study the indoor environment and the change in pollutant levels, we formed two cohorts to follow in Hokkaido. The first cohort consists of newly constructed houses. The second cohort consists of houses built by one construction corporation in Hokkaido. This cohort is divided into three groups: newly built houses, 5-year old houses and 10-year old houses. In this paper, the study design and baseline findings of the indoor environment measurements in 2001 are presented.

4C3o3 The French permanent survey on indoor air quality survey design in dwellings and schools
S Kirchner, N Pasquier, D Cretier, S Gauvin, F Golliot, D Pietrowski and C Cochet

Decided by the French Government in 1999, the permanent survey on indoor air quality provides data for risk assessment and risk management related to exposure to indoor air pollution. Among the potential investigated indoor spaces including all types of indoor environments (excluding industrial ones), dwellings and schools were identified as priority for the first investigations. The first survey includes 1) measurements on 40 priority indoor parameters: COV, NO_2, CO, CO_2, bacteria, moulds, allergens, MMMF, temperature, humidity, 2) questionnaires on building characteristics, occupants description and time activities diaries. For radon, lead and asbestos existing database will be assessed. For particulate matters, legionella and biocides, specific measurement methods are being developed for later inclusion in the survey. A pilot survey has been conducted in 2001 on 99 sites. A full-scale survey on 800 investigation sites should start from 2002. The selection of buildings will aim at a representative sampling of the French building stock.

4C3o4 Air pollutant exposure of adult population in Milan (EXPOLIS study)
M Maroni, P Carrer, D Cavallo, M Jantunen, K Katsouyanni, N Kuenzli, R Sràm, D Zmirou, and M Della Torre

In the framework of the EXPOLIS project a random Milan population sample of 250 subjects was selected for questionnaire applications ("diary sample"). An "exposure sample" (50 office workers) was selected for pollutant exposure evaluation. The results of the Milan study are compared with those of the other European centers participating to the project (Athens, Basel, Grenoble, Helsinki and Prague). The average time spent by the subjects in the different microenvironments varies little between the cities (95-97% of their time indoors, 2-4% in commuting and 1% outdoor). High $PM_{2.5}$ workplace levels were found in Milan and Athens (58.6 and 60.1 µg/m3). In all the cities TVOCs and benzene levels were higher in indoor environments and in personal exposure than outdoor concentrations. In all the cities the highest CO exposure were found during commuting (1.5-6.5 mg/m^3). The degree of perceived air pollution annoyance was higher during commuting than at workplace and home.

4C3o5 Indoor air quality in English homes - introduction and carbon monoxide findings
GJ Raw, SKD Coward, JW Llewellyn, VM Brown, DR Crump and DI Ross

BRE has conducted a national survey of air pollutants in 876 homes in England, to increase knowledge of pollutant levels and the factors associated with high concentrations. Homes were monitored, using passive samplers, for carbon monoxide (CO), nitrogen dioxide, formaldehyde and total volatile organic compounds. Also, in each household an interviewer administered a questionnaire about the characteristics of the home, the occupiers and their activities. This paper describes (a) the survey objectives, design and approach and (b) the findings on 14-day time-weighted average CO levels. Concentrations of CO were

higher in kitchens than in bedrooms, but significantly correlated. Higher levels of CO were found in autumn and winter, in urban areas, in homes with a gas oven, homes with unflued fossil fuel heaters, and in smokers' homes. The CO concentration did not exceed the WHO 8-hour average guideline value in any home.

4C3p1 Indoor air quality in English homes - nitrogen dioxide
SKD Coward, GJ Raw, JW Llewellyn and DI Ross

BRE has conducted a national survey of air pollutants in 876 homes in England, to increase knowledge of pollutant levels and the factors associated with high concentrations. Homes were monitored, using passive samplers, for nitrogen dioxide (NO_2), carbon monoxide, formaldehyde and volatile organic compounds. This paper reports the findings on 14-day time-weighted average NO_2 levels. Outdoor NO_2 concentrations were higher in autumn/winter and in urban areas. Kitchen levels were higher than outdoor levels in homes with gas cooking. Bedroom levels were lower than outdoors due to sink effects. Indoor NO_2 levels were highest in urban homes, older homes, terraced houses, homes with gas cooking and smokers' homes. Seasonal variation in indoor levels resulted mainly from indoor sources, rather than outdoor variations. The WHO air quality guideline for annual exposure to NO_2 was exceeded in more than 50% of kitchens that had a gas oven.

4C3p2 Indoor air quality in English homes - formaldehyde
VM Brown, SKD Coward, DR Crump, JW Llewellyn, HS Mann and GJ Raw

BRE has undertaken a national survey of air pollutants in 876 homes in England, to increase knowledge of pollutant levels and the factors associated with high concentrations. Homes were monitored, using passive samplers, for carbon monoxide, nitrogen dioxide, formaldehyde and volatile organic compounds. This paper reports the findings on 3-day time-weighted average formaldehyde levels. These levels were higher in newer homes (increasing from 1940 onwards); in homes with a particleboard floor, especially a particleboard floor in the room where the sampling took place; and in summer and autumn than in winter or spring. The mean concentrations were well within the WHO air quality guideline, but the guideline was exceeded in six homes (0.7% of the total), of which five were under three years old.

4C3p3 Indoor air quality in English homes - VOCs
VM Brown, SKD Coward, DR Crump, JW Llewellyn, HS Mann and GJ Raw

BRE has undertaken a national survey of air pollutants in 876 homes in England, to increase knowledge of pollutant levels and the factors associated with high concentrations. Homes were monitored, using passive samplers, for carbon monoxide, nitrogen dioxide, formaldehyde and volatile organic compounds (VOCs). This paper reports findings on 28-day time-weighted average levels of total VOCs (TVOC) and seven individual VOCs. Important factors for TVOC and/or one or more individual VOCs include dwelling age, season, building location (urban or rural), having an integral or attached garage, vehicle fuel, smoking, use of toiletries and painting and decorating. In general, TVOC levels were low but 5% of homes exceeded 1000 mg m^{-3}. The current EU target for benzene in outdoor air was exceeded in 4.3% of homes, and 0.7 % exceeded the WHO 1-week guideline for toluene.

4C3p4 A study of the IAQ of residential buildings in Singapore
NH Wong, BRJ Huang, KW Tham, C Sekhar and DKW Cheong

IAQ measurements were carried out in 3 residential dwellings in Singapore to find out the indoor air quality of the bedrooms. It was found that when the subjects utilized air-conditioners while sleeping, there was a considerable build-up of carbon dioxide (>1000 ppm) for all types of air-conditioners. These CO_2 levels were substantial higher as compared to naturally ventilated bedrooms. A survey was also conducted to investigate whether occupants exhibited Sick Building Syndrome (SBS) symptoms while sleeping in air-conditioned as well as naturally ventilated bedrooms. A comparison showed that almost all occupants who used air-conditioners while sleeping exhibited one or more SBS symptoms and these occupants usually displayed more SBS symptoms after using air-conditioning than when they utilised natural ventilation. The survey also revealed that the frequency and duration of usage of air conditioning has important impact on the exhibition of the SBS symptoms.

4C3p5 The perception of dust and dirt in Swedish school environments
K Andersson, G Stridh, I Fagerlund and W Aslaksen

An interesting observation in large-scale surveying of schools in Sweden was the higher frequency of complaints about dust and dirt in large municipalities and school districts in comparison to in smaller ones. Complaints of insufficient cleaning and dust on surfaces were highly correlated (r=0.81) and common in all municipalities and therefore hardly responsible for the observed difference. In larger municipalities the occupants complained more about badly performed cleaning compared to in small ones (32.9 % and 5.1 % respectively). By comments it was obvious that in small municipalities the cleaners, who usually were familiar to the occupants, were assessed to do "their very best", but had insufficient time to do a good job. In larger

municipalities sub-contractors were hired for the cleaning. The admini-stra-tion of cleaning therefore seems to be of importance.

4C3p6 One year measurement of indoor air quality in building offices
A Ginestet, M Henninot and D Pugnet

The main objective of our study was to know more about indoor air quality in building offices over a long period. Our study has been carried out in one building located downtown Lyon (France). Measurements have been carried out one day each month during a one year period. Indoor air quality in the offices along with the one of air flows of the HVAC (Heating, Ventilating and Air Conditioning) installation (outdoor air, blown air and returned air) has been characterised by temperature and relative humidity of air, dust concentration level, air biocontamination and CO_2 concentrations. Air flow from the fan coil units has been measured too. Air filters of the HVAC installation have been characterised in the field and in laboratory (fractional efficiency, pressure drop, mass of dust arrested by the filters). Our results also show how the HVAC installation works.

4C3p7 Indoor air quality of office buildings in the Helsinki area
H Salonen, K Reijula, R Riala, S Lappalainen, and T Tuomi

Indoor air quality (IAQ) was investigated in 19 open-plan offices and 30 office rooms in order to compare the differences in these two different types of office environments. No moisture or mold problems had been reported from the present buildings, but the employees had complained about the IAQ. The results revealed only slight differences in the IAQ of the two different types of office environments. The results indicate that high temperature, low relative humidity and man-made mineral fibers (MMMF) were the most common IAQ problems occurring in offices and possibly causing indoor air complaints.

4C4o1 Modeling the spread of anthrax in buildings
RG Sextro, DM Lorenzetti, MD Sohn, and TL Thatcher

The recent contamination of several U.S. buildings by letters containing anthrax demonstrates the need to understand better the transport and fate of anthrax spores within buildings. We modeled the spread of anthrax for a hypothetical office suite and estimated the distribution of mass and resulting occupant exposures. Based on our modeling assumptions, more than 90% of the anthrax released remains in the building during the first 48 hours, with the largest fraction of the mass accumulating on floor surfaces where it is subject to tracking and resuspension. Although tracking and resuspension account for only a small amount of mass transfer, the model results suggests they can have an important effect on subsequent exposures. Additional research is necessary to understand and quantify these processes.

4C4o2 Improved transport modeling for indoor air pollutants by adding zonal modeling capability to a multi-zone model
Z Ren and JR Stewart

A zonal model has been nested within a multizone model (COMIS) to produce a program which can be used to make improved predictions about local concentrations and the spread of pollutants through buildings. New code was added to implement thermal energy balance equations and pollutant source emission models. Numerical simulations from the new program have been compared with published experimental data and results from other models and demonstrate that this new program is a promising tool for predicting air flows, temperatures and pollutant dispersion within buildings.

4C4o3 A zonal model for predicting simultaneous heat and moisture transfer in buildings
KC Mendonça, C Inard, E Wurtz, FC Winkelmann and F Allard

To study the influence of adsorption/desorption by building materials on indoor air behavior, we have developed a zonal model to predict temperature and moisture fields in a room. This model is composed of two sub-models that represent indoor air conditions and room envelope. The heat and mass transfer across the building envelope are predicted by the “evaporation and condensation” theory. The resulting set of non-linear coupled equations is solved simultaneously by the oriented-object platform, SPARK. In a study case with 27 zones the proposed model is compared to one without adsorption/desorption by building materials. The results indicate that adsorption/desorption influences the moisture field in confined spaces.

4C4o4 Numerical simulations of indoor air quality in a French house: study of the distribution of pollutants in each room, modeling contaminant exposure
B Ribot, QY Chen, JM Huang and H Rivoalen

The study presented in this article concerns the numerical simulation of airflows and occupational exposure to household contaminants. A finite volume code (CFD) is used to simulate a single-family house with several ventilation, heating, and climatic conditions. The concentration and occupational exposure levels of household contaminants CO_2, CO, HCHO, NO_2, and water vapour, all from human metabolism, along with those from gas cooking and smoking, are evaluated over a day for a generic occupational schedule of four family members. The ventilation types incorporated bimodal, relative humidity controlled and balanced systems, coupled with either room convectors or a combination of a heated floor and room convectors. Winter and summer climates provided a wide range of outdoor conditions, and also isolated the effects of the heating systems. Comparisons between the combinations of systems are presented, based upon the breathed concentrations of each family member throughout a normal day. The occupational exposures of the family are also assessed.

4C4o5 Study of particle dispersion in buildings with large eddy simulation
Y Jiang, C Beghein and Q Chen

To predict indoor pollutant level requires investigating the particle trajectories of the pollutants in buildings. This investigation used a large eddy simulation (LES) program, which solves large-scale flow motion and models subgrid-scale stresses, to predict three-dimensional and transient airflows in buildings and implemented a Lagrangian model in the LES program to simulate particle movement in a building. The program was validated with good accuracy by the experimental data of the dispersion of three different types of solid particles in a decaying homogeneous isotropic turbulent airflow. The program was further applied successfully to study particle dispersion in a six-room building.

4C4o6 Reinforced exhaust system: local ventilation with enhanced capture range
D Gubler, A Moser, P Sprecher and T Rueegg

Local ventilation equipment can help to improve the air quality in the workers breathing zone, but existing devices have a limited capture distance. Therefore, installed systems are often not correctly used by workers. The "Reinforced Exhaust System" is a new local ventilation principle for industrial ventilation with improved efficiency for capturing contaminants released by working processes like welding. The system was first proposed in 1965 by C.P. Aaberg in Denmark. The potential of the principle was shown by different investigations (Saunders et. al., 1993 or Hunt et. al., 1993); nevertheless, it did not find applications in industrial premises until now. The paper discusses the optimisation process of the device using Computational Fluid Dynamics (CFD). In particular, a computational assessment of different local ventilation devices is described and the underlying studies are referenced. Finally, the transformation of the results into a working prototype for a demonstration workplace, which was installed in a Swiss manufacturing plant is described.

4C4p1 Application of visualization methods in local exhaust research
E Janotkova and M Pavelek

The contribution deals with the interferometric visualization and a smoke method application in the course of local exhaust systems efficiency research. The interferometric visualization using Mach-Zehnder interferometer has been applied for the research of gaseous contaminants propagation from different sources and for a local exhaust system of these sources. The smoke visualization method has been applied for higher effects to determine efficiency of local exhaust capture. As the smoke method provides clear information of the flow picture in front of the exhaust opening, it allows to determine easily suitable operating parameters of the exhaust system. In this contribution, the attention is concentrated on a flanged exhaust hood and on a reinforced exhaust system combining exhaust and supply of air.

4C4p2 Study of particle movement in ventilation system
Y Li, J Heng and Z Chen

This paper presents the investigation results on a simulation program, which calculates the particle trajectory under different airflow patterns in the multi-zones structure building. The numerical simulation is first used to predict airflow pattern and ventilation performance. Then, the particle movement is determined by employing Lagrangian method. The simulation identifies the characteristics of ventilation and indoor air quality. The investigation results indicate that particle deposition and migration are mainly influenced by particle properties, ventilation conditions and airflow patterns. Smaller particles have greater potential effect on indoor air quality than larger particles.

4C4p3 Prediction of particle deposition in turbulent indoor flows with a 3D Lagrangian model
M Abadie, K Limam and F Allard

This study describes the development of a three dimensional (3D) Lagrangian code of particle transport in indoor turbulent flows. This approach consists of integrating transport equations for each particle at each time step to determine successive positions of the particle. The first challenge was to calculate instantaneous velocities of the airflow. The mean component of these velocities was calculated by a classic CFD code. A stochastic process based on the Gosman and Ioannides method generated the fluctuating component. Corrections were applied to better fit experimental results. The second challenge was the determination of the wall-particle interactions. These interactions were evaluated through the simulation of small-scale experiments to measure particles deposition on real textures encountered in building surfaces. Two kinds of boundary conditions were tested: a particle rebound probability and a critical velocity of rebound. The latter seems more appropriate for simulating the interaction between textures and 5.0 mm particles

4C5o1 Respirable particulate levels in rural households of Andhra Pradesh, India - daily concentrations and time activity data
K Balakrishnan, S Sankar, R Padmavathi, J Arnold, S Mehta, KR Smith, C Rao, S Kumar, P Kumar, S Akbar and K Lvovsky

Indoor air pollution associated with combustion of solid fuels seems to be a major contributor to the national burden of disease in India but few quantitative exposure assessment studies are available. This study quantified daily average concentrations of respirable particulates in 420 rural homes from three districts of Andhra Pradesh, India and recorded time-activity data from 1400 household members. Mean 24-hr average concentrations ranged from 70 to 850 $\mu g/m^3$ (Geometric mean- 56 to 570 $\mu g/m^3$) in gas versus solid fuel using households respectively. Concentrations were significantly correlated with fuel/ kitchen type and fuel quantity. Household sub-groups including women/men/children differed significantly in total time spent in kitchen/living/outdoor area microenvironments. The data are being used to calculate population exposures and develop a model to predict quantitative categories of exposure based on housing and fuel characteristics. This would facilitate the development of a regional exposure database and enable better estimation of health risks.

4C5o2 Levels and determinants of indoor air pollution exposure in young Guatemalan children
N Bruce, J McCracken, R Albalak, M Schei, KR Smith and V Lopez

Objective: To assess levels and determinants of kitchen pollution and child exposure associated with a range of stove/fuel combinations in rural Guatemala. Methods: 204 households with children <18 months, measurement of 24-hour mean kitchen CO and child CO, and 24-hour kitchen $PM_{3.5}$ in sub-sample. Results: Almost 50% homes still used open fires, around 30% chimney stoves (planchas) mostly from a large donor-funded programme. Homes with planchas had lowest kitchen levels: mean (95% CI) CO of 3.09 (1.87-4.30) ppm vs. 12.4 (10.2-14.5) for open fires. The same ranking was found for child CO. Multivariate analysis showed stove/fuel type was the most important determinant of kitchen CO ($p<0.001$), with some effect of kitchen volume and eaves. Stove/fuel type was also the key determinant of child CO ($p<0.001$), with some effect of child's position during cooking. Conclusion: Community stove programmes have been effective in reducing smoke exposure of young children, but further improvement is needed.

4C5o3 Exposure assessment for a rural community using biomass fuel in traditional and improved stoves
RS Patil and S Dash

In developing countries biomass fuels are burnt mostly in primitive stoves causing serious implications for exposure and health. To overcome this problem, the most common intervention attempted is the introduction of improved smokeless stoves. The performance of these new stoves is tested under controlled conditions but there is a dearth of data under field conditions. The objective of this study is to evaluate the effectiveness of the improved stoves in terms of personal exposure in a rural community. In the study Respirable Particulate Matter (PM_5) and CO were monitored on a longitudinal basis i.e., before and after the introduction of intervention (improved stove). Results show improved stoves reduce average PM_5 concentrations by 37% for personal sampling and CO concentrations by 54% near the stove during cooking period. For the community as a whole there is an average 40 % reduction in daily-integrated exposure to PM_5 with the improved stoves ($p<0.0001$).

4C5o4 Relationship among personal, indoor and outdoor fine particle concentrations for individuals with chronic obstructive pulmonary disease living in three areas of Mexico City
M Cortez Lugo, F Holguin Molina, M Hernández Avila1, E Palazuelos Rendón and R Santibáñez Ruelas

Our study characterized indoor and outdoor exposure to PM_{10} and $PM_{2.5}$ in 39 participants with varying degrees of chronic obstructive pulmonary disease (COPD) from the National Institute of Respiratory Diseases in Mexico. Participants were selected based on the area of residence: from the southeast, downtown and southwest areas of the Mexico City Metropolitan Area, and were followed from February through November 2000. Mini-volt samplers were used to measure indoor and outdoor

levels of PM_{10} and $PM_{2.5}$, and personal $PM_{2.5}$ monitoring devices were also used. The highest concentrations of particulates were registered during winter, maximumPM_{10} , $PM_{2.5}$ and personal $PM_{2.5}$ levels were 180.6, 160.5, and 126.8 mg/m^3 , respectively. The highest correlation observed for the study variables, was between personal $PM_{2.5}$ and home indoor $PM_{2.5}$ levels. On average, the southeast area registered the highest levels of PM_{10} and $PM_{2.5}$.

4C5o5 Addressing health and household energy problem in Zimbabwe

L Mika

The success of past stove projects implemented in Southern Africa has been limited mainly due to some social shortcomings. Their focus has been on reducing fuelwood consumption, environment protection and improved fuel supply. Few projects attempted to address the effects of indoor air pollution despite its negative health effects. Recognising this problem, two stove programmes in Zimbabwe have integrated energy saving with improvement in health. Results of an energy and health baseline survey done in two districts of Zimbabwe show that there are serious fuelwood shortages and the communities are at risk from high smoke levels. Measured CO levels in kitchens were within the range of 300 – 1000 ppm. The residence time for women and children in the kitchens were on average 5 hours per day. In Chimanimani District, medical records showed that ARI was prevalent among children below the age of five and in adults it was second to malaria.

4C5p1 Reducing indoor air pollution through participatory development in rural Kenya

N Bruce, E Bates, R Nguti, S Gitonga, J Kithinji and A Doig

Objective: To evaluate effectiveness of smoke reduction interventions in rural homes. Methods: 24-hour kitchen respirable particles ($kPM_{3.5}$), kitchen CO (kCO), and personal CO (pCO) for the cook were assessed before and after interventions in Kajiado (n=25) and West Kenya (n=25). Women participated in developing interventions, including improved stoves (12), enlarged windows (all) and eaves (27), and hoods (17). Results: Pollution/exposure levels were high: mean 24h $kPM_{3.5}$ 5,530 mg/m^3 (Kajiado), 1,710 mg/m^3 (West Kenya); 24h kCO 74.7 and 8.8 ppm respectively; 24h pCO 6.98 and 4.16 ppm respectively. Following interventions, there were marked reductions in all measures. For 15 homes receiving hoods, $kPM_{3.5}$ was reduced 75% (p=0.001), kCO by 77% (p=0.001) and pCO by 35% (p=0.011). Enlarged eaves and windows reduced $kPM_{3.5}$ by 62% (p=0.001) in West Kenya. Residents appreciated better lighting, ventilation and smoke reduction, although concerns about privacy required attention. Conclusion: This participatory approach achieved effective smoke reduction, and promoted interest in further development (155).

4C5p2 Using household characteristics to predict respirable particulate levels in rural households of Andhra Pradesh, India

S Mehta, KR Smith, K Balakrishnan, S Sankar, R Padmavathi, S Kumar and S Akbar

Using Andhra Pradesh, India as a case study, CART and logistic regression were used to assess how household and fuel characteristics can be used to predict whether households have high or low concentrations of respirable particulate matter in kitchen and living areas. Results of both techniques indicate that high concentrations can be classified more accurately than low concentrations. Fuel type is the most important prediction parameter. Indoor kitchens are more likely to have high kitchen concentrations. For living-area concentrations, the specific type of kitchen is less important than whether the kitchen is separate from the living area. Improvements in kitchen ventilation do not occur at the expense of air quality in the living area. Using both kitchen type and kitchen ventilation does not improve prediction over using one of these parameters and a site visit can help inform which to use in future studies.

4C5p3 Modeling of indoor-outdoor relation of air pollutants in Mumbai City

RS Patil and VA Kumar

The objective of this study was to develop an Indoor – Outdoor (I/O) air pollutant concentration model and to validate it with monitored data. The model can be used to predict indoor concentrations and thereby personal exposure levels from outdoor concentrations, which are historically routinely monitored, and relatively easier to measure than indoor levels. The study was conducted in Mumbai City for three typical areas viz. residential, residential cum mixed and industrial, which represent increasing order of outdoor pollution. Middle income group houses were selected where kerosene and LPG fuels are used for domestic cooking. Simultaneous monitoring of both indoor and outdoor concentration of Respirable Particulate Matter (PM_5) and NO_2 was done. An indoor air quality model based on mass balance approach was used to predict I/O ratios. The overall percentage error between observed and model predicted I/O values is –26.0%. Over prediction by the model may be due to the assumptions in inclusion of removal processes.

4C5p4 The investigation and analysis of indoor air pollution in China
Z Tonghua, T Guangbei, W Lai, C Hua and L Jing

People spend more than 80% of their time in room. It is very imperative that the indoor air pollution problem be studied, because it does great harm to people's health with the increasing of the sources of indoor air pollution. The main reasons of indoor air pollution are found by investigation and analysis in some Chinese metropolises, and some measures to improve the indoor air quality are put forward.

4C5p5 Residential air quality in wood burning houses in Costa Rica
K Lee and E Park

Many people in developing countries rely on biomass fuels for cooking. The high levels of $PM_{2.5}$ and PM_{10} in houses with biomass fuels may be a significant risk factor of respiratory illness. We measured residential air quality to improve our understanding on the extent and severity of indoor air quality from biomass combustion. The residential air quality was measured in houses with a wood burning stove in rural areas of Costa Rica. $PM_{2.5}$ and PM_{10} concentrations were measured by single stage impactors and particle size distribution was continuously measured by an aerodynamic particle sizer. CO and CO_2 concentrations were measured. $PM_{2.5}$ and PM_{10} measurements had averages of 42.3 $\mu g/m^3$ and 126.5 $\mu g/m^3$, respectively. Average CO concentrations were between 0.5 and 3.3 ppm. Although particulate concentrations showed high peaks during cooking periods, the levels were quickly decreased after cooking. People at risk, especially women and children, may be exposed to high level of particulates during cooking.

4C5p6 Impact of indoor air pollutants on health of women – a case study
A Mandal and S Mandal

About three quarters of household use biomass as their primary fuels, more than 90% of them use wood or animal dung. Moreover, in India, about one half of all household do not have separate kitchen (IIPS, 1995).Indian cooking needs long hours and since tobacco smoking is not common in Indian women, the main smoke exposure in women is from kitchen. Indian cooking also use lots of oils and gee as frying media, producing oil vapors which are inhaled. So, a study was undertaken to find out the impact of these pollutants on the health of women. The base line health status was determined by questionnaire. Total suspended particulate matter (TSP), smoke density and oil vapors were measured. Results strongly suggest that the use of biomass fuels and wood for cooking increase the concentration of TSP in Indoor and also increase the risk of respiratory infection, cataract and other diseases.

4C5p7 Impact of ambient air pollutants on the indoor air quality in Mumbai
JM Deshpande and UD Holla

SPM, the major pollutant in Mumbai's air exceeds the Indian annual standards for the residential area. The RSP component is minimum in Summer [24%] and maximum in Monsoon [35%]. An epidemiological survey, carried out in (i) commercial cum industrial [Parel] (ii) urban clean [Borivili] having pollution index 76 and 56, showed health morbidity 37% & 26% respectively. Since the person spends 80% to 90% of the time indoors, a pilot survey of the indoor and the monitoring site air quality was carried out. Good correlation between RSP at the monitoring site & indoors during Winter & Summer and weak correlation during Monsoon was observed. Validation of Mass balance model reveals that the predictions are having errors in the range -4.5% to-47.6 %. The over prediction may be due to the location of indoor monitors in living room, whereas the significant indoor pollution source was in kitchen.

4C6o1 Thermal comfort in real live buildings: proposal for a new Dutch guideline
AC Boerstra, SR Kurvers and AC van der Linden

In practice the commonly used criteria for thermal comfort in Dutch buildings (weighted factor method) often lead to confusion. The criteria are hard to understand for non-experts, and many doubt the validity of the present criteria. A project was initiated in order to formulate alternative ways to predict, evaluate and communicate thermal comfort performance of buildings. The result: a draft version for a new Dutch guideline for design and evaluation purposes. Properties of the new guideline are: 1) It distinguishes between requirements for centrally controlled and for occupant controlled indoor environments. 2) Limits are set in terms of maximum allowable operative indoor temperatures. These increase with increasing average outdoor temperature, anticipating on adaptation effects. 3) Limits are set in terms of maximum allowable operative indoor temperatures. These increase with increasing average outdoor temperature, anticipating on adaptation effects.

4C6o2 Effects of velocity variations in ventilated room on comfort, affect and cognitive performance
H Wigö, I Knez and M Sandberg

In many buildings there is no cooling system apart from a ventilation system. The only remedy available to remove excess heat is to supply large quantities of cold air. This may, however cause unacceptable draught problems. There are indications that intermittent variations in velocities can be beneficial to people's perceived comfort. By introducing velocity variations we hypothesised that people's sensation of a pleasant indoor climate can be met at higher room temperatures than otherwise. The velocity variations were obtained by using commercial ventilation systems (mixing and displacement ventilation) and a ceiling fan. A between-subject design was employed in this study. The experiment lasted for 80 minutes, and the subject's perceived comfort and air quality, self-reported affect and cognitive (intellectual) performance were measured. The velocity variations did not have any effect on perceived thermal comfort. There were, however indications for an effect on perceived air quality, self-reported affect and cognitive performance.

4C6o3 Optimal temperature setting of indoor air-conditioning after walking outdoors in summer and winter
A Ohori, M Harada and S Kuno

The aim of this study is to investigate an optimal air-conditioning adjustment for an indoor space where people come in and out. The authors conducted the experiments by measuring the physiological and psychological responses of subjects who walked outdoors and then entered a chamber. Psychological responses to summer climate were grouped within three categories of: "cool" - "comfortable," "hot" - "uncomfortable," and "cold" - "uncomfortable." These responses are related with subjects' perspiration. It seems impossible to completely eliminate "uncomfortable" conditions by controlling room temperature or humidity. Thus, a personal air-conditioning system is recommended. In winter, there were few "cold" responses at 25 deg C, although there were some at 22 deg C. "Cold" responses occurred when the outdoor temperature was low. Therefore, it appropriate temperature adjustment seems to be effective. If the outdoor temperature is low, a high room temperature is required.

4C6o4 Thermal comfort and thermoregulation for elderly people taking light exercise
K Tsuzuki and T Iwata

This paper presents the results of subjective experiments on the thermal comfort requirements of elderly people taking light exercises. The experiments were conducted in a climatic test chamber. Eighty elderly subjects were exposed to four conditions, two thermal conditions (23 C under 60 % RH and 27 C under 60% RH) combined with two exercise conditions. The duration of the experiment for each subject was 180 minutes. The results showed that the exercises increased the mean skin temperature and the metabolic rate. However, evaporative water loss did not significantly increase with the increase of the metabolic rate. The exercises also increased Thermal Sensation Vote. Generally the elderly subjects felt the experimental conditions were warmer than PMV which was determined from the measured metabolic rate.

4C6o5 Effect of replacement air systems on kitchen comfort
D Schrock, D Beardslee and Z Sun

This paper analyzes methods of introducing replacement air with respect to their impact on the thermal comfort of the occupants. Analysis was performed using a combination of mathematical models to predict the kitchen temperature and actual laboratory testing using a thermal mannequin to measure thermal comfort. The results of this paper provide design engineers an understanding of how using different styles of replacement air affect both the exhaust airflow required to capture the cooking effluents and the impact on heat in the kitchen. If the systems are ranked from most tolerable to least tolerable the order is (1) displacement ventilation, (2) mixing ventilation (with air supplied through ceiling diffusers), (3) front-face discharge, and (4) backdrop plenum. The reason behind these results is that the untempered air from the front-face and backdrop systems does NOT all go up into the hood – but rather adds heat to the kitchen space.

4C6p1 Thermal sensation and thermoregulation in elderly compared to young people in Japanese winter season
K Tsuzuki and T Ohfuku

This paper presents the results of an experimental study on the thermal comfort requirements of elderly people compared to college-age people. Subjects were exposed to five conditions: 23 C, 25 C, 27 C, 29 C, 31 C with 60%RH under insensible air flow. We obtained responses to a thermal comfort questionnaire and thermophysiological data to better clarify the relationship between thermophysiological responses and thermal comfort. In all experimental conditions there was little difference in EWL between the younger and older group although the metabolic rate for the elderly group was only 70% that of the younger group. Overall elderly people's reported thermal sensations were cooler than the younger people. The elderly subjects' mean skin temperature was higher at 23 C and lower at 31 C than the younger subjects. It appears that, compared to younger people, elderly people have reduced warmth sensitivity in cold seasons and similarly reduced cold sensitivity in hot seasons.

4C6p2 Field investigations on comfort in office buildings
J Ribéron and P O'Kelly

A method has been developed to investigate the comfort in office buildings. It is based on both measurement and questionnaire. The measurement apparatus, so-called Ambiometre, can record both the main comfort parameters such as temperature, humidity, noise, light, odours and occupant's perceived comfort. Information on indoor climate and working environment is reported on questionnaire. Experiments were conducted on about sixty offices in France. The results have shown that the measured comfort parameters were generally located in the range of comfort conditions. In addition, the perceived comfort data reflect satisfactory indoor environment conditions. A hierarchy within the different components of comfort has been established. Discomfort is reported more often on thermal and visual aspects than on acoustic and olfactory aspects. Often, lighting is poorly adapted for working at VDU and artificial lighting is too strong. Thermal discomfort is often reported in the non-air-conditioned buildings without efficient solar protections.

4C6p3 The impact of humidity on health and comfort in an office building
CE Aizlewood, SKD Coward, L Hamilton, GJ Raw and DJ Wilde

The aim of this study was to test whether changes in relative humidity (RH) over the range 30-40% RH would affect acute symptoms or comfort. The study was carried out in an air-conditioned office building, during the heating season (when the risk of low humidity was greatest). Temperature and RH were monitored, and occupants completed weekly health and comfort questionnaires. During the study, the humidity set point in an experimental area was reduced compared to a control area. Occupants were blind to the intervention. The achieved change in RH was not as great as had been hoped, and did not have a significant effect on symptom prevalence or comfort. There was a slight reduction of building-related symptoms at higher RH. In considering the desirability of humidification, the modest potential benefits indicated in this study must be weighed against the potential long-term disadvantages, such as biological contamination, and the economic/energy cost.

4C6p4 Evaluating the thermal quality of a room
B Kvisgaard

The ongoing development of international standards, which will probably introduce different quality classes of thermal comfort, will increase the need for on-site evaluation of thermal comfort. The question often raised will be “Do this room offer class A thermal comfort?” and the answer submitted must be based on a measurement of the actual environment if it is to have any credence. The paper describes a measurement system to evaluate room thermal comfort, based on the ISO 7730 (Determination of the PMV and PPD indices) standard. The measuring system executes one measurement and the data are subsequently used to evaluate system performance in three steps. The first step is calculating the average PMV level in the room and relating this to the outdoor environment; the next step is evaluating the thermal uniformity of the room; finally, the ability of the climate-control system to maintain a stable thermal climate is assessed.

4C6p5 Measurement of the airflow and temperature fields around live subjects and the evaluation of human heat loss
GH Zhou, DL Loveday, AH Taki and KC Parsons

This paper reports on the successful development of a special garment for measuring convective and radiative heat loss from the clothed human body, thereby enabling the direct determination of local convection coefficients. The garment has been designed to be in the form of a typical office-clothing ensemble and was tested on male subjects who conducted seated office work in a environmental room. Sensors mounted upon the garment permitted measurement of radiation heat transfer from the clothed body to the surroundings; these results were found to agree well with traditional plane radiant temperature data taken with an indoor climate analyser. Airflow and temperature fields around subject were measured from which were derived correlations relating convection coefficients to air speeds in mixed airflow conditions. The correlations obtained are compared with those of earlier studies, in particular those used in the ISO7730 Standard, and the implications for thermal comfort prediction are discussed.

4C6p6 Numerical calculation of mean radiant temperature and temperature asymmetry for complex room geometry
M Prek

Radiative heat losses represent a substantial part of the total heat balance of the human body in a closed space. The thermal balance is strongly affected by surface temperatures and by the angle factor between a body and a wall surface. Since a room’s internal surfaces are composed of various parts, the calculation of view factors becomes more complex. The proposed algorithm is based on the computation of view factors, thus allowing for the complex impact of these factors on thermal radiative heat exchange. The matrix based approach makes it possible to determine the influence of various parameters on

mean radiant temperature, as well as on temperature asymmetry. This approach also enables the consideration of other parameters (air temperature gradient, air velocity...) whose impact on thermal sensation is expressed as the PMV value.

4C6p7 Evaluation of thermal comfort in ceiling cooling system
J-Y Lee, K Natsumi and N Isoda

The purpose of this study is to clarify the effects of air temperature and ceiling temperature in the cool water circulation type of ceiling cooling system. The experiment was conducted in summer. The subjects (11 young females) were exposed to the following conditions: combinations of air temperatures (27 C, 29 C and 31 C), ceiling temperature (22.7 C, 23.7 C and 24.7 C) in still air and RH 50%. The following results were obtained: the thermal sensation vote was neutral at the mean skin temperature of 34.5 C. Each part of the body was affected by the ceiling temperature, as it gave different skin temperatures. For example, the forehead, the scapula and the abdomen were affected. The thermal comfort vote was rated comfortable even at high environmental temperature and the satisfaction to the ceiling temperature was also valued comfortable in this experiment. The mean skin temperature showed higher thermal neutrality-temperature than that of existing studies for floor and wall radiation heating.

4C6p8 Measurement and analyses of the thermal micro-climate in cars
S Quanten, K Janssens, P McKenna, JM Aerts, PC Young and D Berckmans

A Data-Based Mechanistic (DBM) approach was used to model the spatio-temporal temperature distribution in the imperfectly mixed air in a car. The first phase of DBM involves the identification of a mathematical model from experimental data. A second order model proved to be a sufficiently good description of the temperature dynamics ($R^2 = 0.985$) of the system. Furthermore, the second order model proved to give a physical meaningful description of the system and thus could be accepted as an adequate description of the system's dynamics. A Proportional Integral Plus (PIP) climate controller was developed for a Single Input Single Output (SISO) system. The PIP controller was able to follow a temperature level of 18-23-21 C at any point. Also, a unit step disturbance was added after 300 seconds, was controlled rapidly by adjusting an input.

4D1o1 Microbial volatile organic compounds (MVOC) as indicators for fungal damage
H Schleibinger, C Brattig, M Mangler, H Samwer, D Laußmann, D Eis, P Braun, D Marchl, A Nickelmann and H Rüden

Laboratory experiments demonstrated that the production and emission of volatile secondary metabolites by molds is strongly dependent on various influencing factors. A major influencing factor is the substrate. In the case of indoor environment construction material serves as substrate, so the MVOC spectrum encountered mainly depends on the infested site. Differences concerning the MVOC emission exist even between the various strains of the same type of fungus, which was proved by the present study with different strains of *Aspergillus* versicolor (wild strains versus certified laboratory strains). Even the emitted MVOC spectrum was sometimes not constant when experiments were repeated. Field studies in 28 flats showed that typical MVOC were found in housing with considerable mold infestation in the µg/m3 range. We found a correlation between humidity and a total of 8 selected MVOC. However, smoking also correlated to the concentration of the "MVOC" 3-methylfurane, so that interpreting the detection of "typical" MVOC should basically still be done with great care.

4D1o2 Microorganisms and volatile organic compounds in airborne dust from damp residences
A Nilsson, E Kihlström, V Lagesson, B Wessén, B Szponar, L Larsson, and C Tagesson

Airborne dust samples from damp (n=9) and control (n=9) residences were analysed for microorganisms (moulds and bacteria), bacterial markers (3-hydroxy fatty acids and muramic acid), and adsorbed volatile organic compounds (VOC). The number of mould species was greater in the damp residences than in the controls (23 vs.18) and nine species were only found in the former. The levels of 3-hydroxy fatty acids and muramic acid correlated better in damp residences than in controls indicating that damp conditions selectively favour growth of certain bacterial species. Identifications made by culture and microscopy of the major moulds found, i.e. *Aspergillus*, *Cladosporium* and *Penicillum*, coincided with the identification of VOC known to be produced by these species. A number of additional VOC irritating to the skin, eyes or respiratory tract was also found. These results suggest that analysis of airborne dust may help to assess human exposure to microorganisms and chemical compounds.

4D1o3 Modeling of house dust mite concentration
E Hasselaar

Instead of time consuming tests of dust samples, an interview and inspection can provide useful information on the growth conditions and exposure to house dust mite (HDM) allergen. A model of building parameters, occupancy patterns and growth of HDM was designed, to predict HDM allergen levels. The model is being tested on the basis of dust sampling and guanine analyses. Preliminary results show positive correlation when low allergen levels are predicted, but negative correlation at

higher concentrations. The research feeds the debate on the effect of low temperatures in bedrooms, on periodic replacement of mattresses and on insulation of ground floor constructions. Testing and validation of the model will be continued.

4D1o4 House dust mites, humidity of room air and flooring materials
L Gunnarsen, K Sidenius and TE Hallas

House dust mites are known to cause airway allergy. Humidity in the immediate environment of the mites is believed to be decisive for their prevalence. The purpose of the present study was to analyze the impact of microenvironment on the prevalence of mites based data from a cross sectional study in Danish apartments. The room parameters air change rate, temperature and relative humidity was measured in apartments when outside temperatures were in the range –5 to 10 C. Mites were counted under microscope in surface dust sampled from beds and from bedroom floors. In average more mites were found on the floors than in the beds. Far more mites were found on carpeted floors. No relation between prevalence on floor and room air parameters was found. The prevalence in beds correlated with absolute humidity in room air. Temperature and humidity profiles of typical beds and floors can in part explain these results.

4D1o5 Measurements on fungi and mites in houses in the environs of Tokyo
F Shinohara, T Iwata and H Tsukahara

In order to make clear the contamination of fungi and mites in houses, measurements were carried out in ten houses near Tokyo. Temperature, relative humidity, CFU (colony forming unit), number of mites and ventilation rate were measured and questionnaire survey was conducted. Three methods were used to sample fungal spores, suspended fungi measured by RCS samplers, surface fungi measured by contact agar-slide method, settled fungi spores measured by culture plates (PDA and DG-18). A high CFU for suspended fungi and for settled fungi were shown under 20-24 C of air temperature and more than 80% of R.H. CFU for suspended fungi in autumn showed higher value than that in winter. Strong correlation between the amount of house dust and the number of mites were found in the Japanese tatami-mat rooms and the dining rooms. Number of mites in 50 mg of house dust in the Japanese rooms is ten times as many as that in the dining rooms.

4D1p1 Mold problems in first nations housing in Canada
V Salares, K Ruest and B Boles

Studies of housing in several First Nations communities in Canada have shown the presence of mold contamination. Recurring mold after renovations in one reserve and evacuation of houses attributed to severe mold in a second community were followed up using the CMHC Residential IAQ Investigation Procedure. Approaches to solving the mold problems are discussed.

4D1p2 Prevalence of *Stachybotrys* in outdoor air of Houston area residences
KB Dotson and JE Schneider, Jr.

Outdoor ambient airborne concentrations of fungi were measured near 633 residences in the Houston, Texas metropolitan area. The samples were collected in conjunction with indoor air quality surveys conducted in response to occupant reports of internal water damage. Air samples were collected using Air-O-Cell cassettes and compatible Zefon Air-O-Cell Mini-Pumps. Samples were analyzed via light microscopy at 600X magnification. The genus of *Stachybotrys* was identified in approximately 4% of outdoor samples. This data suggests that the prevalence of *Stachybotrys*, while not a frequently detected constituent, can be occasionally detected in the outdoor air in the sub-tropical climate of the Houston metropolitan area.

4D1p3 Consideration on the fungi growth in the Japanese apartment houses for single persons in relation to their living activities
M Shitotsu, K Ikeda, H Yasunaga, K Abe and S Yoshizawa

Measurements on environmental factors related to fungal growth were conducted in June 2001 in 33 apartments selected from 88 apartments in an apartment house, which was constructed in October 2000. The apartment house was built using the building materials specially selected to reduce emission rate of chemicals from the materials. We considered how the fungal growth in the building was affected by use of such materials. Survey items were questionnaire on the living environments, observation of the fungal growth on the surface of wall, window frame and so forth. Measurements of air-borne fungi and environmental conditions for fungal growth were made using “Fungal detector”, which is a tool specially designed for evaluation of the potential effect on the fungal growth.

4D1p4 *Legionella* risks in modern homes in the UK
GJ Raw, C Hunter, L Sargent and D Higham

Legionella is present in 5-15% of UK homes, presenting a risk of illness that is small but of public health importance. Furthermore, it is difficult to eradicate the organism from domestic water systems, making it important that systems are designed to minimise the risk of colonisation. The present study investigated the level of risk in newer homes, where controls on design and installation should reduce the risk. Water samples were collected from 281 English homes built between 1980 and 1993. The majority of the samples were collected in summer/early autumn, when stored mains water would be at its warmest, i.e. optimal for *Legionella* growth. Nevertheless, *Legionella* was not detected in any samples. While this finding does not prove complete absence of risk, it represents a success for control of hazards in the home, and indicates the importance of maintaining and enforcing controls over the design and installation of water systems.

4D1p5 Prevalence of house dust mites, cat, and dog allergens in homes in one northeast American county
P Ren, TM Jankun, and BP Leaderer

Aeroallergens in house dust have been implicated in asthma development and severity. Seasonal concentrations of the major allergens including dust mites (*Der p* I and *Der f* I), cats (*Fel d* I), and dogs (*Can f* I) were measured in eleven dwellings. *Der p* I, *Der f* I, *Fel d* I, and *Can f* I were found in all the homes during all seasons, even in homes without a cat or dog. Type of floor cover in the living room and bedroom was not related to concentrations of any aeroallergens measured in the sofa or bedding dust. A trend for seasonal variation of dust mite allergens revealed that fall had the highest and spring had the lowest concentrations. High correlation coefficients were observed for cat and dog allergens between sofa and bedding ($r>0.8$, $p<0.0001$). The results obtained in this study are of importance for assessing risk factors for high allergen levels in homes and developing mitigation measures to reduce indoor residential exposures in allergic individuals.

4D1p6 Environmental endotoxin concentrations are associated with home characteristics
YJ Huang, JY Huang, LL Lin, PC Wu, YP Ma, and HJ Su

Many studies have suggested that endotoxin exposure is related to severity of childhood asthma. To examine whether endotoxin levels were associated with different home characteristics, this study monitored the house dust endotoxin levels from children's mattress at homes. Environmental endotoxin was collected, and home characteristics were inquired from 45 selected homes. Endotoxin samples were analyzed and presented as ng/mg of dust. Endotoxin levels of children's mattress ranged from 2.49 to 718.91 ng/mg. The geometric mean concentrations of endotoxin in homes were 77.32 and 25.24 ng/mg dust, with and without prior water damage respectively ($p<0.05$). It is possible that the previous experience of water damage had provided an ideal environmental and water contents for microbial growth later on. How this concentration might be associated with the respiratory diseases of resident children is in need of future investigation, and remains high interest for public health implication.

4D1p7 Indoor fungal exposure in some French homes
V Bex, A Mouilleseaux, L Bordenave and F Squinazi

Many studies have focused on relationships between health problems and moisture in indoor environments. Increased moisture level and poor ventilation rate have been shown to increase the presence of fungi in buildings. Health effects possibly caused by fungal exposure are infections, allergies, toxic effects and irritations. We have led environmental audits (n=25), at physician's request, in suspected mold allergic patient homes. An extensive home visit allows the detection of potential indoor fungal sources, afterwards, a sample strategy is determinate. Results show that indoor airborne spores concentrations vary from units (CFU) to more than several thousands per m^3. In dust samples, the number of spores per gram ranges from hundreds to millions. Relative frequence of mold species presence is home specific , depending on various factors (moldy support nature, inter-species competition …). Dominant species characterization is worth studying in any case when searching for health effects, even if it's time consuming.

4D2o1 Dust in the cultural environment
P Brimblecombe, YH Yoon, K Frame, B Knight, K Lithgow and H Lloyd

Dust deposition poses a significant problem in indoor environments associated with museums and historic houses. Our studies have measured the rate of soiling in a range of interior locations at Hampton Court, Osterley Park House, Knole, Audley End and Felbrigg Hall. These quantitative measurements can be combined with observations of particle morphology to indicate dust sources. This work has shown that most soiling arises from the proximity of visitor activity. A small amount of coarse dust is resuspended from carpets, but at eye level it seems to be shed, often as fibres, from visitor clothing. Dust accumulations age and become more difficult to remove over time. This has increased concern that they can also cause chemical alteration to the

surfaces. Our investigations have helped define effective cleaning strategies for cultural property and indicate ways in which careful management of visitor flow can reduce the impact of dust within museums and historic houses.

4D2o2 Measurements of indoor air quality on commercial transport aircraft
MA Waters, TF Bloom, B Grajewski and J Deddens

Exposures to cabin environmental contaminants were measured on 36 commercial transport aircraft. The objectives were to characterize levels of contaminants and evaluate the relationship between flight factors such as aircraft size, occupancy, ventilation, and flight length, and environmental parameters. Monitoring was conducted at two coach locations for the duration of the flight for VOCs, nitrogen oxides, CO, CO_2, O_3, temperature, relative humidity, total particulates, and barometric pressure. Five-minute average concentration ranges were: CO_2 515-4902 ppm; O_3 <0.05-0.24 ppm; CO <0.2-2.9 ppm; nitrogen oxides <0.05-2.0 ppm; and total particulates <0.028-0.197 mg/m^3. Gate-to-gate average concentrations of VOCs were: toluene <3-130 ppb, limonene <3-12 ppb, and ethanol <0.8-2.4 ppb. Carbon dioxide exposures were highest on shorter and high-occupancy flights, aircraft with greater recirculated-to-fresh-air ratio, and narrow-bodied aircraft. In general contaminant levels were low compared to standards. Carbon dioxide levels indicated lower ventilation rates per occupant than most other indoor environments.

4D2o3 Cabin air pollutants and climate in an aircraft with recirculated air on intercontinental flights
T Lindgren and D Norbäck

Measurements of air humidity, temperature, carbon dioxide (CO_2), respirable particles, ozone, nitrogen dioxide (NO_2), formaldehyde, and volatile organic compounds of possible microbial origin (MVOC) were performed during 26 flights with Boeing 767-300. The mean temperature in cabin was 22.2 C (range 17.4-26.8 C), and mean relative air humidity was 6% (range 1-27%). The CO_2 during cruises was below 1,000 ppm during 96 % of measured time. Mean concentration of NO_2 and ozone O_3, were 14.1 mg/m^3 and 19.2 mg/m^3, with maximum values of 37 mg/m^3 and 66 mg/m^3, respectively. Formaldehyde was below the detection limit (<5 mg/m^3), in most samples (77%) (Maximum value was 15 mg/m^3). The mean concentration of respirable particles in the rear part of the cabin was much higher during smoking (mean 49 mg/m^3: maximum 253 mg/m^3) than non-smoking (mean 3 mg/m^3) ($p<0.001$). Different MVOC were detected, including 3-methyl-1-butanol, 1-octen-3-ol, at higher levels than in Swedish dwellings.

4D2o4 Tracking the source of elevated personal exposures to metals to underground subway environments in the TEACH study
SN Chillrud, D Epstein, JM Ross, S Ramstrom, D Pederson, M Aggarwal, JD Spengler, and PL Kinney

The TEACH (Toxic Exposure Assessment- A Columbia Harvard) study was designed to characterize exposures to urban air toxics among inner-city high school students in New York City and Los Angeles.$PM_{2.5}$, VOCs, and aldehydes were monitored. $PM_{2.5}$ filters were analyzed for reflectance and 28 elements. For NYC, personal samples had significantly higher median concentrations of iron, manganese and chromium than medians of home indoor and ambient samples. Fe/Mn and Cr/Mn ratios and strong correlations between these elements suggest steel dust as the source of these metals for a large subset of the personal samples. Time-activity data suggest the NYC subway system as a possible source of these elevated personal metals. Fe, Mn and Cr levels and their ratios in a single set of duplicate $PM_{2.5}$ samples that integrated 8 hrs of underground subway exposure are consistent with the subway system being the predominant source of these metals to subway riding subjects.

4D2p1 Nasal, ocular, dermal and general symptoms among Swedish commercial aircrew
T Lindgren and D Norbäck

Symptoms among commercial cabin crew was studied. A standardized questionnaire was mailed in February-March 1997 to all airline crew on SAS (N=1857), and office workers (N=218). Smoking was allowed only on intercontinental flights. The participation rate was 81% in the airline crew, and 77% in the office group.The most common symptoms among airline crew were fatigue (21%), nasal symptoms (15%), ocular symptoms (11%), dry or flushed facial skin (12%), and dermal hand symptoms (12%). Airline crew had more nasal symptoms (OR=3.12), throat symptoms (OR=5.75), and more dermal symptoms from the face (OR=2.03), and hands (OR=3.68), as compared to office workers. Airline crew atopy had an increase of most symptoms (OR=1.5-3.8), but age, gender, or smoking was not associated with symptoms. Airline crew that had been on an intercontinental flight last week had more complaints on fatigue (OR=1.87), and heavy-headedness (OR=1.89), and difficulties concentrating (OR=3.22).

4D2p2 Indoor air quality in submarines
O Persson and L Wadsö

The next generation of conventional submarines will be submerged for several weeks, creating a need for regenerative air purification methods and new air monitoring instruments. Submarine air is a complex mixture of compounds, where the most obvious contaminant is metabolically produced carbon dioxide. Normal eight-hour occupational exposure limits are not applicable on a submarine, instead special longtime exposure limits must be set. A number of air purification methods for submarines are either available or under development, e.g. cryogenic plants, biological plants and solid amine plants. For air monitoring compact GC/MS is an interesting option, already in use onboard nuclear submarines.

4D2p3 Indoor air quality in a bank strong box
F Pinheiro Carneiro and F Radler de Aquino Neto

The air quality in a specific indoor environment, the strongbox of a commercial bank (vault and associated offices) was evaluated. VOCs, Aldehydes, TPM and Fungi were analyzed. These analyses were performed by HRGC-FID/MS, HPLC, Gravimetry and microbiological techniques. The determinations were made simultaneously in internal and external points, in order to reveal both contributions for the indoor air quality. TVOC occurred in relatively high values, varying from 342 to 423mg/m^3. It was also observed the presence of organo-chlorinated compounds, mainly dichlorobenzene (40-49mg/m^3) that suggests the use of insecticides. A second sampling after one year did not show dichlorobenzene that indicates its removal by dilution or cleaning procedures. The microbiological analysis suggested a secondary source of contamination, which indicated the need for the cleaning of the HVAC. The expected critical situation of contamination by particles or fungi was not found in spite of the intensive manipulation of new and used bills and coins.

4D2p4 The indoor air quality of the national archives of the Netherlands: its purification, quality control and safeguarding the cultural heritage
JBGA Havermans and TAG Steemers

Since 1995 research has been undertaken on the effects of air purification at the National Archives in The Netherlands. For these purpose two storage-rooms are in use, one with and one without air purification. Both rooms are equipped with air pollution analysers and paper test materials. The pollution is constantly analysed and processed, while paper samples are taken yearly. Although the programme is continued till 2004, preliminary conclusions can be drawn. It is found that in our case, i.e. the air circulation rate is higher than the air ventilation rate, air purification does slow down paper degradation.. Also it is suggested that the way of paper wrapping influences its degradation. Besides pollution-monitoring has also a warning function on the quality of the filtration materials.

4D2p5 Indoor air quality of air-conditioned food courts: preliminary findings in a tropical city state
HM Yap and PL Ooi

The indoor air quality at six popular food courts was studied in relation to health and comfort problems among the patrons. Significant environmental findings were high carbon dioxide levels (morning=859 ppm; lunch time=1255 ppm), high bacterial counts (morning=553 CFU/m^3; lunch=639 CFU/m^3), and high air temperature (25.8 C; 25.5 C). Overall, patrons perceived the indoor air quality to be good (93%) although there were complaints of poor thermal comfort (too warm, 31%; too cold, 23%), kitchen odours (80%), nose irritation (2%) and sneezing (2%). While baseline levels of air pollutants remained low, there was scope to reduce the bacterial levels, thermal discomfort and food smell problems through improvement of the air distribution, ventilation design and proper maintenance of the kitchen hoods.

4D2p6 Venting contaminants and fire smoke from an indoor auto-racing complex
Z Zhai, Q Chen and PW Scanlon

It is challenging to design ventilation system for large spaces due to the non-uniform distributions of airflow, temperature and contaminant concentration. This paper employs a validated computational fluid dynamics (CFD) program to assist the ventilation system design for an indoor auto racing facility for acceptable indoor air quality (IAQ) and fire safety. The paper also compares the CFD results with the hand calculation results. The CFD results are informative and accurate.

4D2p7 A CFD simulation and optimization of subway station ventilation
L Wang, G Tu, T Zou and J Yang

In rebuilding Tianjin Metro CFD simulations are performed to evaluate the original design of the ventilation system of Southwest Station and a new system is given to optimize the velocity and temperature fields at the station . Field measurements are conducted to validate the turbulence model and acquire boundary conditions. It is found that two-equation turbulence

model is acceptable in simulating complex flow at the station. A method of simplifying the simulation of the transient flow at the station into steady flow is used and the validation criterion for this simulation is also given.

4D2p8 The relationship of structures and air conditioning to indoor air quality in two indoor swimming pools
T Jauhiainen, T Keskikuru, R Halonen, M Reiman, L Kujanpää, P Yli-Pirilä, T Raunemaa and H Kokotti

IAQ was studied in two indoor swimming pools located in the same city, an old one and a new one. Both the swimming pools had concrete constructions, but the new one had steel framework and wooden roof structure. The old one was equipped with an old HVAC system needing renovation and the new swimming and sport centre was equipped with an HVAC system of the latest technology. The ventilation system in the old building used short circuit airflow, which did not reach the swimmer. Velocities of airflows (0-0.05 m/s in the old building and 0.05-0.5 m/s in the new building) on the water level of the swimming pools were faster along the length of the swimming pool than across width of the pool. The airborne concentrations of microbes were fairly low, although the presence of microbes favouring moisture conditions is not acceptable, e.g. in the air of office buildings.

4D2p9 Heating effects in South Tyrolean churches
A Troi and G Hausladen

With the installation of new heating systems in churches in the course of the last century an increase in damage and decay of valuable interior decoration could be observed. Research has shown the connection between indoor climate and degradation. The present study analyses the effects of different kinds of heating systems on the indoor climate, recording air temperatures and humidity in 18 churches in South Tyrol (Italy) continuously over a period of 4 to 8 weeks. The results show characteristic temporal and spatial heat and humidity distributions, which are compared to the demands of the building and interior decoration in order to estimate potential risks and benefits. Hot air heating with short heating sessions shows up to be most harmful, whereas pew heating, hot air heating with a base temperature and floor heating have each their specific strengths and weaknesses.

4D3o1 Contribution of the inhalation route to cumulative risk estimates from multiple route exposures to pesticides in NHEXAS-AZ residences
DJ Moschandreas, S Karuchit, M Lebowitz, MK O'Rourke and G Robertson

This study apportions cumulative risk from exposures to two pesticides, chlorpyrifos and diazinon, in residences. Cumulative risk is estimated deterministically, using the "individual-by-individual" approach, and probabilistically. The indirect method is used to estimate pesticide dose employing measured concentrations, models, subject characteristics, and other relevant exposure factors obtained from the National Human Exposure Assessment Survey in Arizona (NHEXAS-AZ) database. The hazardous index method is used to estimate cumulative risks. Conventional risk uncertainty analysis is used to estimate only parameter uncertainty, with scenario and model uncertainty sources assumed to contribute negligibly to risk uncertainty. The Scenario-Model-Parameter uncertainty analysis of risk estimates is also used to assess uncertainty from all three sources of uncertainty. Risk apportionment by route reveals that the ingestion route is followed by the inhalation route and the dermal absorption route in contributing to the cumulative risk in residences. Cumulative risk apportionment by pesticide identifies chlorpyrifos as the ranking contributor.

4D3o2 Distributions and quality of pesticide, PAH, and PCB measurements in bag dust from four areas of USA
DE Camann, JS Colt and MM Zuniga

Distributions of the concentrations of prevalent pesticides, polycyclic aromatic hydrocarbons (PAH), and polychlorinated biphenyl (PCB) congeners were measured in vacuum bag dust samples obtained from the homes of case and control adults in four areas of the United States for a study of non-Hodgkin's lymphoma (NHL). All target analytes were efficiently extracted from the sieved fine dust. The distribution of detectable concentrations of prevalent pesticides and PAH spans more than two orders of magnitude. Discontinued pesticides such as DDT and chlordane are still common in house dust, and indicate continual exposure of the residents since discontinuation. Comparing the study sites, percentiles of the dust concentration distributions were generally larger for current-use insecticides and chlordane in Los Angeles County, ortho-phenylphenol in the Seattle area, agricultural herbicides in Iowa, and PAH and PCB congeners in the Detroit area.

4D3o3 Semi volatile organo-chemicals in indoor environment - chlorinated phosphorus and organotin compounds in material und house dust samples
T Haumann and J Thumulla

Semi volatile organochemicals such as chlorinated organophosphorus and organotin compounds are detected in many indoor materials and residential house dust samples. Chlorinated phosphorus based flame retardants are found in 90 % of over 1,500

house dust samples ranging from 0.1 to 1,300 mg/kg. The results of material samples show that many polyurethane soft foams, sealants, and finishes contain significant concentrations of organo-phosphorus additives. High organotin con-centrations are detected in dust samples derived from homes with polyvinyl chloride flooring with maximum values of 2,200 mg/kg. Our organotin pilot study presents the first available house dust sample results. The results show in many cases, that indoor dust ingestions of organotins from vinyl flooring dramatically exceed guideline values for Tolerable Daily Intake (TDI) or Reference Dose for Chronic Oral Exposure (RfD). For long term exposure, especially, there is a considerable concern given by indoor appearances of chlorinated organophosphorus and organotin chemicals.

4D3o4 Ambient monitoring and biomonitoring of pentachlorophenol after indoor exposure
U Helber, F Schweinsberg, G Volland, D Zöltzer and W Butte

Background: The suspected carcinogen, pentachlorophenol (PCP), has been widely used as a wood preservative. Because PCP has the tendency to leach out for a long time, treated products may constitute a long-term health hazard. Methods: Case 1: A family of four that resided in a PCP-treated block house built in 1978. Case 2: A male adult who had resided in a PCP-treated wooden frame house since 1975. Regular ambient monitoring and biomonitoring of PCP was carried out before and after renovation. Results: Before renovation, PCP levels in air were 0.28-0.6 $\mu g/m^3$. PCP in serum before renovation was 60-200 µg/L and after renovation 50-100 µg/L (case 1) and 18 µg/L (case 2), respectively. PCP in urine (case 1) was 25-60 µg/L before and 20-40 µg/L after renovation. No adverse effects were observed in the exposed individuals. Conclusions: Current HBM-II values were successfully applied in judging the 2 case studies.

4D3o5 Pesticide levels in 48-hour personal air samples during pregnancy and in blood samples at delivery from urban minority mothers and newborns
RM Whyatt, DE Camann, DB Barr, JR Barr, HF Andrews, PL Kinney and FP Perera

Residential pesticide use is widespread in the U.S. However, little is known about pesticide exposures among minority women during pregnancy. We have measured levels of 9 contemporary-use pesticides in 48-hour personal air samples collected during the 3rd trimester and blood samples (maternal and umbilical cord) collected at delivery from 194 African American and Dominican mothers and newborns in New York City. Our prior data show widespread prenatal pesticide use among this minority cohort. The organophosphates diazinon and chlorpyrifos and the carbamate propoxur were detected in 100% of the air samples (range 0.7-6010 ng/m^3) and 57%-97% of blood samples (range 0.3-63 pg/g). Blood and air levels were not correlated. Maternal and newborn blood levels were similar and significantly correlated. The remaining pesticides were detected less frequently in air and blood. Results show that prenatal exposure is widespread and that the pesticides are readily transferred from mother to the fetus during pregnancy.

4D3p1 German environmental survey 1998 (GerES III): pesticides and other pollutants in house dust
K Becker, M Seiwert, S Kaus, C Krause, C Schulz and B Seifert

The German Environmental Survey (GerES) is a large-scale population study which has repeatedly been carried out in Germany. GerES I was conducted in 1985/86 followed by GerES II in 1990/92 and GerES III in 1998. In GerES III about 750 samples of house dust collected in homes of the study participants were analysed for their content of PCP, lindane, DDT, propoxur, methoxychlor, chlorpyrifos, polychlorinated sulfonamide diphenyl ethers, pyrethroids and PCB. Flame proofing agents (e.g., TCEP, PBDE) and plasticisers (e.g., phthalates) were analysed in 200 samples. The analytical results are given and discussed. Looking at trends over time, it can be stated that the concentrations of PCP and lindane in house dust have decreased between 1990/92 and 1998 while the concentration of permethrin remained about the same.

4D3p2 The SBS national exposure research laboratory children's pesticide exposure measurement program
RC Fortmann, LS Sheldon, EA Cohen Hubal, MK Morgan, DM Stout, II, KW Thomas, NS Tulve, and DA Whitaker

The U.S. Environmental Protection Agency (EPA) National Exposure Research Laboratory (NERL) is performing research in support of the Food Quality Protection Act (FQPA) of 1996. This act requires that pesticide exposure assessments to be conducted for all potential sources, routes and pathways, not just dietary intake. The goal of the NERL program is to develop and evaluate protocols and methods for assessing children's aggregate and cumulative exposures to pesticides, and to collect data required to reduce the reliance on default assumptions in development of quantitative exposure assessments. This paper provides an overview of the framework and approach for the research program and descriptions of studies being performed to fill data gaps in the following areas: Spatial and temporal distribution of pesticide residues indoors, Pesticide use patterns indoors, Dermal exposure, Indirect ingestion exposure, Microenvironments and macroactivity patterns of children, and Children's exposure measurements protocols and methods.

4D3p3 The distribution of Chlorpyrifos following a crack and crevice type application in the U.S. EPA indoor air quality research house
DM Stout II and MA Mason

A study was conducted in the U.S. EPA Indoor Air Quality Research House to determine the spatial and temporal distribution of chlorpyrifos following a professional crack and crevice application in the kitchen. Following the application, measurements were made in the kitchen, den and master bedroom over 21-days. Airborne concentrations were collected using both polyurethane foam (PUF) and a XAD/PUF (OVS) media. Measured airborne concentrations were similar for the two samplers, were higher in the three rooms following the application, reached maximal levels 24-h post-application, and declined steadily over the 21-day study period. Spatial and temporal distributions were measured using 10-cm^2 cotton deposition coupons. Sections were cut from existing carpet to determine the total extractable residues. Chlorpyrifos was measured from all matrixes in the kitchen, den and bedroom and shows the transport of airborne residues from the point of application to remote locations in the house.

4D3p4 Pesticides in wipes from farmworker residences in North Carolina
SA Quandt, TA Arcury, BG Mellen, P Rao, DE Camann, AM Doran, A Yau, JA Hoppin, and DS Jackson

This pilot study measured pesticides in wipes from residences occupied by farmworker families. Ten households with at least one adult engaged in farm work and one child ages 12 - 80 mo were enrolled. Samples were collected by taking wipes with isopropanol-moistened gauze of the child's hands, toys, and a floor surface. Wipe samples were shake-extracted, cleaned, and analyzed by GC/MS selected ion monitoring for 8 agricultural pesticides and 13 common household pesticides. Pesticides were recovered from 9 households, most commonly from floor surfaces. Three of 8 agricultural and 9 of 12 common household pesticides were detected. Household detection was 0 to 122.53 µg of pesticide residues. Proximity to fields, living in a trailer, and the farmworker currently applying pesticides appear to be risk factors for the presence of agricultural pesticides. Using surface wipes in dwellings is an effective means of obtaining data on indoor exposure in this high risk population.

4D3p5 The persistence of pyrethrum and Chlorpyrifos-ethyl in indoor environment - case-reports
N Weis and G Lammers

Numerous applications for usage of pyrethrum-containing insecticides for indoor use allow the inhabiting of concerning rooms a few hours after bringing out the biocides. Consensus of opinion is, that pyrethrum is no longer detectable within a few days. Correspondingly assumed, after usage of chlorpyrifos the treated rooms show only a residual burden a few days later. In practice we observe, that pyrethrum can be present for months, chlorpyrifos even for years in indoor environment. In certain cases, e.g. about one year after the pest control, up to 170 mg/kg pyrethrum and up to 1700 mg/kg chlorpyrifos in house-dust can be found. Samples taken from material surfaces show a contamination exceeding 9.000 $\mu g/m^2$ for pyrethrum and 43.000 $\mu g/m^2$ for chlorpyrifos. Especially, after an improperly performed pest control in indoor environments a clearly longer-termed exposition of the inhabitants to pyrethrum and chlorpyrifos (and other biocides) as expected was found.

4D4o1 Evaluation of building products in a life cycle perspective
J Snaar, U Duus, K-E Larsson and G Stridh

Based on data of building products from manufactures an evaluation of the impact indoor climate, work environment in manufacturing of materials and in construction and finally on use of nature resources was done. Also factors such as waste, content of hazardous compounds and health- and environment classification were incorporated in the assessment. The evaluation comprised products in direct contact with indoor air, such as flooring products, panels and boards and paints and in indirect contact such as adhesives and insulation products. All the factors were summarised to an over all assessment marked with coloured symbols and a "sun-rise" list of green products were published. No fee had to be paid by the manufactures and the evaluation published in a guide (Byggmiljöguiden) is available without costs for policy-holders and others interested. The guide is revised every second year. Contractors to Folksam are by agreement bound to use recommended materials.

4D4o2 Special environmental requirements for a California state office building
A Bernheim, H Levin and LE Alevantis

A Special Environmental Requirements specification was developed for screening building materials based on modeling maximum chemical concentrations attributable to emissions from their potential sources for use in a State of California office building. In addition, minimum requirements for recycled contents of these materials were specified. Small environmental chamber emission test protocols were developed and maximum allowable concentrations for chemicals of concern were adopted. Contractors were required to submit emission test reports. The architect reviewed these reports for conformance with the specification requirements. Materials were accepted, rejected, or in some cases were chemically re-formulated and re-

tested. While there were difficulties in obtaining emission test reports from some manufacturers, most required test reports were received. This specification will be applied to other building projects with some modifications including standardization and clarification.

4D4o3 Health risk assessment of PCE emissions from dry cleaning activities in France
L Delery and A Cicolella

Tetrachloroethylene (PCE) is a solvent used mostly in the dry-cleaning and metal degreasing industries in Europe. Neurological and renal effects are the main non-cancer human health effects caused by chronic inhalation exposure of PCE. PCE is suspected to be probably carcinogenic to humans by the International Agency for Research on Cancer (IARC). During dry-cleaning processes, people are likely to be exposed to the chemical in a variety of ways because PCE emissions are not currently regulated in France. Exposed persons include workers, residents living in co-location with dry-cleaning establishments and the general population. This paper presents a literature review assimilating human exposure data to assess public health risk from dry-cleaning emissions. At the average indoor air level of 2 mg/m^3, there is concern for health risk to co-located residents living above dry cleaning establishments. A personal exposure of 15 microgram/m^3 of PCE should not cause adverse effects on the health of normal population.

4D4o4 A screening-level ranking of toxic chemicals at levels typically found in indoor air
PK Johnston, G Hadwen, J McCarthy and JR Girman

The U.S. Environmental Protection Agency (EPA) has several programs aimed at addressing radon, environmental tobacco smoke, and several other well-recognized indoor air pollutants. To prioritize activities for other chemicals typically found in indoor air, based on current data, EPA is developing a screening-level, risked-based ranking analysis, which is currently being revised. This paper presents the methodology used, and results found, for the analysis provided in the draft report. While the basic methodology will not change, the final results might be significantly different. In the draft analysis, monitoring data on "typical" levels of pollutants found indoors were combined with publicly available health indices to develop ranking scores for both acute and chronic exposures. Because monitoring data were available for only 112 chemicals and only 59 of the chemicals could be ranked, many chemicals found indoors might rank higher, given more complete information

4D4o5 Integration of occupant health criteria in the design and assessment of sustainable buildings - application to indoor air quality
C Cochet, S Nibel and L Nagy

Many countries are currently developing integrated approaches for the design of sustainable buildings. Environmental criteria to be taken into account are numerous including energy, resources, local and large scale pollution, waste, etc. Occupant health is very often included in the target list. Quite large ranges of issues are related to health in buildings. The designer aiming at sustainable construction will have to select the most appropriate ones according to his project. Indoor air quality, water quality and general sanitary conditions are widely used as sub-criteria for sustainable buildings and operational indicators need to be developed. This paper presents methodological features developed in France for the design and assessment of sustainable buildings. The main focus is given to indoor environment targets, particularly to indoor air quality issues. Discussion is based on environmental assessment tools and frameworks as well as aggregation of indoor air quality with other parameters.

4D4p1 Fiber glass insulation not classified as a human carcinogen by IARC
TW Hesterberg and GA Hart

In October 2001, the International Agency for Research on Cancer (IARC) changed their 1987 carcinogenicity classification of fiber glass wool insulation from Group 2b (possibly carcinogenic to humans) to the more favorable Group 3 (not classifiable as to its carcinogenicity to humans). The 2001 decision was based on new animal evidence that the potential carcinogenicity of a synthetic vitreous fiber is directly related to its ability to persist in the lung (biopersistence). Eleven fibers were tested for both carcinogenicity and lung biopersistence. The biosoluble SVFs, such as fiber glass wool insulation, did not cause any malignant or non-malignant disease in rodents even after lifetime exposure to high levels of respirable fiber dust. These animal study results, along with the finding of no exposure related increase in respiratory system cancer in fiber glass manufacturing workers resulted in the downgrading of the IARC classification (Moore et al. 2002).

4D4p2 Human health damage due to indoor pollutants in life cycle impact assessment
A Meijer, L Reijnders and MAJ Huijbregts

The incorporation of health effects associated with indoor air pollution in the current life cycle assessment (LCA) methodology for dwellings has been studied. A model was developed by which characterisation factors for formaldehyde, radon and particulate matter in the indoor air of dwellings were calculated. Fate factors were derived using a model for the calculation of

indoor concentrations. The effect and damage factors were adjusted to the application in indoor environment using disability adjusted lost years (DALY) as an endpoint. Airflows appeared to be an important determinant of concentration. A preliminary comparison of health effects following from the presence of formaldehyde, radon and particulate matter in the indoor environment with health effects associated with pollution of the outdoor environment following from the overall life cycle impact of dwellings was made. The indoor environment appears to have a large impact on the total health effects of dwellings.

4D4p3 Quality of life: meditations on people and architecture
N Boschi and LM Pagliughi

This paper correlates the definition of architectural spaces to the concept of quality of life. The concept of quality of life covers domains such as the psychological, physiological, interpersonal, spiritual, and financial. Quality of life is dynamic; people and the environment change over time. The 1949 definition of health provided by the World Health Organization (WHO) is a useful blueprint for defining health measures to inform architectural design. Two questions are discussed: Are cultural associations relevant in defining building environmental performances? Can the Vitruvian connection of architecture-climate-comfort and the Palladian theory of architecture still inform modern architecture? The historical domains of durability, convenience and beauty continue to be a valid model because they are meant to be a reflection of the quality of life of individuals at a given time. This paper promotes architectural education that bases its philosophical approach on the historical concept of commoditas/utilitas (convinience) as way to enhance quality of life.

4D4p4 In-residence risks from exposure to multiple pollutants: a study of two populations in Arizona
DJ Moschandreas, YK Arrington, Lebowitz, MK O'Rourke, SM Gordon, and G Robertson

This study compares risks from residential exposures to seven pollutants including metals, pesticides and volatile organic compounds from multiple routes between two geographic populations, the Arizona State population and the Arizona U.S.-Mexico border population. The databases from NHEXAS-AZ and the NHEXAS-Border studies are used to investigate whether proximity to large area and point sources causes environmental justice concerns. The indirect approach estimates exposures to multiple pollutants from multiple routes utilizing measured concentrations in multiple media and questionnaire information for exposure factors. Aggregate risk estimates from exposure to a single pollutant by multiple routes are calculated using deterministic methods for carcinogens and non-carcinogens. Discriminant analysis compares risks from the two geographic populations taking jointly risk estimates from all routes or single route estimates to all pollutants. Results of these analyses indicate that risk is a pollutant and/or route-specific discriminant factor.

4D4p5 An integrated, community-based approach to air toxics reduction
W Long

To date, US efforts to address human exposure to toxic air pollutants has proceeded with separate efforts addressing stationary, mobile, and indoor sources. In 2001, the United States Environmental Protection Agency (US EPA) launched a new pilot project designed to use an integrated approach to reduce local risks from air toxics with voluntary measures. A key component of the pilot is the use of a community-based Working Group to guide decisions and get risk reduction projects in place. Members of this group include residents, neighborhood organizations, businesses, local officials, individuals from area colleges and universities, industry representatives, and environmental advocates. This paper briefly describes US EPA's program to address air toxics, describes the methods used to begin the community-based pilot, and examines key lessons to date. Particularly, the challenge of taking action in the face of imperfect information is discussed

4D5o1 Indoor air pollution from biomass stoves as a risk factor for acute respiratory infections in Kenya
M Ezzati and DM Kammen

55 randomly-selected households (including 93 infants and children; 229 individuals between 5 and 49 years of age; and 23 at ages ≥ 50) in central Kenya were followed up for more than 2 years. Longitudinal data on acute respiratory infections (ARI) and acute lower respiratory infection (ALRI) were recorded in weekly clinical examinations. Exposure to PM_{10} was estimated from 210, 14-hour days of continuous real-time monitoring of particulate matter concentration under the conditions of actual use as well as the location and activities of household members, supplemented by data on spatial dispersion of pollution and interviews. Estimates of risk associated with exposure to indoor smoke (measured by PM_{10} concentration) are presented using linear and logistic models for average daily exposure below and above 1000 mg/m^3. There was increased risk for both total ARI and ALRI for those at higher exposure in both age groups.

4D5o2 Asthma and indoor air pollution among indigenous children in Guatemala
MA Schei, JO Hessen, J McCracken, V Lopez, N Bruce and KR Smith

Objectives: To estimate the prevalence and severity of asthma among indigenous children in Guatemala, and the association with cooking on open fires. Methods: In 1058 homes with children 4-6 years of age, we interviewed the mothers using standardized ISAAC procedures and questionnaire. Results: Only 3.4% reported wheezing symptoms in the last 12 months. In a logistic regression model, use of open fire for cooking was a significant risk factor for a number of asthma symptoms, with odds ratios varying from 1.81 to 3.21. For the different cooking technologies (1=improved stove with chimney, 2=mixture of gas and open fire, 3=open fire) we observed significant trends for some of the symptoms. Conclusions: The asthma prevalence is low among indigenous children in Guatemala, compared to other populations in Latin-America. Use of open fire for cooking, may be an important risk factor for asthma symptoms and severity.

4D5o3 An evaluation of the indoor/outdoor air pollution and respiratory health of farmers living in rural areas of Anhui province, China
X-C Pan, Z Dong, L Wang and W Yue

To evaluate the levels of indoor air pollution in rural areas of China and their effects on respiratory health, we monitored the indoor (bedroom and kitchen) and outdoor levels of PM_{10}, SO_2 and CO in 189 randomly selected households of rural areas, Anhui province, China. We also conducted an investigation of 487 subjects between the ages of 15 – 65 years old with a questionnaire. The PM_{10} level of indoors air was significantly higher than that outdoors (518±27/287±9mg/m^3, P<0.01), in contrast to the SO_2 level that was lower. We didn't find a significant association to asthma onset with these levels of PM_{10} and SO_2 of the indoor air (P>0.05). FVC, FEV1 were closely related with the CO and PM_{10} exposure indices in the bedroom (P<0.01). Conclusion: the indoor air pollution in rural areas may come from combustion of fuel in cooking and heating, which has had adverse effects on the respiratory health of the subjects.

4D5o4 Effects of cooking smoke on asthma in the elderly
V Mishra

Effects of cooking smoke on the prevalence of asthma among elderly men and women (age 60+) are examined using data on 38,595 elderly living in 92,486 households included in India's second National Family Health Survey conducted in 1998–99. Effects of cooking fuel type (biomass fuels, cleaner fuels, and a mix of biomass and cleaner fuels) on asthma prevalence are estimated using logistic regression. Results indicate that elderly living in households using biomass fuels have significantly higher prevalence of asthma than those living in households using cleaner fuels (OR=1.59, p<.0001), even after controlling for effects of age, tobacco smoking, education, living standard, and several other potentially confounding factors. Active tobacco smoking also increases the risk of asthma significantly. As expected, the effect of cooking smoke on asthma is considerably greater among women (OR=1.83, p<.0001) than among men (OR=1.46, p<.001).

4D5o5 Domestic smoke pollution and respiratory diseases in Nepal
MR Pandey

The main respiratory diseases caused by Domestic Smoke Pollution (DSP) are chronic bronchitis and chronic obstructive lung diseases. In our study conducted in Nepal, the increasing trend of the prevalence of chronic bronchitis as the hours of exposure to domestic smoke pollution increased (even after elimination of the age effect and also among the non-smokers) established the definite role of domestic smoke pollution in causing this disease. Another study showed significant correlation of DSP and airway obstruction in smokers but the association was not significant in non-smokers. Significant correlation has also been found of DSP with acute respiration infection in studies done in Nepal and several other countries. Apart from these, there is evidence that DSP can also cause interstitial lung disease, tuberculosis and asthma. Further research work is recommended in these areas.

4D5p1 Investigation and evaluation of firewood consumption in traditional houses in Nepal
HB Rijal and H Yoshida

Firewood consumption and air temperature were investigated in winter and summer in traditional houses in the Banke, Bhaktapur, Dhading, Kaski and Solukhumbu districts of Nepal. The firewood consumption rate was 235-1130kg/capita/year. The results showed that the temperate climate used less firewood than the sub-tropical climate. The indoor and outdoor temperature difference (7.8 C), the vertical temperature difference (7.1 C) and maximum indoor air temperature (42 C) were most significant in the kitchen. The results demonstrated a waste of energy in winter and an uncomfortable thermal environment in summer. If thermal storage on the wall were introduced as well as airtight openings and improvements in fireplaces, we could reduce the usage of firewood, and the thermal and air environment would be improved.

4D5p2 Health impacts of cooking fuels on females in Uttar Pradesh, India
H Biswas and J Parikh

In this paper we try to establish the association between biofuel use and respiratory diseases namely bronchitis, asthma, chest infection, tuberculosis and eye irritation as per British Medical Research Council (BMRC, 1986) questionnaire. This is based on a large comprehensive survey covering sample of 7564 households (HH) (10264 females) in 6 districts and 51 villages in UP. Logistic regressions are carried out using disease variables as dependent variables with adjustments for confounding variables like age, smoking, illiteracy, income, asset possessions, village characteristics, etc. Biofuel cooking has negative impact on the health of the individuals. Level of education too plays a vital role in symptom occurrence. With the improvement in economic status prevalence of diseases decreases. Efficient fuels, adequate ventilation, awareness through education can serve as policy prescriptions for better health status.

4D5p3 Indoor air quality related standards in China
Z Bai, C Jia, T Zhu and J Zhang

In 2001, the Chinese national standard entitled "Code for Indoor Environmental Pollution Control of Civil Building Engineering" along with another 10 indoor air quality (IAQ) related standards were issued. In addition to this standard, the China Ministry of Health also issued the directive entitled "Hygienic Norm for Indoor Air Quality". This paper reviews the development of IAQ-related standards and regulations in China, specifying the scopes, objectives, administrative authorities, and implementation plan.

4D5p4 Economic burden of respiratory illness in rural Uttar Pradesh, India
J Parikh and H Biswas

In this paper we estimate the economic burden of respiratory illness in rural Uttar Pradesh (UP), a state in North India. This is based on a large comprehensive survey covering sample of 7564 households (HH) (16264 individuals) in 6 districts and 51 villages in UP. The survey, collected data on costs incurred on doctors' fees, hospitalization, medicine, additional cost for special diet and days lost. The average costs incurred are higher among males by 1.2 times. The total direct health care cost for the entire adult population (greater than equal to 15 years) in the state of UP (rural) comes to 548.1 Million rupees (1 US $= Rs. 48) per month. The economic value of the days lost due to illness in one month is Rs 4233 Millions. Cleaner fuels, health education and better health care can avoid some of these expenditures.

4D5p5 Studies on indoor air pollution from domestic fuel in China
Y Qin

Coal is used in most of homes as domestic fuel in China. Many Chinese scientists conducted investigations on indoor air pollution and adverse effects on human health. The paper reviewed the major findings. The concentrations of pollutants in indoor air in households where coal is used as domestic fuel for cooking and heating are much higher than those in households where piped gas or liquefied petroleum gas are used. The levels of nearly all pollutants measured in kitchens are higher than those in bedrooms in different seasons. The concentrations of pollutants in indoor air are higher than those in atmosphere. Studies also showed that coal burning induced higher incidence of respiratory illness. Particularly, the study in Xian wei revealed that the concentrations of PAHs in homes using smoky coal were higher than those in homes using wood and a strong relationship between concentrations of PAHs and incidence of lung cancer was found.

4D5p6 Impacts of cooking coal smoke and heating coal smoke on respiratory health of children in four Chinese cities
Z Qian, J Zhang, F Wei, and RS Chapman

Data collected in a large epidemiologic study were analyzed to examine respiratory health effects of residential coal use in 7058 school children living in four Chinese cities of Lanzhou, Chongqing, Wuhan, and Guangzhou. A Scenario Evaluation Approach was used to develop two exposure variables, heating coal smoke and cooking coal smoke. Estimated lifetime exposures to heating coal smoke, and cooking coal smoke, were both classified into four-level ordinal scales, as follows: control; lightly exposed; moderately exposed; and heavily exposed. Zero-one dummy variables were constructed for each exposure level other than the control level (total six variables). These variables were entered into the analytical model. We tested for exposure-response relationships using logistic regression models, controlling for relevant covariates. We observed exposure-response relationships between heating coal smoke and prevalence rates of phlegm, cough with phlegm, and bronchitis. We observed no consistent associations between cooking coal smoke and the examined health outcomes.

4D5p7 Preliminary analysis of 6 coals associated with different lung cancer rates
LW Tian, CP Koshland, RS Chapman, SK Hammond, and D Lucas

Indoor air pollution from coal burning causes high lung cancer mortality in Xuanwei County, China, but the lung cancer rates vary among the communes in this county that use different coals. We explored the association between coal composition and lung cancer rates in this region. Similar values of aromaticity were found among all the coals studied. The two coals associated with the highest lung cancer rates had the highest free silica and organic sulfur. Iron contents (measured as ferric oxide) in coal were in excellent correlation with the lung cancer rates. These results suggest that polycyclic aromatic hydrocarbons (PAH) alone are not responsible for the observed lung cancer rates, but that a complex chemical mixture is involved.

4D6o1 The effect of a personalized ventilation system on perceived air quality and SBS symptoms
J Kaczmarczyk, Q Zeng, A Melikov, PO Fanger

Perceived air quality, SBS symptoms and performance were studied with 30 human subjects. Experiments were performed in an office set-up with six workplaces, each equipped with a Personalized Ventilation System (PVS). Each PVS allowed the amount of supply air and its direction to be controlled. Subjects participated in four experiments: (1) PVS supplying outdoor air at 20 C; (2) PVS supplying outdoor air at 23 C; (3) PVS supplying recirculated room air; and (4) mixing ventilation. Room temperature was kept constant at 23 C and relative humidity at 30%. Results showed that the best condition in regard to perceived air quality, perception of freshness and intensity of SBS symptoms was when PVS supplied outdoor air at 20 C. Perceived air quality in this case was significantly better ($p<0.01$) than with mixing ventilation. Supplying outdoor air by means of the PVS decreased complaints of headache, and improved the ability to think and to concentrate.

4D6o2 A study of thermal comfort in an office environment with floor return type underfloor ventilation system
MP Wan and CY Chao

Thermal comfort of the Floor Return (FR) type underfloor ventilation system was evaluated based on the temperature and velocity distribution as well as the PMV and PPD indices. Experiments were conducted in an office type controlled chamber under different supply air temperatures and internal heat loads. Temperature variations in the vertical direction were found within 0.6 C between 0.1 to 1.7m height levels. Air velocities were found lower than 0.25m/s in tested positions. Presence of solid partitions significantly blocked the low-level supply air. The PMV values ranged within ±0.5 and the associated PPD values were lower than 10%. The experimental results satisfied major international comfort standards. The underfloor ventilation system maintained a comfortable environment under the tested conditions.

4D6o3 Measurements and prediction of inhaled air quality with personalized ventilation
R Cermak, M Majer and AK Melikov

This paper examines the performance of five different air terminal devices for personalized ventilation in relation to the quality of air inhaled by a breathing thermal manikin in a climate chamber. The personalized air was supplied either isothermally or non-isothermally (6 C cooler than the room air) at flow rates ranging from less that 5 L/s up to 23 L/s. The air quality assessment was based on temperature measurements of the inhaled air and on the portion of the personalized air inhaled. The percentage of dissatisfied with the air quality was predicted. The results suggest that regardless of the temperature combinations, personalized ventilation may decrease significantly the number of occupants dissatisfied with the air quality. Under non-isothermal conditions the percentage of dissatisfied may decrease up to 4 times.

4D6o4 Ventilation efficiencies of a desk-edge-mounted task ventilation system
D Faulkner, WJ Fisk, DP Sullivan and SM Lee

In chamber experiments, we investigated the effectiveness of a task ventilation system with an air supply nozzle located underneath the front edge of a desk and directing air toward a heated mannequin seated at the desk. The task ventilation system provided outside air, while another ventilation system provided additional space cooling but no outside air. Test variables included the vertical angle of air supply (-15º to 45º from horizontal), and the supply flow rate of (3.5 to 6.5 L s^{-1}). Using the tracer gas step-up and step-down procedures, the measured air change effectiveness (i.e., exhaust air age divided by age of air at the mannequin's face) ranged from 1.4 to 2.7, which is higher than typically reported for commercially available task ventilation or displacement ventilation systems.

4D6o5 Long term evaluation of the general thermal comfort conditions
BW Olesen and M de Carli

If thermal comfort criteria have to be met 100% of the time of occupancy, including extreme weather conditions, the heating and cooling capacity of any HVAC installation would be prohibitive. Economic or environmental considerations lead to a more

pragmatic position of allowing the thermal conditions to exceed the recommended ranges for a limited time. By computer simulation and measurements in existing buildings, comfort conditions are often tested over longer periods of time, for evaluation of different building and HVAC designs One method to quantify long term performance would be to estimate the number of hours where the thermal conditions are outside the recommended range. Another would be to weight the number of hours with a factor depending on the number of degrees away from the comfort range or weighted according to the PPD-value. Based on data from measurements in an existing building, different methods for long term thermal comfort evaluations are demonstrated and discussed.

4D6p1 Indoor airflow behavior and thermal comfort in a courtyard house in warm humid tropics
I Rajapaksha, H Nagai and M Okumiya

This paper assesses the effects of indoor airflow behavior modifying the indoor air temperature on thermal comfort conditions in a residential tropical courtyard building where courtyard maintains direct contacts with outdoor environment through openings found in the envelope. Results taken from a field investigation and a computer simulation reveal that given the ambient climatic conditions particular indoor airflow behaviors are sufficient to lower the indoor air temperatures below the ambient level in the courtyard as well as in surrounding internal spaces. Thus, thermal comfort condition not correlated to the number of openings but to the distribution pattern and volumetric rate of indoor airflow in enhancing heat exchange between wall surfaces and air. The optimum range of ambient wind direction, which required for optimum distribution and volumetric flow of indoor air, was found within a range of 30-60 degrees to the longitudinal axis of the courtyard and building.

4D6p2 Central heating installation for older, low income households: what difference does it make?
J Rudge and R Winder

Older people are particularly vulnerable to adverse health effects of cold living conditions. Yet, in the UK, they are often least able to afford sufficient heating to achieve recommended indoor temperatures and most likely to live in hard to heat housing with inefficient heating systems. This study was designed to evaluate a local authority initiative to install central heating, in terms of improvements in comfort, warmth and self-reported health. The sample consisted of 210 tenants, aged 70 or more, who were offered free central heating installation. They were interviewed and their home temperatures were monitored using miniature data loggers. Preliminary results from 102 participants who were monitored concurrently through a cold period are examined compared, and indicate indicating reductions in temperature differences between rooms after heating installation. This is important, considering the health effects of 'thermal stress' on older people. Methodological issues are also discussed.

4D6p3 The effects of moderate heat stress and open-plan office noise distraction on office work
T Witterseh, DP Wyon, and G Clausen

Thirty subjects clothed for comfort at 22 C performed simulated office work for 3 hours at 22/26/30 C (7.4 g/kg dry air, i.e. 45/35/28 %RH) in quiet and recorded open-plan office noise (55 dBA) conditions. Warmth decreased perceived air quality ($P<0.01$) and increased odour intensity ($P<0.05$) and stuffiness ($P<0.01$). After 2 hours, forehead sweating was observed on 4/36/76% of subjects ($P<0.001$), while 0/21/65% felt “warm” or “hot” ($P<0.001$). Raised temperature increased eye, nose and throat irritation and headache intensity ($P<0.05$) and decreased concentration ($P<0.05$) and self-estimated performance ($P<0.001$). Noise increased fatigue ($P<0.05$) and decreased concentration ($P<0.05$) but did not interact with any thermal effects on subjective perception. In an Addition task, noise decreased the workrate by 3% ($P<0.05$), subjects who felt warm made 56% more errors ($P<0.05$) and there was a noise-temperature interaction ($P<0.01$): noise removed the effect of warmth on errors. Noise increased typing speed ($P<0.05$) and reading speed ($P<0.05$).

4D6p4 Experimental study of facial air supply method for the reduction of pollutant exposure
HG Zuo, JL Niu and WT Chan

Current ASHRAE ventilation standard promulgates an outdoor intake around 10 l/s.person, whereas, the metabolic human respiration rate is only around 0.1 l/s. We are testing the concept of supplying ventilation in close proximity to nostrils and the facial area at much reduced airflow rate. A thermal manikin with a simulated lung is placed in a normal air-conditioned office. Fresh air is directed at the facial area of the manikin at flow rates raging from 0.1 to 2 l/s. CO_2 concentrations in the inhaled air, supplied air, and the ambient room air were measured, which were used is to calculate two newly-defined indices, i.e., the fresh air utilization efficiency hu and the pollutant exposure reduction efficiency hPER. It is perceived that such a facial air supply method may have application potentials in those work places where occupants are sitting in a fixed position for prolonged period.

4D6p5 The effects of localized cool air flow on thermal comfort in muggy condition
J-Y Lee, C-O Ahn, D-U Mun, C-S Lee, S-W Chin and K-S Cho

The purpose of this study is to clarify the effects of localized cool airflow on thermal comfort in muggy condition. The experiment is conducted in summer. The subjects are exposed to the following conditions: combinations of air temperatures (Ta=30 C, 33 C), discharge temperature (Tdc=15 C, 20 C) and relative humidity (RH=50%, 80%) The following results are obtained: For the whole parts of the body thermal sensation were voted [-1: slightly cool]~[+1: slightly warm]. The skin temperature of the head in contact with the air flow was affected by the low discharge temperature (15 C). The skin temperature mentioned was from 31.5 C to 33.3 C. The mean skin temperature ranged from 33.8 C to 34.5 C. We prove that localized airflow could relieve muggy conditions even to 35 C of mean skin temperature.

4D6p6 Residences of the elderly: ventilation and indoor air physical properties
J Laakso and LM Reinikainen

Air change, temperatures, relative humidity (RH) and air flows were measured in January to February 2000 in 63 apartments built for the elderly in southern Finland. Residents were inquired about indoor climate conditions. Associations between type of ventilation and sensations of heat and coldness, and ventilation habits were assessed using Chi square analysis. 4 (6.3%) apartments were provided with natural ventilation, 46 (73.0%) with mechanical exhaust, and 13 (20.6%) with mechanical inlet and exhaust. Mean indoor temperature was 24.2 (20.3-26.5oC). In apartments with mechanical exhaust, excessive heat was less common compared with mechanical inlet and exhaust which, instead, was associated with less coldness (Chi square, $p<0.05$). Type of ventilation is associated with heat comfort in residences of the elderly. High indoor temperature is compensated by opening windows. Mean indoor temperatures are higher than recommended for people of working age.

4D6p7 Seasonal field survey on thermal comfort conditions in semi-outdoor spaces
J Nakano, K Goto, M Noguchi, H Fujii, T Shimoda, and S Tanabe

A series of seasonal field surveys integrating thermal environment measurement around the occupant and questionnaire survey was conducted from the summer of 2001 in order to investigate the thermal comfort conditions in semi-outdoor spaces from the viewpoint of short-term occupancy. Four architectural environments in Tokyo, Japan with different levels of environmental control were selected, two of which were closed atria with air conditioning and two of which were open spaces without air conditioning. A total of 1275 questionnaires were collected during the summer and autumn survey. Average occupancy period was 11 minutes for non-HVAC buildings and 19 minutes for HVAC buildings. Clothing was found to correlate with air temperature of the occupied zone in autumn, but less in summer. Seasonal difference of thermal sensation was observed in non-HVAC buildings, while small difference existed for HVAC buildings. Thermal acceptability rate was above 85% for all cases.

4D6p8 Comfort criteria and design aspects in high temperature radiant heating
P Brunello, M De Carli, A Polito and R Zecchin

High temperature radiant heating is becoming increasingly popular, particularly for industrial and commercial applications. For assessing the thermal behaviour of a room heated in this way some simulation models have been recently proposed: in most of them the radiative heat exchanges between the heating and the surrounding surfaces are very carefully treated, but some uncertainties still remain about the convective components, especially when suitable devices (baffles, etc.) are applied in order to reduce convection (and consequent thermal stratification). In this paper field measurements and comparisons with a model are presented; such tuning allows to evaluate better solutions for the indoor climate, taking into account different configurations of the systems.

5A1o1 Airborne mycotoxin sampling and screening analysis
E Johanning, M Gareis, K Nielsen, R Dietrich and E Märtlbauer

The indoor mycotoxins inhalation exposure of patients (n=25) using a high-volume air sampler (60 cfm x 24 h) with a micropore-paper filter (8x11 inches) was studied. The filters were evaluated using the MTT-cell culture bioassay for cytotoxicity testing and by culture identification. A subset of samples was analyzed with an enzyme-immuno assay for occurrence of macrocyclic trichothecenes produced by *Stachybotrys chartarum* and HPLC-DAD and GC-MS analyses for different mycotoxins. Highly toxic air samples ($IC_{50} \leq 31$ mg/ml) were found in seven cases; moderate toxicities ($IC_{50} > 31$ to ≤ 125 mg/ml) in 14 cases, and four cases were not toxic compared to controls. The subset testing demonstrated that macrocyclic trichothecenes and other mycotoxins could become airborne. In conclusion, an inhalation risk could be confirmed (84% of cases) with the 24-hour high volume air sampling test method due to the detection of airborne cytotoxic fungal particles and specific mycotoxins, including trichothecenes.

5A1o2 Dampness in buildings and health. Building characteristics as predictors for dampness in 8 681 Swedish dwellings
L Hägerhed, CG Bornehag, and J Sundell

Questionnaire data on 8,681 dwellings included in the Swedish study "Dampness in Buildings and Health" has been analyzed for associations between dampness indicators, perceptions of indoor air quality and building characteristics such as time of construction, type of ventilation and type of foundation. Visible mold or damp stains were reported in 1.3 and 1.6% of single-family and multi family houses respectively, dampness connected to the floor in 6.5 and 13.9% and condensation on windows in 12.5 and 16.9%. "Stuffy air" was reported in 22.3 and 42.8%, "Moldy odor" in 3.9 and 5.8% and perception of "Dry air" in 17.3 and 33.7 % respectively. Older buildings and the use of natural ventilation were associated with increased frequency of dampness indicators as well as to increased frequencies of complaints on bad indoor air quality.

5A1o3 Dampness in buildings as a risk factor for health effects: European multidisciplinary review of the entire literature (EUROEXPO)
CG Bornehag and J Sundell

The scientific literature on health effects associated with "dampness" in buildings including literature between 1998 and 2000 over the periodhas been reviewed by an European group (EUROEXPO). The groups consisted of scientists with experience from medicine, epidemiology, toxicology and engineering. Of the 104 reviewed articles 52 were excluded as they were judged as background papers or "non-informative" or "inconclusive" or the study did not present data on exposure, health effect or analysis of the association between exposure and health. The review groups concluded that "dampness" in buildings is a risk factor for health effects such as cough, wheeze, asthma, general symptoms and airway infections among atopics and non-atopics, both in domestic and public environments. However, the literature is inconclusive in respect of causative agents in such buildings. Suggested causative agents are mites, microbiological agents and organic chemicals from degraded building materials.

5A1o4 Double blind placebo controlled exposure to moulds
HW Meyer, KF Nielsen, KA Jensen, J Kildesø, S Norn, H Permin, LK Poulsen, HJ Malling, S Gravesen and F Gyntelberg

The objective was to study the clinical importance of experimental exposure to moulds in sensitive subjects with experienced building related symptoms (BRS) at work. From three water damaged schools eight employees with a positive histamine release test to *Penicillium chrysogenum* were on three different days double blinded exposed to either placebo, air with app. 600 000 spores/m^3 of *P. chrysogenum* or *T. harzianum* for app. 6 minutes. A statistically significant rise in symptoms from mucous membranes appears from the 9-graded symptom scale after exposure to *T. harzianum* or placebo. Dichotomising the data, whether the participants experienced at least a two-step rise on the symptom scale or not, gave near-significant increase in mucous membrane symptoms after exposure to *P. chrysogenum*. In conclusion exposure to two different moulds in large concentrations did not result in more reactions than placebo in this double blinded set-up involving sensitive school employees.

5A1o5 Mold in homes and schools: state and local agencies respond to increased public concern
L Oatman, T Allan, and D Jones

State and local health departments throughout the United States have experienced a significant increase in the number of complaints regarding moisture and mold problems during the past decade. A survey of 28 state and local health departments with indoor air programs found that the general public is asking the same types of mold-related questions regardless of climate. The responses of public health agencies are varied and range from providing direct services such as inspections, research, development of guidance documents, and building the capacity of city and county agencies to respond locally. Although the policy questions faced by health departments are similar, the Cuyahoga County Board of Health and the Minnesota Department of Health have taken different approaches in responding to indoor mold complaints.

5A2o1 Semi-quantitative mold exposure index predicts building-related respiratory symptoms
JH Park, PL Schleiff, MD Attfield, JM Cox-Ganser, K Kreiss

The National Institute for Occupational Safety and Health (NIOSH) investigated 13 college buildings to examine whether a semi-quantitative mold exposure index (EI) could efficiently predict work-related respiratory symptoms. We collected work-related symptom data and room locations/time fractions through questionnaires. Industrial hygienists classified rooms for factors including extent of water stain, visible mold, mold odor, and dampness. We estimated 323 individual EIs based on each factor or a combination of the factors weighted by time fraction in particular rooms. In logistic regression models adjusting for age, gender, job position, hire years, smoking, allergies, and use of latex gloves, we found a significant exposure-response relationship for wheeze (Odds Ratio(OR)=2.3) with stain-based EI. EI based on the combined factors showed significant exposure-response relationships for chest tightness (OR=2.2) and shortness of breath (OR=2.7). Our findings suggest that an

observational semi-quantitative exposure index can support public health action to prevent risk of building-related respiratory disease.

5A2o2 The role of ventilation and HVAC systems for human health in non-industrial indoor environments. A supplementary review by EUROVEN group
P Wargocki, J Sundell, W Bischof, G Brundrett, PO Fanger, F Gyntelberg, SO Hanssen, P Harrison, A Pickering, O Seppänen and P Wouters

A continuation of the earlier work of the multidisciplinary group of European scientists, EUROVEN, is presented. The group has previously concluded that increased ventilation rates in indoor nonindustrial environments are strongly associated with improved comfort and health and may be associated with increased productivity, and that air-conditioning systems may increase the risk of sick building syndrome (SBS) symptoms. Taking these findings into account, the group has elaborated 35 hypotheses on the role of ventilation and HVAC systems in nonindustrial indoor environments with regard to human health; 108 peer-reviewed papers have been reviewed among which 74 supported or refuted the hypotheses. The group concluded that increasing outdoor air supply rates is necessary for dilution/removal of pollutants generated indoors (including allergens), and that improper design, functioning and maintenance of ventilation and air-conditioning systems, as well their intermittent operation, may be potential reasons for health problems of people staying indoors.

5A2o3 Review of mechanisms of effect of ETS with relevance to health effects in children
C Courage, P Holmes, LK Shuker and PTC Harrison

Environmental tobacco smoke (ETS) is widely accepted as a significant risk factor for ill health in children, and links have been suggested with sudden infant death syndrome, middle ear disease, increased susceptibility to respiratory infections, and increased severity and prevalence of asthma. Elucidating the toxic mechanisms underlying the effects is, however, difficult, particularly given the complex mixture of more than 4000 chemicals that make up ETS. A detailed critical assessment of the published literature, focusing on studies in neonatal and juvenile animals, with supporting data from *in vitro* work, concludes that: (i) ETS exposure early in life may lead to changes in immune response, leading to airway hyper- or hypo-responsiveness; (ii) in experimental animals, chronic stimulation by ETS of C-fibres and rapidly adapting receptors (RAR) may account for cough, wheeze and sputum production; and (iii) the perinatal period is a critical period for exposure to ETS.

5A2o4 Respiratory tract effects of repeated exposures to isoprene/ozone reaction products in mice
AC Rohr, SA Shore and JD Spengler

Upper airway irritation and airflow limitation have been reported in mice during single exposures to the oxidation products (OPs) of isoprene, a hemiterpene emitted by humans and vegetation. This study evaluated the respiratory effects of repeated exposures to isoprene OPs. Male mice of 6 strains were exposed to a reaction mixture comprised of 3,227 ± 157 ppm isoprene and 1,080 ± 155 ppm ozone 3 hours/day for 4 consecutive days, and respiratory parameters were monitored via head-out plethysmography. Endpoints evaluated were sensory irritation, pulmonary irritation, airflow limitation, and airway responsiveness. Marked enhancement of the sensory irritation and airflow limitation effects was observed with repeated exposures, and pulmonary irritation developed in several strains. A reduction in airway responsiveness occurred in most strains, which may reflect airway mucous hypersecretion. The cumulative effects observed with repeated OP exposures have important implications for non-industrial indoor environments in which exposure may occur over many years.

5A3o1 EuroPart. Airborne particles in the indoor environment. A European interdisciplinary review of scientific evidence on associations between exposure to particles in buildings and health effects
T Schneider, J Sundell, W Bischof, M Bohgard, JW Cherrie, PA Clausen, S Dreborg, J Kildesø, SK Kjærgaard, M Løvik, P Pasanen and K Skyberg

The relevance of particle mass, surface area or number concentration as risk indicators for health effects in non-industrial buildings has been assessed by a European interdisciplinary group of researchers by reviewing papers identified in Medline, Toxline, and OSH. Studies dealing with dermal effects or cancer or specifically addressing environmental tobacco smoke, major allergens, and pesticides were excluded. Seventy six papers were identified for evaluation and eight of these were judged to be conclusive and included in the final review: five experimental studies, two cross-sectional office studies, and a longitudinal study among elderly with cardiovascular conditions. Given the limited and inconclusive scientific evidence, the group concluded that indoor particulate mass or number concentrations cannot be used as generally applicable risk indicators of health effects in non-industrial buildings and that there is an inadequate scientific basis on which to establish limit values or guidelines for particulate mass or number concentrations.

5A3o2 Personal, indoor and outdoor monitoring of exposures to polycylic aromatic hydrocarbons among a cohort of pregnant women from Krakow, Poland
K Peki, R Whyatt, W Jedrychowski, D Camann, A Penar, U Bawle, J Adibi and F Perera

Polycyclic aromatic hydrocarbons (PAH) are widespread pollutants produced by incomplete combustion. The city of Krakow in Poland is an industrialized area with high concentrations of PAH in the ambient air. As part of a prospective cohort study being conducted among pregnant women from Krakow, we have measured PAH levels in personal, indoor and outdoor air monitoring over 48-hours collected from 27 women during the 2nd trimester of pregnancy. The monitoring was conducted between January, 2001 and August, 2001. Results show high but variable exposures (ng/m^3): Benz(a)pyre (0.24-36.79); Benz(a)anthracite (0.39-36.69); Benz(b)fluoranthene (0.42-32.64); benzo(k)fluoranthene (0.18-11.25); chrysene (0.34-29.72); dibenz(a,h)anthracene (0.17-9.41); indeno(1,2,3-cd)pyrene (0.55-50.20); pyrene (1.46-47.12). Outdoor PAH levels were higher than indoor levels. Personal levels were lower or similar to outdoor levels and higher than indoor levels. Indoor, outdoor and personal levels were all highly correlated (r>0.93). PAH levels were higher in the samples collected during the winter compared to the summer months. These finding show substantial PAH exposures among cohort women during pregnancy.

5A3o3 Distributions of residential organochlorine pesticide residuals along the Arizona/Mexico border
G Robertson, M Lebowitz, L Needham, MK O'Rourke, S Rogan, J Petty and J Huckins

The use of DDT has been banned for many years in the United States. Mexico began a 10-year phase out of DDT in 1997. DDT was banned in the U.S. primarily because of its environmental persistence. Thus, DDT is still found in the outdoor and indoor environment. We report the results from samples collected in 83 homes in Arizona along the Arizona/Mexico border. The media sampled included indoor air, floor dust, dermal wipes, and blood serum. 4,4'-DDT was detected in 62% of the floor dust samples, 19% of the indoor air samples, and 31% of the dermal wipes. This may be from spray residuals in older housing stock, recent use of chemicals obtained in Mexico, track-in from outdoor usage, or other sources. We report on the concentrations found, examine the distributions of occurrence of DDT analogs in the various media and discuss possible sources of these occurrences.

5A3o4 A test chamber study of the contribution of human body surfaces to the "personal cloud"
MA Byrne, G Kearns and C McKenna

In exposure studies, the existence of the "personal cloud", the amount by which personal exposure exceeds indoor and outdoor concentrations, is well documented but its source is not well understood. The relative contributions of clothing, hair and skin to the personal cloud were studied in a test chamber, where volunteers wearing a range of clothing, and having a variety of hair types, participated in a consistent activity pattern. Airborne particle number concentration data in six size ranges (between 0.5 mm and 10.0 mm) were collected. For each volunteer, parts of the body were excluded sequentially, so that aerosol concentrations arising from the face, hands, hair and clothing could be evaluated individually. The results indicate that the major contribution to total particle number concentration arises from clothing. In experiments where fabrics were pre-exposed to aerosol particles, the difference in retention characteristics of various clothing types was observed.

5A3o5 The transformation of outdoor ammonium nitrate aerosols in the indoor environment
MM Lunden, TL Thatcher, D Littlejohn, ML Fischer, SV Hering, RG Sextro, and NJ Brown

Recent studies associate particulate air pollution with adverse health effects; however, the exposure to indoor particles of outdoor origin is not well characterized, particularly for individual chemical species. In response to this, a field study in an unoccupied, single-story residence in Clovis, California has been conducted. Real-time particle monitors were used both outdoors and indoors to quantify $PM_{2.5}$ nitrate, sulfate, and carbon. The results show that reduced indoor sulfate and carbon levels are primarily due to deposition and penetration losses. However, measured indoor ammonium nitrate levels were often observed to be at significantly lower levels than expected based solely on penetration and deposition losses. The additional reduction appears to be due to the transformation of ammonium nitrate into ammonia and nitric acid indoors, which are subsequently lost by deposition and sorption to indoor surfaces. The size of the effect is dependent upon factors such as temperature, relative humidity, and ventilation rate.

5A3o6 Production and levels of selected indoor radicals: a modeling assessment
G Sarwar, R Corsi, D Allen, and C Weschler

Indoor radical concentrations were estimated using a new indoor air quality model. Model results indicate that typical indoor hydroxyl, hydroperoxy, and methylperoxy radical concentrations are lower than typical urban outdoor daytime levels during summertime conditions, but can be similar to or greater than typical outdoor nighttime levels. Predicted indoor nitrate concentrations are less than typical outdoor daytime levels, but can be similar to typical nighttime levels at high air exchange rates. Indoor hydroxyl and methylperoxy radical concentrations are predicted to increase with indoor alkene eission rates.

Indoor methylperoxy radical concentrations can be similar to typical outdoor daytime levels at higher indoor alkene emission rates. Indoor temperature has moderate impacts on indoor hydroxyl and methylperoxy radical concentrations, and significant effects on indoor hydroperoxy and nitrate radical concentrations.

5A4o1 An analysis of some subjective assessments of indoor air-quality in five European countries
MA Humphreys, JF Nicol and KJ McCartney

The country of origin was found to dominate the perception of air quality. Next most important was the respondents' subjective thermal state. Least important was the thermal environment itself. The concentration of CO_2 had a slight negative relation to the perceived air quality. The relative humidity affected the perceptions, air quality being rated most highly at moderate levels of humidity. The air temperature did not affect the perceived air quality if the respondents were in thermal comfort. When respondents felt too warm, high temperature and humidity had an adverse effect on the perceived air-quality. When respondents felt too cool, low temperature and humidity had an adverse effect. These results do not support the view that people prefer the air to be dry and cool, but do support the view that combined high temperature and high humidity have an adverse effect on perceived air quality if people are feeling too warm.

5A4o2 Prediction of thermal sensation in non-air-conditioned buildings in warm climates
PO Fanger and J Toftum

The PMV model agrees well with high-quality field studies in buildings with HVAC systems, situated in cold, temperate and warm climates, studied during both summer and winter. In non-air-conditioned buildings in warm climates, occupants may sense the warmth as being less severe than the PMV predicts. The main reason is low expectations, but a metabolic rate that is estimated too high can also contribute to explaining the difference. An extension of the PMV model that includes an expectancy factor is introduced for use in non-air-conditioned buildings in warm climates. The extended PMV model agrees well with quality field studies in non-air-conditioned buildings of three continents.

5A4o3 Climate, clothing and adaptation in the built environment
CA Morgan, R de Dear and G Brager

Specification of acceptable indoor temperatures depends, in part, on assumptions about what people will be wearing. These assumptions have implications for optimising both thermal comfort and energy conservation. Recent proposed revisions to ASHRAE Standard 55 include an adaptive comfort standard that allows a wider range of acceptable indoor temperatures, presented as a function of outdoor weather conditions. Clothing behaviour is one of the causal linkages between indoor thermal comfort and outdoor weather. This paper quantifies this relationship using a cross-sectional study of clothing insulation patterns observed in Sydney, Australia. Fifty two percent of the day-to-day variance in mean daily clo values was accounted for by daily outdoor temperature, and no statistical association between clo values and prevailing indoor temperatures. This paper concludes with an equation for a weighted running mean weekly temperature which can be used in an adaptive algorithm for defining variable indoor comfort temperatures in air conditioned buildings.

5A4o4 Predicted vs. Recorded summer thermal responses in air-conditioned and naturally ventilated dwellings in Israel
M Paciuk and R Becker

A summer field study conducted in 117 air-conditioned and naturally ventilated dwellings included detailed physical measurements and documentation of actual thermal conditions, occupant responses and behavior patterns. Predicted mean thermal sensation votes were found to be lower than those reported, especially for the air-conditioned sample. Predicted percentage of satisfied respondents for the naturally ventilated sample exceeded the percentage of reported comfortable responses. In the air-conditioned sample, the computed percentage fell short of the recorded one, with predicted dissatisfaction stemming from colder than slightly cool sensations instead of, as reported, from overly warm sensations. The discrepancies between predicted and recorded responses highlight the role of contextual variables (local climate, occupants' expectations, available control) in thermal adaptation in real world settings. Thermal comfort models should therefore allow for statistical adjustments that would enable them to reflect the environmental context for which they are intended.

5A4o5 Redefining appropriate thermal comfort standard for naturally ventilated buildings in tropics (Singapore and Indonesia perspective)
H Feriadi, NH Wong, S Chandra, KW Cheong, KW Tham

In naturally ventilated buildings (NVB) located in tropical regions, thermal comfort prediction based on PMV standard has shown some deviation from observed results. Hot and humid environmental conditions throughout the year and personal adaptation make the people in tropics expect and perceive thermal comfort differently. The proposed thermal comfort standard

based on adaptive modeling approach is still not convincing enough for application since it sometimes rely on one environmental parameter for prediction. This study has collected more than 1,000 data through extensive field survey in Singapore and Indonesia. The potential of combining the fundamental thermoregulation with the adaptive approach that considers behavioral adaptation has been explored. The reciprocal effects from environmental parameters and occupant's behavioral adaptation were investigated. In tropical free running buildings where the air temperature and humidity can not be modified without mechanical means, the people were observed to prefer substantially higher wind speed.

5B1o1 Indoor pollutants, Trends, Chemical reactions, Human exposure
B Seifert

The type of pollutants that have been determined indoors has changed over the years. While in earlier times the focus has been on the "classical" pollutants as measured in outdoor air, new insights on and concerns about, potential health effects, and the advances in analytical techniques have contributed to broaden the view and draw a more complex picture of indoor pollutants. In particular, the vast array of organic compounds has attracted the interest of analytical chemists and will continue to play an important role. Growing attention is also being paid to the study of microbiological indoor pollution. Whatever the progress in information is, it must be borne in mind that the knowledge about the qualitative and quantitative presence of pollutants indoors - as important as a comprehensive description of the status of an indoor space may be - is not an end in itself. Rather, it is only one - though important - element of the various facets of indoor sciences, which has to be evaluated in relation with its meaning for human exposure and its relevance for human health.

5B1o2 Building design for good indoor air quality
K Kimura

Problems with architectural design in recent buildings of poor indoor air quality are discussed and proper measures to modify the design process in future buildings for good indoor air quality are proposed with a focus to material selection based on the recent advancement in research on emission from various surfaces. Interconnectedness between indoor air and outdoor air is discussed to be extended to some interesting devices in building design with natural ventilation system. Cooperation between architects and scientists for good indoor air quality is stressed for future new buildings and retrofitting processes of existing buildings

5B1o3 Ventilation, energy, and indoor air quality
O Seppänen

As ventilation is a significant consumer of energy the rates of ventilation have often been minimised, particularly after the energy crisis in the early 70's, in order to reduce equipment and energy costs. Buildings, particularly those in cold climates, have also become more airtight a factor which has reduced ventilation airflow through the building envelope. This has caused in many countries indoor air quality problems. It has been shown that ventilation rates have adverse effects on communicable respiratory illnesses; on sick building syndrome symptoms; on productivity and perceived air quality. In many studies, the prevalence of sick building syndrome symptoms has also been associated with the characteristics of ventilation systems. Often the prevalence of SBS symptoms is higher in air-conditioned buildings than in naturally ventilated buildings. The evidence suggests that improvements in the hygiene, commissioning, operation and maintenance of air handling systems may be particularly important for reducing the negative effects of air conditioning systems.

5B1o4 Research futures for healthy indoor air
JD Spengler

Indoor air researchers should have an overarching objective to create a more sustainable world through provision of healthful, comfortable, and productive indoor environments with the wise use of materials and energy. Sustainability will not be achieved until the systemic causes of poverty are redressed including universal availability of clean and inexpensive energy. The current use of biomass and low-grade fossil fuels for heating and cooking contributes to several million premature deaths annually. The expanded use of tobacco could shorten as many as 10 million lives per year. Pervasive exposures to hundreds of new synthetic compounds may contribute to respiratory distress, immunological, neurological and development disorders, and cancer. Many of these compounds have the potential to exert toxicological effects on the ecosystem. Researchers should be informed about these health and ecological effects, cognizant of the limitations of current knowledge, and prepared to express professional opinions protective of public and ecosystem health.