4 Contaminant Control

4.1 Air cleaners

4.1-1 Photocatalytic oxidation for aircraft cabin and indoor pollutant control
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Few acceptable methods exist for the removal of low concentration VOC pollutants in aircraft cabin and indoor environments. Photocatalytic oxidation (PCO) is a novel approach which chemically destroys pollutants rather than adsorbing them into a matrix. The PCO approach is light weight, maintenance-free, and avoids issues related to desorption of contaminants from saturated media. Experimental studies have shown that high conversion of organic pollutants can be obtained in a 0.1m³ PCO unit and an air flow of 236 L/s. Conversion is not accompanied by production of ozone; the air cleaner removes background ozone effectively. Lab scale studies show that a broad range of pollutants can be removed, and that the major oxidation product is carbon dioxide. Low concentrations of aldehydes can be generated if high concentrations of specific pollutants are present. The PCO unit also effectively disinfects the air. Experimental studies with Serratia marcescens, Bacillus globigii, and Micrococcus roseus indicate that a range of bacteria can be eliminated. The implications for improvement of comfort in indoor environments will be discussed.

4.1-2 The study in the indoor air purification of a new type of lamp-house of photo-catalyse
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It has been found in this paper, by experiment, that blue rays along the surface of the cold plasma reacting piece contains the ultraviolet rays wave band that Titanium dioxide rays catalyzing needs, the regular relation and conclusion of the capacity of the cold plasma reacting, the wavelength of ultraviolet rays and relative light intensity. Then this paper analyzes the application of UV/O3/TiO2 synergize in indoor air purification.

4.1-3 Sorptive effects of volatile organic compounds (VOCs) on activated carbon fibers (ACF) and indoor sink materials – a test chamber study
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Detailed studies on sorption properties of VOCs on ACF evaluated the effectiveness of ACF for removal of indoor VOCs in the passive mode. Sorptive properties of selected indoor sink materials were also investigated. Three VOCs: toluene, acetone and limonene were examined in this study, and four indoor sorptive materials: carpet, cotton, polyester and gypsum board were tested. The experimental data for indoor materials and empty test chamber surfaces was found to be in good agreement in fitting the linear sink model based on the Langmuir adsorption process, while the experimental data for ACF was found to be acceptable in fitting the non-linear sink model based on the Freundlich adsorption process. These experimental results on sorption kinetics of ACF in the passive mode appear to be promising for control of indoor VOCs, even considering the potential competition from indoor sorptive materials.

4.1-4 Function research of plasma air cleaner
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To research the function of plasma air cleaner the paper combined with the finished product test which was entrusted by some business enterprises, completely discussed and analyzed indoor air cleaner in all sides. In addition the application of electronic filter in split-floor type air-conditioner’s indoor unit was stated in detail, its cleaning principle consists of utilizing static electricity function to gather dust, uniting low temperature plasma with titanium dioxide photocatalytic technique to remove dust, germ and other pollutant in indoor air. With these standards, the type of air cleaner was tested to evaluate the performance of removing dust and germ, function parameters were analyzed and calculation model was verified. Through these tests, the conclusion is drawn that uniting low temperature plasma with titanium dioxide photocatalytic technique can available remove dust and germ in indoor air, so the popularization and application of this theory progressively promote air cleaning technique development.

4.1-5 Some innovative considerations in modelling indoor formaldehyde concentration
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Indoor concentrations of air pollutants are higher than outdoors and therefore people nowadays spending the largest part of their time indoors is exposed to high risk of indoor air pollution. The concentration of the indoor air pollutants as formaldehyde, ammonia, benzene, NO, and other Volatile organic compounds are usually not acceptable with respect to human health aspects. In present work, some innovative considerations in modeling formaldehyde concentration are considered. The result indicates as to the circumstances mentioned below, i.e., air leakage, nature ventilation, plants, plants combined with air ventilation, about 20 hours later, the formaldehyde concentrations are 208, 5, 178 and 5µg/m³, respectively. Nature Ventilation has the excellent effect in eliminating formaldehyde. Plant also has an effect on the purification, but its effect is not as good as nature ventilation.
4.1-6 The assessment and function research of plasma air cleaner

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Since modern population typically spends most of their time indoors, indoor air quality is recognized as an important environmental and health problem. The aim of this research is to discuss and analyze the particulate removal effect of plasma air cleaners. The assessment criteria of air cleaner are presented and discussed in detail. In addition, the application of electrostatic filter in split-floor type air conditioner’s indoor unit is stated. This type of air cleaner is tested to evaluate the practical performance of removing dust. Relevant function parameters are also analyzed. It has been concluded that uniting low temperature plasma with titanium dioxide photocatalytical technique is able to effectively remove indoor particles; therefore the application of this theory advance the development of air cleaning technique.

4.1-7 Controlling the indoor concentration of 2-ethyl-1-hexanol emitted from carpets using carbon absorption

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Exponent Inc., 1970 Broadway, Suite 250, Oakland, California, 94612, USA 2-ethyl-1-hexanol is a common indoor air pollutant in some indoor environments, especially those that contain carpets with a polyvinyl chloride backing placed on concrete slabs. This volatile organic chemical is believed to be associated with reports of offensive odors and mucous membrane irritation symptoms in some buildings. This study presents the results of the attempts to use carbon absorption to reduce the airborne concentrations of this chemical in an office space where remodeling activities had released the chemical from the exposed concrete slab. Carbon absorption from the affected atmosphere was considered due to the complexity and costs associated with alternative methods to control the concentration of this chemical. Carbon absorption in portable plug-in recirculating fan systems was found to be an effective short term solution and reduced airborne concentrations by 2 orders of magnitude, dramatically reducing the complaints expressed by most occupants. The role of carbon absorption for long term control of the presence of this chemical in office environments is also discussed.

4.1-8 Testing of the effectiveness of air purifiers

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A series of total volatile organic compounds (TVOC) removal performance measurements was conducted in the optometry clinic in the Hong Kong Polytechnic University. As to test the overall performance of the air purifier in removing TVOC, the air purifier is installed in the waiting area of the clinic connecting with the air distribution system above the ceiling. The significance of adopting titanium dioxide (TiO₂) on chamber testing and TVOC removal performance tests were measured for comparison. The results indicated that the effectiveness of air purifier was better with installed titanium dioxide coated media. The air change rate equivalent to titanium dioxide filter was about 1.572hr⁻¹ which implied that it dominated 62% of the whole removal performance of the air purifier.

4.1-9 Enhancement effect of TiO₂ immobilized on the activated carbon fiber filter used in air cleaning devices

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Activated carbon fiber (ACF) filters are widely used to remove volatile organic compounds (VOCs) in air cleaning devices. The performance of ACF filters could be enhanced combining adsorption process with photodegradation process. In this work, the enhancement effect of TiO₂ immobilized on the ACF filter used in air cleaning devices was investigated by two methods. First, an ACF filter was tested using a square duct system. The benzene, toluene, and m-xylene (BTX) were used as test VOCs, and the VOC concentration ranged from 200ppb to 1400ppb. It was found that the VOC removal efficiency of an ACF filter depended on the VOC species, the upstream concentration and the air velocity. The benzene removal efficiency of an ACF filter was greatly enhanced by TiO₂, however the toluene removal efficiency was slightly increased. Second, an air cleaner including an ACF filter was tested in a 4-m³ cubic chamber. The enhancement effect of TiO₂ immobilized on the ACF filter was also verified by the chamber test.

4.1-10 On the use of activated carbon filters for building applications

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During the past half century, filtration techniques based on the use of solid grains or fibrous activated carbons have been widely used in industrial applications, and considerable knowledge about the mass transfer processes involved has been developed. Surprisingly, the use of activated carbon filters in buildings has remained marginal, and one reason is probably the lack of information on the actual efficiency of such systems in realistic configurations of building operation. In the present paper, models combining advection, sorption and diffusion in a porous medium were implemented in the Matlab/Simulink environment to simulate the dynamic behaviour of a integrated building/ HVAC with activated-carbon filter system. The emphasis was put on studying the ability of the filter to improve the indoor air quality of office-like buildings in urban areas. Various configurations were tested considering the real weather and outdoor contaminant concentration data of Rome, Italy. The results show that the filter may contribute to lower the workers’ mean exposure by more than 30% provided it is thermally purged during the night. Moreover, for the cases simulated, the competition between species for adsorption was found to have a negligible influence.

4.1-11 The efficacy of air cleaners under the circumstance of air infiltration

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As the quality of human lives improves, the indoor air quality has become important issues. The products for improving indoor air quality are thus popular, among which air cleaners are most common. Our studies have found that the performance of an air cleaner is subject to the
outdoor air change in the space where it serves. The results have also revealed that when the outdoor air change rate of that space approximates the clean air delivery rate of an air cleaner, the efficiency of the air cleaner declines. Inversely, as the clean air delivery rate of an air cleaner exceeds the outdoor air change rate of the space it serves for by more than four times, the air change of that space has negligible effect to the air cleaner’s performance. Thus, this paper is to suggest a principle for the selection of appropriate air cleaners for the needed application.

4.1-12 The effect of reducing pollution sources and photocatalytic air purifier quantified with proton-transfer-reaction mass spectrometry

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Proton-Transfer-Reaction Mass Spectrometry (PTR-MS) was used to measure volatile organic compounds (VOCs) in an office in which common pollution sources were present or absent and a photocatalytic air purifier was in operation or turned off. Outdoor air supply rate was 0.6 h⁻¹ (18 L/s), air temperature was 22°C and relative humidity was 40%. PTR-MS showed that the concentration of many air pollutants was reduced when the air purifier was in operation or the pollution sources were removed. The on-line measurements made it possible to observe how quickly each of the interventions had an effect on the concentration of air pollutants in the office. Present results suggest that PTR-MS can provide useful supplementary information in indoor climate investigations on real-time changes in composition and concentration of a wide range of indoor air organic pollutants.

4.1-13 Influence of fins on formaldehyde removal performance of annular photocatalytic reactors

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The influence of fins on formaldehyde removal performance of annular photocatalytic reactors was theoretically, numerically and experimentally studied. The simulated and the experimental results agree well. It is found that the bottleneck of formaldehyde removal of conventional annular photocatalytic oxidation (PCO) reactors tends to be mass transfer. For a PCO reactor, after applying fins coated with titania, the reaction area can be greatly enlarged and the convective mass transfer can be obviously enhanced, although the reaction coefficient may be reduced. On the whole, the formaldehyde removal performance of an annular PCO reactor may be obviously improved by using fins in the reactor. The analysis is helpful for annular PCO reactor design, and performance optimization.

4.1-14 Experimental characterization of portable ion generators

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A conservative assessment suggests that over 1% of homes in the U.S. use ionizing air cleaners. Ion generators use charged plates to remove oppositely-charged particles and often generate ozone as a byproduct of their operation. In the present paper, five commercially available ionizing air cleaners were evaluated and compared to a portable HEPA filter and dedicated ozone generator. Air flow rate, ozone emission rate, and size resolved (0.1–1 μm) clean air delivery rate (CADR) were measured in a stainless steel test chamber for each cleaner. The air flow rates ranged from less than 30 m³/hr to 75 m³/hr, about an order of magnitude lower than a portable HEPA filter. Ozone emission rates were 0.7–4.1 mg/hr, about an order of magnitude lower than a dedicated ozone generator. Although the ozone emission rates for ion generators were low, they still may represent a health concern. The ionizing air cleaners remove submicron particles with CADRs ranging from 8–82 (m³/hr), considerably lower than the 200–250 m³/hr range for the tested HEPA air filter. These results allow for a more complete analysis of the positive and negative indoor air quality impacts of portable ion generators.

4.1-15 Photocatalytic effect on plasmid DNA damage under different UV irradiation time

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Microbiological contaminants such as mold and mould (both of them fungi), pathogenic bacteria, viruses that widely exist in indoor environment can cause respiratory allergic reactions, asthma, and infectious diseases ranging from influenza to Legionnaires disease. Photocatalytic oxidation (PCO) by TiO₂ is a new technology that can decompose a wide range of chemical pollutants and disinfect microbiological contaminants by utilizing a semiconductor catalyst such as TiO₂ and near-UV (ultraviolet) radiation.

In this research, a solution of supercoiled plasmid DNA has been used to demonstrate photodynamic DNA strand-breaking and hydroxylation activity at photocatalyst surfaces. Index of DNA damage degree induced by a commercial TiO₂ and a non-commercial nanocatalyst were compared, with the UV illumination time as the controlled variable. Results show that as illumination time increased, the photocatalytic effect on DNA also increased, and the nanocatalyst has a better photocatalytic effect on plasmid DNA than P25 under the same test conditions. Even for the 1 minute illumination time, plasmid DNA damage appeared, which has significant implication to application of the PCO techniques when the factor of short residence time of microbes in PCO reactor is considered.

4.1-16 The removal of volatile organic compounds by adsorption and photocatalytic oxidation

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It is important to remove volatile organic compounds (VOCs) emitted frequently from daily activities because they may endanger human’s health. In this work, based on the study of equilibrium adsorption on viscose rayon-based activated carbon fiber (ACF) by gravimetric method, mounting of TiO₂ on PAN-based activated carbon cloth (ACC) and their photocatalytic activity as well as adsorption performance for benzene were investigated. The crystallinity of TiO₂ and pore structure was characterized by XRD and N₂ adsorption. The results showed that crystallinity of TiO₂ and pore structure could be postulated by treatment condition. Both crystallinity of TiO₂ and pore structure of hybrid have effects on photocatalytic performance of TiO₂-mounted ACC. It would be more attractive and prospective that combination of TiO₂ photocatalytic activity and adsorption ability of porous materials.
4.1-17 What is considered an ‘effective’ air cleaning device?

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The most widely used method in the United States to assess the performance of new portable air cleaners is the procedure described in the American National Standards Institute (ANSI)/Association of Home Appliance Manufacturers (AHAM) AC-1-2002. The test protocol is straightforward, yielding a performance metric that is based on the measured decay rate of contaminant concentrations with the air cleaner operating compared with the measured decay rate with the air cleaner turned off. The resulting metric, the clean air delivery rate (CADR), permits both an intercomparison of performance among various air cleaners and a comparison of air cleaner operation to other contaminant removal processes. In this paper we comment on the testing process, discuss its applicability to various contaminants and evaluate the resulting performance metrics for effective air cleaning.

4.1-18 Experimental investigation of the air cleaning effect of a desiccant rotor on perceived air quality

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A laboratory study was conducted to investigate the co-sorption effect of a desiccant rotor on improving perceived air quality. A rotary desiccant dehumidifier was used for the investigation. Carpet and linoleum emissions as well as human bio-effluents were used as air pollution sources. Up to thirty subjects served on a sensory panel to test and judge the effectiveness of pollutant removal by a desiccant rotor. The results of the experiment showed that a desiccant rotor has great potential for air cleaning. The effectiveness of air pollutant removal in terms of sensory pollution load was better than 80% for the three types of air pollutant. The air-cleaning effect was found to be independent of air humidity and the processed airflow rate of the dehumidifier. The effect of the reactivation air temperature on the effectiveness of pollutant removal by the dehumidifier remains to be further investigated. The observed air-cleaning effect of a desiccant rotor can be used to improve indoor air quality and decrease energy consumption of HVAC systems that use desiccant cooling.

4.1-19 Using ozone air cleaners to remove indoor volatile organic compounds

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Indoor volatile organic compounds (VOCs) are known to cause many human health problems. Ozone air cleaners were claimed to remove the indoor VOCs, but their effectiveness was still unclear. In this study, we selected six ozone air cleaners to evaluate their effectiveness on the control of target VOCs (toluene and formaldehyde). The experiments were conducted in a 11.3-m3 stainless steel environmental test chamber under 25°C and 60% relative humidity. The clean air delivery rate for toluene and formaldehyde ranged from 0.0565 to 0.424 m3/hr, and from 0.0068 to 0.747 m3/hr, respectively. The removal rates observed were much higher than the removal rates based on the ozone-toluene and ozone-formaldehyde reaction constants measured in previous studies. Thus, the removal of toluene and formaldehyde may result from the other mechanism such as adsorption, and high-voltage electric discharge or ultraviolet lamp, used to generate ozone.

4.1-20 Using the electret filter to remove the submicron aerosols

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This study elucidates the effects of using an electret filter on the aerosol penetration. Various factors, including the particle size (0.05 to 0.5 µm), the aerosol charge state (neutral and singly charge), the face velocity (0.1, 0.3, 0.5 and 1.0 m/s), and the relative humidity (RH 30% and RH 70%) were considered to evaluate their effects on the aerosol collection characteristics. Experimental results from our study indicate that the electric fields of the electret and discharged filter are −1.53 × 104 and −1.3 × 107 (V/m). The penetration through the electret filter with singly charged aerosol was in the range of 0.4% to 13% and penetration ranged at 14% to 29% with neutral aerosol. As the results shown, the Coulombic capture force is dominant for the smaller aerosol and the dielectrophoretic capture mechanism works at larger aerosol size. Additionally, the penetrations through the electret increased with the face velocity and relative humidity.

4.1-21 Studies on chemical substance removal rates of domestic air cleaners and development on the indoor pollutant concentration prediction method

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There are several types of air cleaners on the market in Japan. They are classified into several types by their mechanic-removal system. Some of the air cleaners are designed to remove gas-phase pollutants as well as particulate matters. In Japan, such air cleaners are noted with a great expectation to solve the sick building problem. However, scientific studies on the removal effectiveness of portable or domestic air cleaners on gas-phase pollutants are limited. So we carried out an experimental study with using the test method in the pollutant constant-emission to the air cleaner. Air cleaners’ performance was expressed by the index of ECAR [m3/h] or equivalent clean air rates. This index is equivalent to CADR [m3/h] or clean air delivery rates. Three types of air cleaners’ ECAR or CADR ranged from 16.1 to 17.3 [m3/h]. In this report, our prediction equation on indoor concentration ranged at 14% to 29% with neutral aerosol. As the results shown, the Coulombic capture force is dominant for the smaller aerosol and the dielectrophoretic capture mechanism works at larger aerosol size. Additionally, the penetrations through the electret increased with the face velocity and relative humidity.
4.1-22 An experimental study on activated carbon fiber filters to remove indoor gaseous contaminants
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This paper calculated the pore distribution and specific surface area of an activated carbon fiber (ACF). The pore distribution of ACF sample centralized on 7–8 Å, micro-pores (r < 10 Å) were rich, while medium pores (10 Å < r < 250 Å), especially macro-pores (r > 250 Å), were a little. The specific surface area was 1224.806 m²/g. Its adsorption curve for N₂ was very close to the corresponding desorption curve, and the saturated sorption capacity was 275.3 cm³/g. The results indicated that the micro-pore character of ACF is better than that of granulate activated carbon (GAC). Three type structures (panel, bypass and pleated) of ACF filter were made to test their adsorption performances. Formaldehyde and ammonia were selected as two typical indoor air contaminants, the adsorption performances of filters were tested for various airflow rates and contaminant concentrations using a spectrophotometer. At the meantime, their pressure loss performances and dust efficiencies were also tested. On the whole, the panel type presented obvious superiority; furthermore, it had the advantages in batch process and cost. The pleated type wasn’t adaptive to comfort air-conditioning systems owing to high resistance, nor was the bypass type owing to low efficiency.

4.1-23 In situ tests about removal performance of airborne microbe particles by an air filter
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In order to design the indoor air cleanliness on bioaerosol appropriately, it is necessary to quantify the filtration efficiency over airborne microbes of an air filter installed in the air-conditioning system. This paper reports the in situ experimental results about the filtration efficiency of low- and medium-efficiency particulate air filter over both suspended particles and airborne microbes under real operating conditions of three air-handling units and one package air-conditioner located in Tokyo. Results show that there are significant correlations of filtration efficiency between airborne microbes and distributed suspended particles. Each of the filtration efficiency over airborne staphylococcus aureus, bacteria, and fungal spores is almost equal to the filtration efficiency over suspended particulates larger than 1 μm, 2 μm, and 5 μm in diameter, respectively. This result indicates that it is possible to design an indoor air cleanliness on bioaerosol by using the filtration efficiency of the air filter over distributed suspended particles instead of airborne microbes such as bacteria and fungal spores in office buildings.

4.1-24 Removal of formaldehyde by air cleaner with TiO₂-mounted ceramic filter
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The photocatalytic technology was applied to reduce formaldehyde. A photocatalytic filter used is made of the porous ceramics, is coated with TiO₂ and has a three-dimensional structure. The experiment to reduce formaldehyde in the air was conducted by circulating the air through the filter irradiated with UV light in a 1 m³ air chamber. The result showed that the formaldehyde was almost completely oxidized into carbon dioxide when the intensity of UV light is over 2.9 mW/cm². The removal performance of formaldehyde was improved as the intensity of UV light increased or as one more photocatalytic unit or two were set in series.

4.1-25 Basic study on the chemical reaction between ozone and sesqui-terpenes emitted from cedarwood
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Full-scale chamber of test house was used to investigate emission data of sesqui-terpenes from cedarwood. This experiment involved placing samples of cedarwood and an ozone generator in one room of the test house. The sesqui-terpenes were identified. The indoor sesqui-terpenes concentration with ozone emission was much lower than that without ozone emission. It was found that the higher the indoor ozone concentration, the lower the sesqui-terpenes concentration. The sesqui-terpenes might have been consumed by the reaction with ozone during the experiment. The concentrations of formaldehyde (HCHO) were not changed regardless of the change of ozone concentration.

4.1-26 Experimental research on photocatalytic oxidation air purification technology applied to aircraft cabins
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The experiment presented in this report was performed in a simulated aircraft cabin to evaluate the air cleaning effects of two air purification devices using Photocatalytic Oxidation (PCO) technology. Objective physical, chemical and physiological measurements and subjective human assessments were used for the evaluation. Comparisons were made between conditions with and without the PCO units installed in the re-circulated air system. Four groups of 17 subjects were exposed for 7 hours to each test condition. Chemical analysis indicates that Ethanol, Isoprene and Toluene were decomposed by oxidation in the PCO units tested. However, some intermediate products, such as Formaldehyde and Acetaldehyde, were detected. Physiological measurements did not show any significant effects of the two PCO units. Both positive and negative effects of using PCO units on subjective assessments were observed after the first 3/4 hours of exposure. After 6 hours of exposure, a positive effect of using either PCO units on symptoms of dizziness and claustrophobia were observed.

4.1-27 Application of Active Carbon and Nano-titanium Dioxide photocatalysis web in air-conditioning system
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According to the current situation of application and research on air purification techniques, the article proposes that the active carbon and nano-titanium dioxide photocatalysis technique is applied on air conditioning system to purify indoor air quality, and studied the process of purification and capability of purification. Active carbon and nano-titanium dioxide photocatalysis purification technique not only makes up for the disadvantages of traditional purification technique.
such as active carbon absorption technique and TiO₂ photocatalysis technique are very low purification efficiency under the condition of high air velocity and low contaminants concentration but also the compounded technique is feasible for active carbon and TiO₂ and the price is inexpensive, and meanwhile it still be able to save energy consumption of fresh air. Finally the feasibility and the scheme in air conditioning system applying are proposed. Consumers can accept the air conditioning system with active carbon and nano-titanium dioxide photocatalysis purification section.

4.1-28 Experiment of Active Carbon and Nano-titanium Dioxide photocatalysis technique to eliminate tiny contaminants in air

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Now progress of techniques indoor air contaminants of controlling is rapid, and many techniques have been applied to interrelated materials and equipments. For practical application, disposing air tiny contaminants still exists some problems. In this article, a new purification technique is introduced, namely Active Carbon and Nano-titanium Dioxide Photocatalysis technique, and its capability for purifying air contaminants is compared with active carbon purification web and Nano-titanium Dioxide Photocatalysis purification web. The result shows the effect of the new purification technique is obvious. Meanwhile air resistant of the web and factors that influence purification efficiency are analyzed, and the result shows the new purification technique exerts the advantages of active carbon purification technique and Nano-titanium Dioxide Photocatalysis purification technique, as purification web with new purification technique possesses stronger capability of absorption and decomposition on organic and inorganic contaminants and less resistant of airflow, and decreases concentration of contaminants and enhances the purification efficiency and avoids the producing of new contaminants, and realizes the regeneration of active carbon on the same place and prolongs the life-cycle of active carbon etc.

4.1-29 Experiment of nanometer photocatalytic to eliminate dilute formaldehyde in air

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To search the eliminate performance of nanometer photocatalytic to the indoor dilute concentration contamination; makes measurement with formaldehyde through changing the original concentration and the outside parameter (the temperature, relative humidity, the airflow velocity and TiO₂ concentration). Compared with the adsorption result of activated carbon fiber, the results show that the eliminate performance of the nanometer materials was more effective than the activated carbon fiber; at the condition of single influencing factors the effect of the temperature was more obvious than the others; to the interaction of all the influencing factors the average discrimination of the original concentration was bigger than the others so the effect to the photocatalytic performance was the most obvious; the effect of the relative humidity was unobvious.

4.1-30 The filter efficiency on bacteria of a new metal filter material

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Fresh air system plays a very important role in indoor air quality. With the increasing pace of the civilization and population, outdoor air quality is being worse and worse, because of the waste gas continuously producing from people’s production and living. Under this circumstance, the introduction of fresh air will not dilute the dirty indoor air, but deteriorate it. Bacteria in air do not exit as monomers, but as coenobium or spores. So their size is not very small. Moreover, there is an adherence between the coenobium and dust. These two reasons make filter material has a higher filter efficiency on bacteria than on dust in the aerosphere. We investigate a new type of metal filter material on its filter efficiency. Measured, cultivated and counted the air before and behind the filter material separately by using Andersen sampler, LWC-1 sampler and particle counter when filtering velocity is 0.2 m/s, 0.4 m/s, 0.5 m/s. Analyze the relationship of the filter efficiency on bacteria, the filter efficiency and the resistance pressure. The results show that this type of filter material has a high filter efficiency and it has a virtue that can be cleaned, which make us can reasonably believe that it will has a booming prospect when applied in fresh air system of center air conditioning system or even in cleaning air conditioning system.

4.1-31 Removal of NO₂ and VOCs by short-wavelength UV and TiO₂

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Gaseous pollutants NO₂ (NO and NO₂) and toluene were subjected to UV-C254+TiO₂ irradiation in humid air, and their photodegradation was quantitatively studied. The pollutants were efficiently decomposed by the ozone and OH radicals produced by UV-C254+TiO₂ irradiation. Because the decomposition products were water soluble, they could be removed with an air washer, which was used for post-treatment. When the photoreactor was dip-coated with a TiO₂ catalyst, the photodegradation of the pollutants was enhanced. We propose that the coupling of UV-C254+TiO₂ irradiation and an air washer would be a useful system for the removal of gaseous pollutants.

4.1-32 Measuring the performance of gas phase filtration

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Building materials, occupant activities and operation of equipment may emit a rainbow of gaseous contaminants. These sources of pollution have been recognized explicitly in the ASHRAE ventilation standard, which requires that the ventilation rate specification be based on the contribution from occupants as well as the building materials and equipment. That means a higher ventilation rate is needed and this concomitant increase in energy consumption will affect the global environment. One approach to alleviate symptoms of SBS in an indoor environment and, at the same time, reduce the ventilation rate substantially is the use of an effective air cleaner. As more air cleaning devices enter the market, it would be essential to develop a method for comparing their effectiveness. Most devices have been designed for the
removal of gas phase compounds. The gas phase air filtration cleaners can play a significant role in the reduction of building energy operation cost. This paper describes the development of a test procedure for measuring both the percent removal efficiency and removal capacity of gas phase air filtration. An experimental set-up was designed and constructed, and a number of commercially available filters were tested. The measurements showed that some of the filters are not efficient.

4.1-33 Experimental study on the photocatalytic oxidation of mixed toluene and benzene

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Volatile organic compounds (VOCs) are major indoor air pollutants which may do great harm to human health and cause numerous economic lose. Photocatalytic oxidation (PCO) is an innovative and promising approach to eliminate VOCs indoors. Many researchers have reported that ultraviolet (UV) illuminated titania exhibits high activity to decompose many single kind of common VOCs, such as toluene, benzene, formaldehyde and so on in indoor air. Although many researchers have done lots of work on this subject. There is little work conducted on the photocatalytic oxidation of mixed VOCs. However, in practice. There are usually several or even many kinds of VOCs in indoor air simultaneously. This paper investigated the photocatalytic oxidation of typical binary VOCs indoors: toluene and benzene by applying a kind of common titania (P25) radiated by UV irradiation. The reaction coefficients of each single pollutant and of the mixture were measured. The accuracy of the measured reaction coefficients was analyzed. A correlation between the reaction coefficient of the mixture and that of each composition is obtained by fitting the measured data. And the mechanism for the correlation was discussed.
4.2 Source controls

4.2-1 Settlement of dust pollution in pneumatic transport system
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To eliminate the dust damage to workers, put an end to pneumoconiosis in pneumatic transport system, dust pollution must be controlled at its genesis. After aborative work to analyze the dust pollution problem, the reason for the pollution in pneumatic transport system was found. A new ventilation system with auto control system was designed. The keystone investigation was how to get the appropriate wind speed to get the best effect of dust removing and energy saving. After mechanics analyse of a tiny part of fluid in ventilation pipeline, the connection between wind speed and fluid moving state was found. And the connection was proved by experimentation. After that new system’s design principle and work flow were discussed. And effect of dust removing was expounded. The new ventilation system is constructed according to the pneumatic transport system. It eliminates the condition that caused dust pollution before.

4.2-2 Different methods of sealing secondary emissions in floor constructions
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When floors damaged by moisture, in which the adhesive has undergone alkaline degradation, are renovated, the repairers may want to use a preparation that can be ‘painted’ on the concrete surface to prevent the emission into the indoor air of the degradation products stored in the concrete. In this study, an investigation has been made of the flow resistance of all preparations which are sold in the Swedish market as such emission barriers. The investigation was made using the cup method in which the preparation is first applied to a concrete disc. The experiment was made with the three volatile liquids water, n-butanol and 2-ethylhexanol for all preparations. There was only one type of preparation, that based on epoxy, which exhibited properties as a seal for both water, n-butanol and 2-ethylhexanol.

4.2-3 Renovation of five office buildings – effects on sick leaves, productivity and comfort
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Indoor air quality problems have many effects on workers’ health. Five office buildings were selected in the Helsinki area. Moisture and mould problems were found in two buildings and three buildings had problems concerning man made mineral fibres. All five buildings were renovated. The aim of this project was to investigate the effects of renovating buildings on productivity, well-being and the number of sick leaves. At the same time the psychosocial environment was monitored. According to the workers, indoor air quality improved in the renovated buildings. However, the symptoms and sick leaves did not decrease significantly. Reliable statistics on short sick leaves and diagnoses were hard to find because short sick leaves are not usually systematically registered, and they are often based on the workers’ own notice. Productivity was difficult to measure. An increase in direct productivity was found in one case. Subjective productivity measures showed that work fluency and productivity improved.

4.2-4 Experimental study on heating HEPA by far infrared radiation
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Due to spreading of the SARS and other respiration illnesses, people pay more and more attention to airborne microorganism contaminants. It is a great challenge to control the microorganisms’ reproduction, growth and transmitting indoor. High Efficiency Particulate Air (HEPA) filter is a suitable device to catch the airborne microorganism particles in environmental air. In this study, a HEPA filter was combined with several mini far infrared radiation heating panels, it doesn’t only catch airborne microorganism particles but also kill them with high temperature in the HEPA filter media. The far infrared radiation panels heat HEPA filter media at the downstream face of HEPA filter. In the experiment, a digital thermometer system, which measurement error is 0.1°C, is used to measure the temperatures of the HEPA filter’s front and back surfaces. An airborne particle counter is used to measure the particle concentration in upstream and downstream for calculating the efficiency of HEPA filter. The result shows there are no visible changes in HEPA filter’s efficiency with radiation heating the HEPA filter media or not, it proves there is no damage when heating HEPA filter. Furthermore, airborne microorganism can be killed in a limit experimental temperature after improving the HEPA filter media temperature by radiation heating.

4.2-5 Indoor particle contamination in an airlaid papemaking workshop
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Dry formed paper technique can avoid water pollution but brings serious particle contaminants into workshop, mainly including xylary fiber and Super Absorbent Polymer (SAP) particles, which are harmful with the health of workers in the workshop, especially SAP particles. Experimental investigations of particle concentrations were carried out in an airlaid papemaking workshop in Tianjin, China. The theoretical calculation acquired SAP size and its existent state in indoor static airflow of this workshop. The sodium percentage content in pure SAP papermaking workshop 4.2-5 Indoor particle contamination in an airlaid papemaking workshop
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production process. Most of the SAP raw material particles are changed to suspending form by inevitably extrusion and friction. Additionally, the correlation between SAP, PM₁₀ and TSP had also been achieved to compare with that in atmospheric environment.

4.2-6 A few behavioral changes can go a long way to improve indoor air quality in Ghana

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Research has shown that on average human beings spend about 80 to 90 percent of their lives in indoor spaces including homes, school, offices and vehicles. The quality of air in such spaces has tremendous effects on the quality of life. Developing countries like Ghana are not much informed about the impact of indoor air on the quality of life. This work intends to make Ghanaians aware of the impact of indoor air quality. The cultural practices that contribute to indoor air pollution are explored. Effective solutions are also offered to help the individual to address the problem of indoor air quality. The costs of the solutions offered are inexpensive compared to the cost of health treatments in Ghana. Expenditure on health will be reduced and the government can redirect health treatments subsidies to address other issues.

4.2-7 Improve of IAQ by a new bake-out method based on chamber tests

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In the severe cold region of China, trend towards tighter envelope construction in residential buildings has led to increasing awareness of indoor air quality issues. Compared with conventional bake-out method, the aim of this study is to try to develop a new method that can solve the problem of IAQ more quickly and efficiently. In this paper, a test chamber was conducted to be representative of the newly renovated residential house in China. The principle of this method is to supply mechanical ventilation into the indoor space intermittently to eliminate indoor air pollutants when their concentrations reach a high level according to the baking effect. An index is introduced to find out which pattern will be the best for disposing indoor air pollutants. The experimental results suggest that after several times of bake-out with mechanical ventilation, the concentrations of pollutants have decreased sharply to the acceptable levels.

4.2-8 Study of reinforced exhaust slot system

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The contribution deals with research on capture efficiency of a slot reinforced exhaust system. A designed exhaust hood can work as traditional exhaust system or as reinforced exhaust system (REEXS). With the appropriate ratio of amount of exhaust and supply air the aspiration of exhaust air is intensificated along the axis of the exhaust hood. The contribution also describes the modification of the experimental set-up for research of traditional exhaust system and research of reinforced exhaust system. A tracer gas method was used for capture efficiency measurements of the system. We can identify a capture efficiency distribution of the tracer gas by this method, which can simulate the real contaminant formation in the working environment. This information is very useful for analysis of the ventilation and through this capture efficiency of the contaminant we can rate the exhaust system. The contribution includes results of measurement with the traditional exhaust system and the reinforced exhaust system and their comparison.

4.2-9 IAQ control and solutions with CSIRO chamber technology

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CSIRO Manufacturing and Infrastructure Technology, Australia has used small and full scale dynamic environmental chambers for several years to characterise and control the emission of indoor air pollutants from a wide range of materials, products and appliances. The combination of small and full scale chambers provides a key research tool for IAQ and this is demonstrated with emission tests for three materials and products: (1) particleboard and MDF wood panels (2) furniture, both conventional and low-emitting, and (3) carpet. It is shown that the full scale chamber can be used for validating small chamber results, and for computer modelling and scaling up of emissions to room like environments.

4.2-10 Performance characteristics of scaled vortex amplifiers

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Gloveboxes are maintained at a normal depression to ensure confinement of airborne dangerous substances. An example of this occurs in nuclear reprocessing where alpha emitters are machined and handled, creating dust that would be very dangerous if ingested. In the event that the confining wall is breached (for example if a glove is ripped during handling of radioactive substances) then depression will be lost, so some means must exist to ensure a containment velocity into the glovebox through the breach; preventing contamination of room air beyond the glovebox. This is achieved by speedily reducing line resistance, either by activating valves or automatically by the response of a vortex amplifier. Traditionally linear and switching type vortex amplifiers have found application in ventilation and process engineering, but recent development has concentrated on the hysteric type. This paper introduces the subject and reports on laboratory and field trials of a hysteric vortex amplifier. Consideration is given to the influence of control port design and the effect of placing a cone or rod on the rear wall to affect the aerodynamics of the flow.

4.2-11 A new method to determine age of air under less perfect conditions

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At present, the local mean age of air and the room mean age of air may be measured by three versions of the tracer gas technique, which are the Decay method, the Pulse method and the Step-up method. All of the methods require that the concentration of tracer gas at the supply should be constant during the whole test procedure (Pulse method requires the concentration of tracer gas at the supply should be constant after injection). Thus it needs more equipment to maintain the tracer gas to be constant during the test procedure. Moreover, as we know the most air conditioning system is mixing system, which means the concentration of tracer gas at the supply could not be constant at
all. So this experiment cannot be done at all. Facing these problems, the paper deduced new expressions for the local mean age of air and the room mean age of air. And also some cases are used to validate the theory.

4.2-12 Study on IAQ based demand controlled ventilation
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Fresh air is one of the important affecting factors in air conditioning system. On one hand, it contributes to good indoor air quality (IAQ). On the other hand, it partly determines the energy consumption of air conditioning system. This paper focuses on the study of IAQ based demand controlled ventilation (DCV) in which CO2 concentration is used as the controlling index of building produced contamination due to the fact that human beings is the main source of indoor CO2, and TVOC concentration is used as the controlling index of human produced contamination.

4.2-13 The role of consumer specialty products in improving the indoor environment
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Many questions arise from the use of chemicals in the indoor environment. This paper discusses many of their functions in consumer specialty products, including important health and safety benefits as well as potential health implications. It also analyzes the nature and extent of US federal and state regulations. Product formulators conduct safety assessments of their products to assure that the products can be used safely. These assessments consider both acute and chronic exposures and effects, and consider both proper use (according to label instructions) and reasonably foreseeable misuse. There is often a failure to consider the public health and indoor air quality benefits of many of the formulated consumer products that are instead, inappropriately, considered only as potential sources of indoor air ‘pollutants.’ Many products play a key role in lowering indoor exposures to biological contaminants such as dust mites, cockroaches, bacteria, viruses, and mold, which cause significant health problems.

4.2-14 Influence of movements on contaminant transport in an operating room
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The influence of persons’ movements on contaminant transport during an orthopaedic surgical operation is examined. Orthopaedic surgical operations require an ultra clean environment usually provided by a LAF device. During hip replacements bone cement is sometimes applied. Due to practical reasons cement mixing is performed outside the LAF area. During the cement transport from the mixing location to the surgeon there is a potential risk of bacteria transport to the clean zone. This phenomenon is examined by smoke visualisation and CFD. The movement of the person transporting the bone cement is modelled by steady state CFD using distributed momentum sources. A significant risk of contaminant transport from the less clean zone to the ultra clean zone is found. The results indicate that it is possible to simulate the influence of movements using a relatively simple CFD model that considers the significant influence of a transient phenomenon in an approximate way.

4.2-15 Air curtains as a protection for indoor cultural heritage: a proposal for Michelangelo’s David in Florence
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The employment of air curtain to segregate pollutants diffusion near the sources for fire prevention is actually more and more diffused in industry buildings. Their success is due to the peculiarity to compact spaces without fixed barriers which should interfere with people and equipments. The application of air flows in museum deals with the problem to separate visitors and objects in order to protect the latter from pollutants. When the device is installed near the object to protect, this represents a ‘direct protection method’, and a proposal of this kind of system is on to go in the HVAC and air distribution system retrofitting of the Galleria dell’Accademia in Firenze where Michelangelo’s David and other masterpieces are placed in. CFD characterisation of the two case-studies, before and after the proposal, are reported.

4.2-16 Improvement of IAQ by use of selective-adsorption polymer for some kinds of VOCs, aldehyde and basic gases: the adsorptive characteristics and evaluation in fields
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A material of adsorptive polymer by graft polymerization was developed for the purpose of improving IAQ. The adsorption and sealing ability of the material was evaluated by adsorption isotherm with a simple and small glass chamber. The material applied to coating material and non-woven sheet has an adsorption ability for following perceived gaseous compounds in addition to formaldehyde: Acetaldehyde, toluene, styrene, ammonia, tri-methylamine and acetic acid. Addition of the material to the aldehyde-generating adhesive, mounting of that to bean-curd refuse and the gelled material mixed with agar were, respectively, effective for decrease of the odor gases. The coating material and the gelled material were applied to improve IAQ in new buildings as field test, and were evaluated by measuring VOCs concentrations of the indoor air.

4.2-17 Different strategies to investigate sick buildings
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Numerous investigations and remedial measures have been carried out regarding the indoor environment in buildings where people suffer from SBS. These investigations are often done in spite of a lack of knowledge of the relationship between bad health and pollutants in the indoor air. Many of these investigations are also performed in spite of an absence of any scientific foundations or causal explanation. In Sweden, there are no regulations or recommendations regarding the strategies and measurement methods to be used, nor the education or other background of IAQ investigators. The investigators also often have only their own professional experience as the basis for the work.
The strategies and measurements used are also affected by the different co-operating laboratories etc. The consequence is that a number of different strategies and different measurements methods are used. Generally, the principles for these different strategies and measurement methods could be identified. The research includes an analysis of the ‘dog method’, the ‘canvassing method’, the ‘mould method’ and the ‘obsession method’ and more. The methods and analyses are described with respect to their advantages and shortcomings. In a broader context, the value of performing an indoor investigation based on scientific foundations is also discussed.

4.2-18 The study for indoor air chemical pollution prevent control of civil building engineering
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Indoor air pollution directly results in damage to human health and has attracted great many attentions in recent years, especially in which of chemical pollutants. In China, the studies mainly focus on assessment and control indoor air pollutants in existence by comparing the concentrations of air pollutants. Hence there is a need for the advanced researches in the field. In the world, the studies mainly focus on the emission character mechanisms and the mass transfer regular pattern of indoor air pollution from building materials and the health effects of exposures to indoor air pollutants, describing the emission laws by mathematics model and processing visual information by computer. Deming Circle model is a popular modern management model in the world, and many management systems such as ISO9000, ISO14000 and OHSAS18000 etc were established according to its fundamental principle. It’s an opening management system, therefore, on which many control methods run as software, for example goal-dynamic control, active control, passive control, active-passive combined control and so on. The objective of the research is to construct ‘healthy building’ by means of the surveillance management and indoor air quality forecast, regarding comprehensive prevention and control of indoor air pollution as leading principle. The study carried out management and supervision in the whole construction process of the demonstration of a civil building engineering, acquired the qualified IAQ.

4.2-19 Smoke free architecture – smoke protection without walls
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In an increasing number of countries the consumption of tobacco products is discouraged and legal measures have been taken to protect non-smokers from environmental tobacco smoke (ETS). In many cases this implicates a total smoking ban in buildings. In those places where smoking rooms are realized they are physically separated. Through this separation unity is lost: visual, functional and social. In restaurants a party consisting of smokers and non-smokers often wish to share the same table, and moreover separate rooms will often be impracticable for instance business meetings. The same is true for eating and drinking places in lounges and waiting rooms of airports, conference and exhibition facilities etc. and day-rooms in homes for the elderly, nursing homes and institutions. Open smoking rooms, not separated by partitions but by air curtains, provided with dedicated ventilation systems could be a solution for these problems. This option is investigated at Delft University of Technology, faculty of Architecture. In the central hall of the faculty of architecture smoking was allowed in a restricted area without ventilation facilities, but as from 2005 a legal smoking ban will come into force in the hall. This change in policy was used to combine a solution for the faculty as such with relevant research into alternative solutions. The existing smoking area is provided with air curtains and an exhaust ventilation system, the airflow of both systems being adjustable. At first the system is optimally adjusted with the use of tracer gas. Some 45 smokers are invited to smoke continuously during the final test and measurements are taken from some typical constituents of tobacco smoke (nicotine/solensol/3-ethenylpyridine/PM2.5) inside and outside the smoking room at different speeds of the air curtains and exhaust fan. It is demonstrated that air curtains in combination with an exhaust system can provide an effective barrier between smoking and non-smoking zones.

4.2-20 The effectiveness of antifungal agents as inhibitors of mold growth on gypsum wallboard
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Microbial growth on indoor surfaces has the potential to lead to indoor air quality problems. The purpose of this study was to test three antifungal agents, thymol, benzoate and sorbate, as inhibitors of fungal growth on wallboard. A series of progressive experiments were conducted to develop the best method to initiate and establish mold growth in the shortest time possible to test the effectiveness of the antifungal agents. Initial wallboard samples consisted of 2 x 2 x inches sections placed in Petri dishes, spiked with Aspergillus niger and Penicillium chrysogenum, and maintained at a variety of humidity, temperature and moisture conditions. Some samples were spiked with a glucose solution to promote additional growth. In these initial experiments, growth was seen as early as 1 week and as late as 11 weeks, but was never consistent or considered sufficient enough growth to effectively test the agents. The final series of experiments involved larger sheets of wallboard held vertically in troughs of water and placed in basements with high humidity and known mold activity. Without the inhibitor on the wet control boards, growth was seen within 14 days. At the initial antifungal agent concentrations tested (thymol – 0.2%, sorbate and benzoate – 1%), some mold inhibition continued for 28 days compared to the untreated controls. At three times the initial concentrations, the antifungal effectiveness was greatly increased, with no fungal growth on the saturated boards for over 3 weeks. Thymol alone was also tested, at both 3 and 6 times the original strength, and was almost as effective. Storing treated boards for a month prior to saturation still provided significant antifungal activity for over 2 weeks. The results of this research indicate that application of the thymol, benzoate, sorbate mixture to the surface of wallboard shows promise as a means of reducing mold exposure from wet wallboard.

4.2-21 Performance test results for a full scale IAQ chamber
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Determining volatile organic compound (VOC) emissions from materials and products (building materials, material systems, furniture, consumer products, etc.) and equipment (printers, photocopiers, air cleaners, etc.) under environmental and product usage conditions that are typical of those found in office and residential buildings is one of the most important method to solve the problems of indoor air quality (IAQ). However, now there exist different opinions to construct the chamber, including different scientific and technical opinions. After plentiful investigations and enough argumentations, based on ASTM D 6670–01, experiences from Syracuse University, Demark Technical University and Qinghua University, one IAQ (indoor air quality) chamber is built in Shanghai Research Institute of Building Science (SRIBS). This paper provides a summary of the results of performance
testing in IAQ chamber. The chamber has stainless steel interior surfaces, duct, and other components including AHU are made of glass, polytetrafluoroethylene (PTFE) and aluminum to minimize the sink effect on the chamber surfaces and heating, ventilating, and air conditioning (HVAC) systems. Some of measurement equipments, such as nozzle, is made of stainless steel also. It could simulate indoor thermal and air quality conditions. It is controlled with a direct digital control (DDC) system. There are two kinds of ventilation systems, one is overhead air distribution system, which is often meet in practice, and the other is underfloor air distribution system to ensure mixing level. The chamber can be used to study various emission sources of chemical, particulate, biological pollutants, and air cleaning technologies.
4.3 Building design (related to indoor air quality and climate)

4.3-1 An investigation on the adsorption of a non-woven fabric with activated carbon for CO₂
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With the increased closeness of buildings, carbon dioxide is becoming common pollutants in indoor air. The adsorption of CO₂ on a non-woven fabric with activated carbon before and after dipping treatment has been studied. It has been found that dipping treatment with Na₂CO₃ and KOH can improve the adsorption of CO₂ on the non-woven fabric. KOH is a better dipping agent than Na₂CO₃. High temperature is beneficial to the adsorption of CO₂ on the fabric dipped with KOH. With increasing relative humidity, the adsorption efficiency is decreased for both original fabric and that dipped with KOH, indicating that the physical adsorption on the fabric dipped with KOH still account for sizeable proportion. Increasing adsorption layer number can improve adsorption efficiency. However, when the number of adsorption layers exceeds 3 the increased amplitude of adsorption efficiency is obviously reduced, while the pressure loss of the system is remarkably increased.

4.3-2 A review of the concept of discharge coefficient for designing natural ventilation in buildings
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The need for improving energy efficiency and air quality in buildings has promoted the revival of natural ventilation in various types of buildings in the last 20 years. There is a practical need for improving design accuracy of natural ventilation. Accurate specification of discharge coefficient is essential for providing accurate engineering design. We have reviewed literature on the concept of discharge coefficient and provided a summary of the existing studies. We have summarized how the discharge coefficient is affected by aspect ratio of the opening, opening degree, and the pressure difference and the temperature difference across the opening etc. Considering the current status and the applications of natural ventilation in China, characteristics of airflow from the opening with screen were discussed.

4.3-3 Hybrid air-conditioning system design used in atrium buildings
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The atrium is proliferating, with an increasing frequency, in new, renovated, and converted office and commercial buildings. This paper firstly states the fundamental of stack-driven natural ventilation in atrium buildings. According to its ventilation characteristics and the defect that direct introduction of outdoor air through the windows does not necessarily guarantee the indoor thermal environment within a comfort range, a hybrid air-conditioning system, utilizing cross ventilation and under-floor air conditioning or radiation panel cooling is advised to be used into this kind of buildings. The hybrid air-conditioning system with radiation panel cooling is of more energy efficiency. Finally, the use of cooling system incorporated to a waterscape in atrium is considered, and the measures that fan and filling installations are proposed to improve the heat and mass transfer. However, the heat released from the waterscape should further be investigated, for it may affect the air flow patterns and thermal comfort in the buildings.

4.3-4 The influence of porous screens on natural ventilation in a dwelling unit
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This study aimed to investigate the influence of porous screens on indoor airflow field and air changes in a dwelling unit under the circumstances of natural ventilation with CFD numerical simulations. Small-scale wind tunnel experiments were carried out initially to test the performances of porous screens to measure some hydraulic parameters for CFD simulations. According to the wind tunnel experiment result, the relationship among impedance factor, porosity rate and outdoor wind speed was hereby inferred with recursive analyses. The numerical results showed that when the wind speed is between 0.3 and 1 m/s, it is recommended to use the mode of optimal opening location and the screens with porosity rate between 60.10% and 80.10%.

4.3-5 A study on the influence of horizontal louvers on natural ventilation in a dwelling unit
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According to previous research, the central horizontal pivot window could contribute to the improvement of indoor air quality under single-sided ventilation. But for interior space using, it would be inconvenient. In the present study, the horizontal pivot window would be replaced by horizontal louvers and the work was focused on what is a proper opening design, which could be used to promote natural ventilation, and keep users be comfortable. We tried to use numerical method (CFD) to simulate ventilation performance of different louvers’ depths as well as different wind speed. Air flow was considered, turbulent, steady, and the effects of buoyancy were taken into account. Our major findings were as below: 1. The proper horizontal louvers can be used to improve indoor air quality by means of increasing air change rate, especially the site under lower velocity. However when a louver depth is smaller than 4cm, it cannot be helpful to increase air flow rate. Furthermore, in this situation hot air would not be moved out effectively, that is to say, people would not feel thermal comfortable. 2. Generally speaking, the draft rate, DR, of a room with a longer depth of thirty-six centimeters louvers opening is over Class A, 15%, established by ASHRAE. The DR of 144 centimeters louvers can’t get up to Class...
C, 25%. According to the results of the simulations, and the way of regression analysis to evaluate the correlation on ventilation performance, the depths of louvers, and outdoor velocity, we established the empirical model. And the finding may help designers to predict ventilation performance of a room before building it.

4.3-6 Modeling of VOCs in indoor environment with a modular toolbox
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This paper presents a numerical simulation program which can be used to assess concentration and duration of VOCs in indoor environment with respect to surrounding building constructions, furniture, appliances and ventilation systems. Unlike from empirical models where storage and release of VOCs is treated as surface phenomena, the model presented takes into account the volumetric storage capacity of building materials. Simulations show that gypsum boards both take up and present VOCs storage and release of VOCs is treated as surface phenomena, the model present VOCs fast while the release from concrete walls takes longer time. These results are validated against measurements. As an illustration of program possibilities, the VOCs concentration over time has been calculated for a typical office room with constant VOCs source and variable ventilation airflow (working time–non working time). The room has a solid concrete structure. Compared to a tight structure, the release of VOCs from concrete increases the concentration in indoor air by around 10 % during working time.

4.3-7 Indoor air quality control for museums in China
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When one thinks of IAQ, the health and well-being of people most often comes to mind. However, IAQ is not only a people issue, it is also a materials issue. Just as people can suffer due to poor air quality in a building, many different types of materials can suffer as well. There are a number of environmental factors that can cause the degradation of materials and artifacts in museums, libraries, and archives. Among these are temperature, humidity, particulates, and gaseous pollutants. Of these, gaseous pollutants are the most destructive. Throughout China, the specialized air quality needs of museums and other cultural heritage sites are being acknowledged. Continuous monitoring of gaseous pollutants has become a requirement in order to provide accurate environmental assessments and develop appropriate control strategies – whether that may involve direct or indirect control of gaseous pollutants. This paper will look at air quality in and around three museums in Beijing and one in Shanghai. Significant findings will be reported along with recommendations for air quality and the establishment of long-term gaseous pollutant monitoring and control requirements for the protection of China’s cultural heritage.

4.3-8 Study of the thermal comfort, of the energy consumption and of the indoor environment control in surgery rooms
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In this research were investigated the influence of different layouts of operating rooms on thermal comfort, on the indoor environment control and on energy consumption. The layouts studied were: Case 1 (a surgery room and a hallway); Case 2 (a surgery room and two hallways); and Case 3 (a surgery room, an anteroom and a hallway). These environments were simulated for five Brazilian cities. It was used the software EnergyPlus. The environmental parameters were pre-established by standards. On Case 2 the energy consumption was the lowest and the thermal sensation for people was the best. The thermal sensation of the patient was extreme discomfort, while the anesthesiologist presented discomfort in some cases and in other much discomfort. The other people remained in comfort or in a little discomfort. In the three layouts, the temperature and relative humidity remained within in the required range. Therefore, there was not growing of microorganisms.

4.3-9 Life cycle environmental impacts assessment for residential buildings in China
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Building industry has made significant contribution to economic development of China, but meanwhile it has harmed the environment to a severe extent, which aroused broad recognition. Since building is an interactive integration of building materials and products instead of a simple collection and environmental impacts of buildings are various and long-term, how to assess and quantify in which way the buildings affect the environment becomes a worth concerning topic. In this study, through a perspective of a life-long span, we will analyze the environmental impacts of a building within its every stage, propose some hypothesis and simplification according to Chinese particular conditions, and advance the framework of Life Cycle Assessment (LCA) aimed at buildings, especially for residential buildings. By using this framework and relative toolkits developed for research, not only can the environmental impacts of existed buildings be observed, but guidance for architectural designs is provided. Consequently, it contributes to green or ecological design and assessment of buildings. Further more, an LCA case study on residential building fabrics design and construction effecting on the environment energy and resource consumption is introduced.

4.3-10 Comparison of spill plume equations
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Various methods have been proposed for calculating smoke production rates in spill plumes. Some have been adopted in technical standards, public and guidance documents. Results of using five such adopted methods are now compared and their suitability for practical use is discussed. The different smoke production rates given by the five methods imply that careful selection is needed during design to ensure that the resulting mechanisms of smoke control are suitable; creating a paradox for authors and readers of those documents purporting to guide engi-
neers. A relatively simple empirical relationship is proposed for initial design review purposes to assess likely scale of smoke production rates in a specified range of conditions.

4.3-11 Indoor air quality of longhouses in Sarawak
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Sarawak, the world’s leading producer of pepper, has 54% of her population living in rural and remote longhouses (Massur, 2000). There are about 2000 longhouses in Sarawak (Entamin, 2000). A longhouse is practically a village on stilts because the whole population of the community (10–110 families) lives in one longhouse and each unit of private living room, bedroom and kitchen belongs to a family with a common hall area (ruai) and a platform area (tanju). Traditionally these houses totally made of wood. Occurrence of longhouse fire every two months have prompted new longhouses to be built from bricks and spandex roof and removing the tanju. Temperature measurements for 21 longhouses (565 apartments) were made in the Bintulu and Tatau districts covering an area of 12,166 km². Traditional longhouses have indoor temperatures of 28°C at midday, semi-modern houses that use wooden wall and flooring, and zinc rooms have indoor temperature of 30°C (outside 32°C). Modern longhouses have indoor temperatures 28–30°C (outside 32°C). Only traditional longhouses use firewood for cooking. Results of the study show that with careful selection of materials, it is possible to maintain reasonable indoor air quality in Sarawak longhouses.

4.3-12 CFD modelling as a part of integrated design process for optimised indoor environment
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The paper deals with the CFD (Computational Fluid Dynamics) application to optimise the indoor environment through using the integrated design process. Usually, CFD modelling in buildings is a difficult procedure, because of time consumption and high cost as a stand-alone process. Both the time consumption and the cost can be reduced by using already existing data generated in various stages of building project. The integrated design process is a method to systemise the building project in a way that earlier calculations and design process could promote the quality of CFD simulation. The earlier more primitive computations help to identify where the rather complicated CFD simulation is required. The integration of different software tools used in building design process can be achieved through IFC (Industrial Foundation Classes) file format. By performing the air flow and contaminant simulations based on reliable numerical BC’s (Boundary Conditions) creates a unique possibility to optimise the indoor environment by comparing different system configurations. This method helps the engineer to choose the best alternative ensuring certain design criteria’s and target levels.

4.3-13 The evolution and future development of clean operating room in hospital of China
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Before ‘Architectural technical code for hospital clean operating department’ was promulgated, clean operating rooms in hospital differed among different districts in China. Chemical disinfections and large amounts of antibiotics were chiefly used after operation to avoid patients’ infection. In some big hospitals, foreign standards were usually referred to. As a result, many kinds of operating rooms had been built. But construction technique and low management level made some rooms do not make it and unable to exert their actions normally, which led to large amount of energy wasted. Now, the design and construction technique has been increased rapidly. After satisfying the clean needs, the optimizing of clean system and the energy saving are being paid more attention to. This article focuses on choosing a better pattern of clean operating rooms in hospital.

4.3-14 Passive moisture control research using one kind of nanoporous materials
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Humidity levels in a building significantly affect comfort of occupants and performance of air conditioning system. High or low humidity levels will make occupants feel uncomfortable. Decreasing temperature set point of air conditioner may obtain thermal comfort while the humidity levels are high. However, it should increase the space heat gain and energy used for air conditioning. Furthermore, high humidity levels will accelerate the growth of mold, mildew and deterioration of building materials. The arising humidity levels may be due to the intermittent operation of air conditioning system, moisture sources in the building, infiltration and so on. In addition, moisture adsorption/desorption effects at interior building surfaces may be an important component of the latent space cooling load when a building is operated with day air conditioning and night ventilation. The moisture adsorption provides a storage capacity for indoor moisture which is similar to the capacitance of thermal mass for sensible heat. The primary motivation for this research is to determine the moisture capacitance of one kind of nanoporous material. Sorption isotherm measurements were carried out for common four building materials and the nanoporous materials. Experimental results showed that this kind of nanoporous silicon gel material will assist us to maintain the relative humidity of the environment.

4.3-15 Regeneration of an aged building by naturally ventilated approach
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‘View globally, and act locally’ is a key term to how we shape our future, and to the sustainabilty of this future. More and more evidences show that the local agenda should focus on the climatic, cultural and economic conditions, while recognizing their diversity and the fact that solutions can only be appropriate if arrived at on a local level. According to the common challenges and opportunities of Taiwan, this study is aimed to learn from ancient wisdom to propose and test the renovation of naturally ventilated design for maintaining the indoor climate in the acceptable and healthy benchmark which of course is to eliminate the cooling energy in hot seasons of subtropical region.
To recognize the thermal stratification in the naturally ventilated condition, the field investigation and measurement of the existed building was conducted. The magnitude of flow structure and temperature profiles will be obtained by the smoke generator system and the 12-channel thermal-couples data-logger respectively. The flow structure and air-exchange efficiency will be visualized and calculated from the k-ε turbulence model of CFD numerical simulations. The POE results of the field measurement of the demonstration project will also be conducted after renovation during the end the 2004, and be addressed in this study.
4.4 Dilution and ventilation

4.4-1 A new building ventilation effectiveness index
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This paper proposes a new index that can provide a practical and quantitative evaluation of building ventilation effectiveness. Using non-vent and mixing-vent cases as references, the index can serve as a simple criterion for assessing pollutant removal efficiency of building ventilation systems. The paper demonstrates the application of this index for judging the ventilation performance of a displacement ventilation system in a building complex, with the contaminant concentration data obtained from numerical experiments. The same analysis procedure can be followed with field test data.

4.4-2 Research towards IAQ based on fresh air random control
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The paper takes the concentration of CO₂ as index of reflecting personnel relating contamination and the concentration of TVOC as index of building relating contamination, this meets the purpose of saving energy and indoor air quality requirement through air conditioning fresh air random control. In control system, the information of concentration of CO₂ and TVOC can be transformed into electric signal continuously by sensor and converted into digital signal by A/D. The digital signal is be sent to computer and compared with the given value, and the discrepancy is then changed into electric signal by D/A and sent to controller. According to the discrepancy, controller generates electric signal to drive the motor running and adjust the opening of wind valve to actualize the random control of fresh air volume. The paper also presents the principle of the control system and relating researches. Experimental results show that the system is stable.

4.4-3 Comparison of different ventilation systems for commercial aircraft cabins
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The ventilation systems in commercial aircraft cabins are important for providing a healthy and comfortable environment for the passengers and crew. The mixing ventilation system currently used provides a uniform air temperature distribution and dilutes contaminants in the cabin. However, the mixing ventilation system could spread infectious airborne diseases such as influenza and SARS. It is therefore necessary to improve the current design of ventilation systems for aircraft cabins. By using a validated Computational Fluid Dynamics (CFD) program to simulate the cabin environment for a Boeing 767 airplane during cruise flight, this paper compares and analyzes the simulated cabin environment with mixing, under-floor displacement, and personalized ventilation systems. The results show that the personalized ventilation systems could effectively decrease the risk of spreading infectious diseases but could also create a temperature stratification.

4.4-4 Ventilation efficiency experiment research based on tracer gas distribution
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Building environment and indoor air quality (IAQ) not only affects occupants’ health, but also determines the productivity of indoor occupants. Elaborate ventilation system design helps building to overcome sick building syndrome. Theoretically, ventilation and pathways of air movement can obtained by hydrodynamics equations, however, this method is greatly complex because of the non-linear character of the hydrodynamics equations. The use of tracer gas measurements provides a very useful tool in the performance of IAQ and ventilation efficiency. This project studies marketplace ventilation efficiency about 40000 squares meters by tracer gas test. In this tracer decay test method, a small quantity of tracer (SF₆) is released into space to be evaluated marketplace through air conditioning ductwork. The tested building locates Dongguan city, Guangdong province, since it is a recently utilized building, so some investigated occupants of the building complained the poor IAQ and odors. There are existences of inadequacy outdoor air being delivered to building breathing zone, which is introduced of air distribution inefficiency. With the tracer gas concentration measurement and analysis, the reason of the marketplace poor IAQ can be characterized into following three ways (1): leakage of supply air into the return plenum, (2) short circuiting of supply air at the ceiling, and (3) delivery of supply air to unoccupied areas.

4.4-5 A study on the control of a hybrid ventilation system using a test house
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A hybrid ventilation system with a pressure difference sensor in the central exhaust duct was installed on a detached test house. Performance of this ventilation system was evaluated through the field measurement. The results of the measurement showed that the exhaust airflow rate was relatively stable while the temperature difference between indoor and outdoor varied and the wind velocity changed. The airflow rate met almost the target airflow rate in 75% of the measuring period. But the exhaust airflow rate was far from the target airflow rate while the wind velocity was strong from the west.

4.4-6 Planning and designing laboratory ventilation systems for the safety of the users and protection of the environment
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The paper intends to bring a contribution in evaluating air quality in laboratories handling hazardous materials and minimum air flow...
requirements for ventilation. Laboratory ventilation should provide a safe environment, health and comfort of the occupants, as well as protection of the outside surroundings, while minimizing the energy consumption. Concentration level of hazardous materials in laboratory air and in the exhaust systems is analyzed in interaction with toxicity, flammability and air exchange rates.

4.4-7 Ventilation rates in schools
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Research shows that poor indoor air quality in school buildings can cause a reduction in the students’ performance assessed by short term computer based tests; whereas good air quality in classrooms can enhance children’s concentration and also teachers’ productivity. Investigation of air quality in classrooms helps us to characterise pollutant levels and implement corrective measures. Outdoor pollution, ventilation equipment, furnishings, and human activities affect indoor air quality. In school classrooms the occupancy density is high (1.8 to 2.4 m²/person) compared to offices (10 m²/person). Ventilation systems expend energy and there is a trend to save energy by reducing ventilation rates. We need to establish the minimum acceptable level of fresh air required for the health of the occupants.

This paper describes a project which will aim to investigate the effect of indoor air quality and ventilation rates on pupils’ performance and health using psychological tests. The aim is to recommend suitable ventilation rates for classrooms and examine the suitability of the air quality guidelines for classrooms.

4.4-8 The reduction effect of VOCs (volatile organic compounds) by TiO2 coated on the wall in a polluted house
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In order to reduce these pollutants such as VOCs in indoor air, we considered the coating method of a photocatalyst (TiO2) on the wall of house. This method is to degrade various pollutants by utilizing the oxidative-reductive power of hydroxyl radicals and electrons formed on photo-irradiated TiO2. We investigated the reduction effect of TVOC (Total Volatile Organic Compound) in polluted indoor air by photocatalytic reaction through the Mock-up test. Along with TVOC, Toluene, Styrene and Formaldehyde were selected as target pollutants. Results showed that the reduction effect of target pollutants by a photocatalyst was very slight. The cause of these results is attributed to the lack of indoor ultraviolet rays.

4.4-9 Method to select the optimal gas range hood
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On trend of ‘wellbeing’, installation of large gas range hood has taken place in recent times in the domestic super high-rise & high-quality apartments to improve the life quality in Korea. Due to the lack of sufficient information on the performance level of these hoods, however, the construction industry is forced to rely on each supplier’s simple catalogue. But most of these suppliers can not afford any independent performance testing of their own products, resulting a credibility problem. At the same time, due to the height and pressure difference between the upper-level floor and the ground level, occurrences of significant foul ordure have been reported because of the back flow of its ventilation circulation from vertical duct, resulting a lower quality of life of the tenants. So residents claim for the bad indoor quality, asserting all responsibility are belong to construction company. To solve this situation, first of all, to know and test the hoods sold in market thoroughly, especially performance, may be the first step and critical. Purpose of this research is to acquire the method to select the optimal gas range hood through the performance test under KS or prEN codes, such as performance curve, noise level, capture efficiency and power consumption and the reasonable grounds to adapt the optimal one to our construction fields. After research, to bestow weigh function on noise level is considered more important item than any others. Additionally, the comparison general hoods and functional hoods was accomplished under economical efficiency.

4.4-10 Long term ventilation variation in two naturally ventilated Stockholm dwellings
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Passive tracer gas measurements of ventilation were performed in a single-family house and in a flat in Stockholm during four consecutive winter seasons. Measured averages of ACH data are reported for 47 two-week periods for the two naturally ventilated dwellings. The variation of ventilation is discussed in terms of variation in the ventilation driving forces induced by inside-outside temperature differences. The detached house shows a slightly better correlation between ACH and indoor-outside temperature difference than the town flat. It is concluded that the correlations are not good enough for predictive use for either dwelling. Therefore it does not seem possible to ‘normalise’ ventilation measurement data, obtained during one time period with a specific weather condition, to what would be expected during a period with ‘normal’ weather conditions. A possible reason for the lack of good correlation between ACH and natural driving forces is a highly variable influence from occupant behaviour.

4.4-11 Feasibility study of ventilation rate measurement by spatial mean concentration by Open Path Fourier Transform Infrared Spectroscopy
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There were many issues in the existing ventilation rate measuring methods such as the spatial distribution of tracer gas, the environmental effect of the tracer gas itself such as it being a greenhouse gas and etc. A new method for ventilation measurement using an Open Path Fourier Transform Infrared Spectroscopy (OP-FTIR) will be proposed. The tracer gas between the optical-path will be measured so the effect of spatial distribution of the tracer gas will be moderated. A feasibility study this measuring method was taken place using an OP-FTIR and compared with the traditional measurement method using a Photocoucoustic Gas Monitor. As a result the errors between these 2 methods were about 10%. Considering the artificial errors, analytical errors and other errors, we can say that this measuring method is feasible for practice.
4.4-12 Comparison between wall confluent jets and displacement ventilation in aspect of the spreading ratio on the floor

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This paper reports CFD and experimental results that show the behaviours of wall confluent jets in a room with regards to the vertical and horizontal spreading on the floor. The flow in wall confluent jets is compared with the flow in displacement ventilation supply. The air distribution index was used to evaluate and compare the ventilation performance for both systems for different room loads. It is concluded that the wall confluent jet has a greater spread over the floor than displacement flow. Also, a wall confluent jet is capable of cooling a room with a heat load more than 35W/m² which a displacement system is not able to cope with.

4.4-13 Comparison on indoor thermal environment and energy consumption of large space with sidewall opening and top opening

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With the study results based on numerical simulation and site measurements, the paper simulates a series of thermal environment conditions in a large space of stratified air conditioning varied with different height of nozzle and upper openings, area of upper and bottom openings, inflow velocity through the upper openings with sidewall opening and top opening respectively. And the paper investigates the indoor thermal environment and the energy consumption in large space. In any case, upper opening is advantageous to improve the indoor air quality. Top opening is superior to sidewall opening in getting a better temperature field and airflow distribution. And it is seen that the cooling load in the case of sidewall opening is larger than that of top opening. The results of this paper are important to engineering and air-conditioning design. It will provide the theoretical foundation and design basis for structure design.

4.4-14 Stratum ventilation – a conceptual introduction

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The purpose of this paper is to propose a new mode of ventilation. The ventilation system involves the use of large supply inlets located at the side of a room. A supply of fresh air is then delivered into the room forming a stratum of fresher air in the occupant breathing zone. A case study, a typical office in Hong Kong under local thermal and boundary conditions, is used to illustrate this new mode of ventilation. Computational results show that with properly designed supplied air velocity and volume, locations of diffusers and exhausts, the proposed system has the potential to maintain better thermal comfort with a smaller temperature difference between the head and foot level, lower energy consumption, and better indoor air quality (IAQ) in the breathing zone. Much further work is needed to determine if the benefits are significant.

4.4-15 FANROOMLESS ventilation system for an underground parking lot

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Underground parking lot serious is emission of CO, with its known risks. In order to dilute CO to acceptable level, under ground parking lots ventilation systems can be decided as duct system, ductless system or combined. Regardless of which system design is chosen, the mechanical rooms should be considered in planning the system. If larger fans are installed to meet code requirements, initial construction costs for the mechanical room will be increased in a traditional system accordingly. Otherwise, the FANROOMLESS ventilation system can meet the code requirements without supply fan room. Furthermore, the outside air is supplied to the premises at high speed by air jet in the required direction. The air jet provides the air supply with impulse that causes the supply outside air to be carried onwards with low noise and low energy consumption. On top of this, FANROOMLESS system can reserve an extra parking space 27.9m² per flat in case of area 9000m² compare to a traditional ductless system. Additionally, this paper suggests a flat exhaust rate (m³/h) per square meter depending on the types of facility based on actual calculations over 10 years throughout various types of building using correlation equations and experience refer to 25 ppm CO limit.

4.4-16 Effectiveness of confluent jets ventilation system for classrooms

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The method of distributing the outdoor air in classrooms has a major impact on indoor air quality and thermal comfort of pupils. In a previous study, Karimipanah et al. (2000) presented results for four types of air distribution systems tested in a purpose built classroom with simulated occupancy as well as CFD modelling. In this paper, the same experimental setup has been used to investigate the indoor environment in the classroom using confluent jet ventilation (Cho et al., 2004). Measurements of air speed, air temperature and tracer gas concentrations have been carried out for different thermal conditions. In addition, CFD simulations have been carried to provide additional information on the indoor air quality and comfort conditions throughout the classroom, such as ventilation effectiveness, air exchange effectiveness, etc., and these are compared with measured data.

4.4-17 Simulation-based ventilation system study for chemical laboratory

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Chemical/biological laboratories have unique demands on heating, ventilating and air-conditioning (HVAC) systems. It not only requires effective exhaust of airborne contaminants through local hood systems but also needs sufficient fresh air from central air systems to maintain satisfactory indoor environment quality. This paper uses a validated computational fluid dynamics (CFD) tool to study indoor air quality in a typical chemical laboratory. The research explores the performance of ceiling-supply mixing ventilation systems and side-wall-supply displacement ventilation systems and their effects on hood containment. The results reveal that contaminants may leak from hood sashes with poor design and improper installation of hood and central air systems. Although displacement ventilation has less adverse impact on hood...
performance than mixing ventilation, a standard fume hood can not prevent contaminants from leaking into lab space through a large sash opening.

4.4-18 A new approach on zonal modeling of indoor environment with mechanical ventilation

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To improve the overall performance in zonal modeling for thermal and indoor air quality predictions, we have developed a new zoning approach. Its principal issue is that zoning should be based on the distributions of flow field and the zoning results should indicate the uniformity of zones in space. In this work, air age is adopted as a basis for zoning in mechanically ventilated rooms. Rigorous zoning criteria are developed based on deviation ratio of air age and location of sources. Case study is performed to demonstrate the applicability of the new approach for predicting indoor temperature in a displacement ventilated room. The simulation results were compared with those of a CFD model and those of another zonal model. Comparisons show the practicability for engineering design and the advantages for calculating more accurately the room temperature distributions of the new approach.

4.4-19 Reducing energy consumption for ventilation in dwellings through demand controlled ventilation

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The Danish Building Research Institute has initiated a 3-phased research programme. The main purpose of the programme is to develop energy-efficient ventilation strategies that will provide both a healthy and a comfortable indoor climate and reduce energy consumption compared with present standards. Phase 2 of the research programme is presented in this article. Investigations were conducted in an almost full-scale apartment built inside a laboratory hall. Four scenarios, each with a different ventilation strategy, were investigated. Two scenarios are presented in this article. The ventilation set up in one of the scenarios complied with current Danish Building Regulations, while the other scenario was fully demand-controlled ventilation. The results indicated that it is possible to save energy without compromising indoor air quality.

4.4-20 Indoor air quality control for green hotels in Beijing

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Indoor air quality (IAQ) issues are very critical for green hotels. Some factors related to IAQ, such as typical indoor contaminants, formaldehyde, NH₃, SO₂, and NO₂, etc., were measured and analyzed in seven representative hotels in Beijing. The results showed that different period of time, different places and even different areas in those hotels exhibited different pollution levels due to differences in sources, location, human activities and ventilation. Based on measurement data and associated with domestic and overseas related standards, a propositional standard of IAQ evaluation for the green hotels with 4 stars or above was proposed.

4.4-21 Effect of natural and forced ventilation systems on decay and deposition rates of particles produced by indoor sources in Indian urban households

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The decay rate of indoor air particulates represents their removal rates and is an important process in the context of indoor air quality. In this study, the decay and deposition rate of particulates is estimated in typical Indian urban kitchens. The overall decay rate of particulate was determined by raising the particle concentration by smoldering of Benzoin, then measuring the concentration variation with time of various particle size (0.05–3.2 μm) with a quartz crystal microbalance impactor. The mass size distribution of Benzoin was lognormal with MMAD 0.8 μm and produced size distributions consistently through out the experiments. Even though, there is considerable variation in the observed decay rate between houses, the exhaust fan decay rates were greater than that of natural ventilation followed by electric chimney and no ventilation condition. The size segregated particle decay rates varied in a wide range under the exhaust fan and natural ventilation conditions compared to no ventilation conditions. A numerical model has been used to calculate the deposition rate on to smooth surfaces and the observed deposition rates were consistent with the predicted trend.

4.4-22 The reduction in air infiltration in dwellings due to window replacement

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In the UK, existing dwellings have been traditionally considered as ‘leaky’ with unnecessary air infiltration resulting in excessive energy use. However, when ‘old’ windows are replaced, it is likely that the new windows will have a lower air permeability. If most, or all, of the windows in a property are replaced, then the overall reduction in the infiltration rate may be significant. If a dwelling already has a low infiltration rate, then the reduction which will occur upon replacement of the windows may result in an unacceptably low air change rate. Currently, the widely recommended minimum air change rate is 0.5 ach⁻¹. This study set out to investigate if window replacement is likely to reduce infiltration rates to below this level in a significant number of dwellings in the UK. A sample of dwellings was thus pressure tested before and after window replacement and the change in the air infiltration rate determined. If the results are taken as being representative of the UK building stock then the data suggests that approximately 65% of dwellings in the UK could have a predicted heating season mean infiltration rate below 0.5 ach⁻¹ after the installation of new windows.

4.4-23 An experimental study of ventilation effectiveness and pollutant transmission in an aircraft cabin

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Ventilation effectiveness in aircraft cabins is a critical factor for minimizing the cross-contamination of airborne pathogens exhaled by passengers. In this study, a full-scale section of a Boeing 767 cabin containing 35 mannequins were used, each with a body heater and an
4.4-24  Ventilation strategies to improve indoor air quality
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IAQ may be not always improved by only increasing ventilation rates, and favorable ventilation strategies are the keys to improve IAQ. The impacts of ventilation on IAQ are discussed, measured or experimented on four aspects. (1) Some regeneration compositions owing to potential chemical reactions among indoor contaminants on some indoor conditions may be more harmful to habitants; (2) Some outdoor contaminants may flow into indoor space with fresh air, and return air may be another indoor contaminants source; (3) A favorable air distribution and high ventilation efficiency is the key to improve IAQ in breathing zone; (4) Cleaning duct system may play double roles, namely to improve IAQ and energy efficiency. Some ventilation strategies to improve IAQ are proposed and discussed, they are: (1) Low-temperature air supply can increase acceptability of IAQ and decrease the rate of VOCs emission; (2) Demand-controlled ventilation systems can automatically control the rate of ventilation in response to variations of IAQ; (3) A task supply ventilation system can facilitate fresh air to breathing zone.

4.4-25  Evaluation on the performance of the ventilation system in the large welding working place
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In this paper, numerical analysis using computational fluid dynamics (CFD) was performed to evaluate the performance of the ventilation system in the large welding working place. When the welding fumes into the factory are not removed efficiently, the exposure to welding fumes for a long time may cause a serious problem to workers' health. To prevent from this problem, the jet fans were used in the present factory which based on concept of total space ventilation. It was found that the fumes in occupied zone were not diluted efficiently when the ventilation system was not installed. Also, the welding fumes concentration exceeds the regulation limit in this case. With the ventilation system, the welding fumes generated in the factory were exhausted well and their concentration was maintained below the regulation limit. It is recommended that the ventilation equipments using jet fans are useful in a large welding factory.

4.4-26  The natural ventilation system using form tie holes and window trickle ventilators in flats
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As Buildings have been designed and constructed to be airtight since the energy crisis the indoor air quality have become worse. The objective of this study is to improve airtight and IAQ problems through the natural ventilation. The previous study shows that recently built flats are more airtight than flats in past. Natural ventilation systems using form tie holes and trickle ventilators were proposed and performances of natural ventilation were predicted. The result shows that form tie holes cannot satisfy the target the air change rate, 0.35/h while a combination using the form tie holes together with the ventilator within the window frame provides the air change rate, 0.47/h.

4.4-27  Effect of ventilation on TSP concentration
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Ventilation is necessary for a building to perform various functions including supply of air motion, heat removed and dissipation of contaminating fumes. Providing sufficient and proper ventilation is one of the best and the easiest methods for keeping the pollutants concentration under allowable limits. This paper makes an attempt to study the effect of different ventilation systems on the concentration of Total Suspended Particulates (TSP) in the indoor environment, that may help to come up with a solution where TSP concentration is within allowable limits. The experiment has been carried out under three indoor conditions viz. Natural ventilation, Mechanical ventilation (exhaust fan) and combined Natural and Mechanical ventilation. The study has been performed in flats located in Delhi at Rohini, having almost similar conditions such as size, direction & position of kitchen, and fuel used. TSP concentration has been found to be highest in case of Mechanical ventilation while lowest in combined ventilation.

4.4-28  Making the case for reducing ventilation requirements through selection of low-emission materials
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Most ventilation rates have not been based on pollutants emitted from building materials and furnishings. An approach using the existing Material Emission Database and Indoor Air Quality computer model is presented. The approach examines by how much ventilation rates can be reduced through control of indoor sources of air pollutants while still maintaining acceptable IAQ for residential settings and the consequences on indoor air contaminant concentrations of reductions in ventilation rates below current design requirements.
4.4-29  Numerical analysis of ventilation for defending SARS  
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Spread of SARS (Severe Acute Respiratory Syndrome) was a calamity for mankind during the Spring of 2003. It is believed that ventilation is an effective method to defend the SARS virus spread. In this paper, the distribution of SARS virus in rooms with three different ventilation types and two kinds of virus source location are compared. On the other hand, applied the SARS particle thresholds, we analyze the SARS particle concentration around the SARS sickroom when the exhaust chimney is located with different positions. The numerical method is used here. Some conclusions are presented to instruct the design of ventilation for the purpose of defending SARS.

4.4-30  Measurement of ventilation rate by concentration decay method with law-environmental-loading tracer gas  
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Tracer gases and its monitoring method were studied in measurement of ventilation rate by use of concentration-decay method. Five kinds of gases of sulfur hexafluoride, nitrous oxide, carbon monoxide, carbon dioxide and isobutene were compared from viewpoints of global warming potential, toxicity, performance and cost of the gas and the smonitor. The system of isobutene and PID for the measurement was proposed and the procedure of the system and performance conditions in field was studied.

4.4-31  The design of ventilation and air-condition system in lazaretto  
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The ventilation in lazaretto has been paid more and more attentions since SARS indulged in willful persecution in China in 2003. The ventilation fashion, the fresh air amount and how to sterilize mean that if pathogens could be avoided diffusing to other wards and if they could be sterilized off. This article describes the urgent remediation manner about ventilation taken during the SARS occurred and after it took place. It sets forth some new measures used in hospital air-condition design now, also. At the same time, writers simulate and optimize the ventilation of the hospital wards from the angles of the security and energy-saving. In addition, after evaluating disinfection measure by ultraviolet radiation usually used in China now, we think that it is inapplicable to running air-condition system that using ultraviolet radiation to kill germs. Finally, reasonable recommendations are brought forward about the ventilation and air-condition system design and running in lazaretto.
4.5 Emergency ventilation

4.5-1 A new model for estimating neutral plane in fire situation

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A new model is proposed for predicting the location of neutral plane in fire situation. The shaft space is divided into two-zones (fire zone and inner space of shaft) in the model. In each zone, the temperature is assumed uniform. For validating the proposed two-zone model, a computational fluid dynamics (CFD) code, which is named FDS based on large eddy simulation (LES) developed by the Building and Fire Research Laboratory, National Institute of Standards and Technology, USA, is applied. It is shown that the location of neutral plane is above the mid-height of building, and the simulation results are uniform with the two-zone model approximately. Under fuel-control condition, the value of neutral plane height as a percentage of ceiling height is independent of the building height, the HRR of fire, the dimension of ventilation, the dimension of fire zone, and the mode of ventilation. Its value is found between 0.5 and 0.6.

4.5-2 Study on emergency ventilation using an evacuation model

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Terrorist attack in buildings by chemical and biological agents could be a fateful event which can not be ignored in our lives. Traditional idea of emergency ventilation strategy to remove or other contamination, such as fire safety design, is to supply sufficient fresh air into rooms for diluting the indoor pollutant as soon as possible, without taking notice of the different roles of the different regions in the room. However, many investigations show that, the occupants only move in a limited region of the room for evacuating when they know such emergency event occurs. So that, the emergency ventilation should emphasize on the temporal development of contaminant in the coming finite period of time after contaminant generated, and just in the partly space which can influence the people. This investigation use an occupant evacuation model of fire science, standing on the occupants, gives a more rational objective function of emergency ventilation in a large, open space. The pollutant influence on the people is evaluated by Harber’s Law.

4.5-3 Smoke management for renovation of a furniture shopping center

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An existing furniture shopping centre will be extended by constructing a new extending building part and closing the space in between by an atrium. The client wants to have as much open-sight as possible. Therefore, the internal façade will be destroyed allowing a fully open area at the second floor. The fire brigade required a demonstrable safety evacuation route in case of a fire in the atrium or the buildings. Computational Fluid Dynamics (CFD) techniques have been applied to study fire and smoke development in both cases. The influence of a sprinkler system has been taken into consideration. The results show a satisfactory situation for the underlying design.

4.5-4 An evaluation of shelter-in-place strategies in four industrial buildings

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Shelter-in-place (SIP) strategies were evaluated in four industrial buildings with volumes ranging from 111 to 3084 m³. Air exchange rates were determined to be between 0.61 and 2.81 h⁻¹ using tracer gas techniques, and air tightness was found to be between 12.1 and 41.4 air changes per hour at 50 Pa (ACH₅₀) using fan pressurization methods. SIP strategies were evaluated by measuring concentration reductions of indoor ambient particles relative to outdoors for particles from 0.5–5 µm in diameter. The tested SIP strategies included sealing air leakage pathways and deploying portable high-efficiency particle arresting (HEPA) filters. Sealing leaks in two buildings increased air tightness but did not reduce indoor particle concentrations. HEPA filters reduced indoor particle concentrations in all buildings. The effectiveness of HEPA filtration as a SIP measure against particles depends upon contaminant size, filtration duration, and filter flow rate relative to the infiltration flow rate of the building.

4.5-5 Fourier analysis of room temperature response to fire

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Flashover marks a critical stage in fire development that will quickly and severely curtail the chances of survival for trapped occupants. It is imperative that flashover is not allowed to occur in occupied spaces, but modeling and prediction of an impending flashover are difficult. In this paper, a Fourier analysis is undertaken of temperature histories. The analyses are presented of 78 experimental results taken at two different scales. The results of this preliminary investigation confirm that Fourier analysis of temperature history provides a means to distinguish between flashover and non-flashover conditions. A means of providing early warning of flashover is suggested, based on temperature history up to 300°C. The analytical results are promising but refinement of theory is needed and testing at full scale is necessary in order to develop a practical means of early warning.
4.5-6 High security filtration system for protecting buildings from airborne chemical, biological, and radiological hazards

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Buildings are vulnerable to airborne chemical, biological or radiological (CBR) hazards. Toxic agents released in a building or into an air intake would spread rapidly throughout the building via ventilation system. Efficient filtration is one of the few measures that can be implemented in advance to reduce the consequences of an intentional CBR agent release. However, due to their high pressure drop, large space requirements and high initial and operating costs the present high efficiency filter systems consisting of a HEPA filter followed by an impregnated activated carbon bed are not practical solutions for existing buildings. The aim of this study was to improve the security of building occupants by developing a novel low pressure drop protective filtration system for continuous removal of both particulate and gaseous toxic agents from the supply air. The protective filter consists of electrically enhanced particle filter to remove liquid and solid toxic aerosols combined with a chemical filter to remove gas phase agents. The performance of the high security filter was measured in laboratory tests and compared with conventional filters. The results showed that the new filter provides high removal efficiency for particulate (>99.97% @ 0.3 μm size) and gaseous contaminants at a much lower pressure drop than present solutions. With the aid of the new filtration system, protection against toxic agents can be flexibly and cost-efficiently increased in specific high-risk areas in a building without extensive modifications to the ventilation system. The side benefits of the improved filtration include healthier indoor air quality, increased building cleanliness, and limited effects from accidental releases of toxic chemicals.
4.6 Sensors and detectors

4.6.1 The study of the influence of the latent chemical reaction among indoor air pollutants on air quality
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This paper discusses about the latent chemistry property and physics property that relates to the indoor air quality. It also analyzes the possible chemical and photochemistry reactions between indoor chemistry property pollutants. The influence of these reactions and physics environment on the indoor air quality has been discussed.

4.6.2 The measurement of low air flow velocities
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Air flow velocity is measured with an acoustic sensor, which can be used especially for measuring low air flow velocities as well as the temperature of the air simultaneously. Two opposite transducers send a sound pulse towards each other. From the difference of the transit times, the air flow velocity is computed. With this method, it is possible to determine the flow direction even at low velocities. Two calibration methods are carried out. First, a set of calibration experiments is carried out in a wind tunnel, in which a uniform air flow is generated. In the centre of the wind tunnel, the sensor and a reference speedometer of Pitot tube are installed to measure the air flow velocity independently. Second, a set of calibration experiments for low air flow velocity is performed with the Enotemp sensor in a moving tube with a controlled velocity. The sensor shows good and accurate results corresponding to the speed of the tube.

4.6.3 Highly sensitive SnO2-based gas sensor for indoor air quality monitoring
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The present work is concerned on developing a high performance and reliable SnO2-based gas sensor to detect HCHO and NO2 gas for indoor environmental monitoring. The sensors were fabricated with the radio-frequency induction plasma deposition (IPD) method. SEM (Scanning Electron Microscope) and XRD (X-Ray Diffraction) method were used to examine the physical properties of the sensing films. The obtained sensors showed high sensitivities to HCHO and NO2 gas at extremely low concentration 20 ppb (parts-per-billion) with rapid response and recovery time less than several minutes. Finally, the temperature dependency of the sensors was described in the paper. The results indicated that the fabricated sensors are promising for monitoring indoor air pollution.

4.6.4 Development and validation of a visual ventilation guiding device (VVGD) for use in dwellings and schools
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Especially in northern European countries the insulation and the sealing of buildings increases in order to save energy. Thus the exchange between indoor and outdoor air is reduced. On the other hand, modern building materials often show considerable emissions of volatile organic compounds and thus may contribute to a decrease of indoor air quality, if there is no adequate ventilation of the rooms. An increasing indoor air humidity can be a possible consequence of insufficient air exchange rates, which may lead to an increased risk of mold growth. Within a research study, a visual ventilation guiding device (VVGD) for online-measurement of indoor air quality was developed. It contains sensors responding to volatile organic compounds, temperature and humidity and supports the users with an optical recommendation for free ventilation, i.e. opening or closing the windows. The VVGD was used and calibrated in dwellings, flats and schools supported by simultaneously performed ‘classical’ analytical procedures.

4.6.5 An online detection system for the assessment of VOC surface emissions
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Online detection of volatile organic compounds is still a difficult topic, many tradeoffs have to be accepted regarding the selectivity, sensitivity and the suitability to analyze complex mixtures of volatile organic compounds (VOC), especially when portable systems are required. To analyze the emission of VOC from freshly produced surfaces an emission test cell with online detector was developed. The system consists of a mobile air supply unit to provide mass-flow-controlled, humidified inlet air, a surface test cell with laminar flow over the surface and a detector unit. To achieve a selective detection of a wide range of volatile organic compounds, a miniaturized ion mobility spectrometer with a multi-capillary column was utilized as online detector. Selected compounds could be measured with detection limits down to 10 µg/m³, but the limited resolution qualifies the system more for applications like production control, where VOC concentrations above 300–500 µg/m³ are to be expected.

4.6.6 Evaluation of a PID-based portable detection system for TVOC as an indoor pollution analyzer
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In this study, we conducted a preliminary study to evaluate the performance characteristics of a portable analyzer equipped with a
photoionization detector (PID) for the analysis of total volatile organic compounds (TVOC). For the purpose of our study, we made a total of six side-by-side experiments to measure TVOC using both the PID-based portable detector and GC/FID system. The former system was calibrated against a gaseous toluene standard after modifying its spanning system to accommodate linearity deflection above certain concentration range (e.g., 3 ppm). To simplify the comparison of TVOC data, we operated the GC chromatographic technique by integrating and calibrating all peaks eluting between C6 and C16 by the same toluene gas standard. The sum of six comparative analysis conducted in a newly built apartment unit indicated that the results from both approaches agree fairly well with the bias of about 10% range. It is perceived that PID detection characteristics can vary depending on chemical speciation of VOC or environmental conditions of study area (e.g., changes in RH). However, the results of our preliminary study suggest the possibility that its application to the indoor environments can be made fairly effectively under certain environments such as a newly built apartment.

4.6-7 Particle sensors for the twenty-first century
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Particulate matter (PM) exposure and health effects are top environmental research priorities. Epidemiological studies rely on information from both sides of the dose-response equation: risk factor measures and health outcome data, and resolution of their relationships depends upon the quantity, accuracy, specificity and precision of both. Major limitations for existing PM exposure measurement technologies include expense (operational and analytical); size and weight; operating noise; and ability to characterize multiple aspects of indoor environmental aerosols. These limitations impact the practicality of conducting population-based PM exposure-related health studies. Advances in PM sensors have not kept up with those of microelectronic innovation, in fact, although expensive electronic monitors exist, most PM monitoring relies upon 19th century technology. This paper presents results from our development and testing of microelectromechanical system (MEMS) sensor that combines a size selective inlet integrated with a microchip-based PM mass concentration detector and selected PM source characterization, all integrated into a single package.
4.7 Cleaning and maintenance

4.7-1 Assessment of side exhaust systems for residential kitchens in Taiwan
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In response to concerns about the health of housewives who are regularly exposed to excessive quantities of air pollutants when cooking, a number of domestic documents have recommended solutions such as: ‘decreasing the installation height of the range hoods’ or ‘using desktop ventilators’. However, few if any studies have addressed the issue of how to make improvements to the traditional Taiwanese style of range hood. This study investigated the design and experimental assessment of side exhaust systems in a full-scale model kitchen. Tests were carried out to understand how different exhaust configurations could affect the overall exhaust performance.

4.7-2 Cleaning reduces personal exposure of office staff by tens of percents
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Office cleaning is reported to reduce surface and airborne concentrations of PM₁₀ and biocontaminants, and is associated with a reduction in health complaints. It is believed that the lower airborne contaminant levels lead to reduced personal exposure, which could explains the health effects. No data on personal exposure were available, to our knowledge. We have assessed personal exposure using a particle monitor based on Mie-scattering in a controlled office environment. The obvious dust resuspension by some office activities (document filing, the act of sitting down) was reduced if not nullified by targeted cleaning of files and chairs. Also, thorough office cleaning including vacuuming and damp wiping was able to reduce personal exposure with 25 to 50%, which is consistent with reported data on concentration reductions and health effects.

4.7-3 Effect of steam cleaning carpets on airborne viable fungi and fine particulates in residential homes
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The removal of carpets in homes in response to asthmatic responses in children or allergen avoidance has been recommended by many medical practitioners. This study looks at an alternative to removal and examines the concentration of airborne fine particulates and indoor fungi in homes undergoing a wet extraction or ‘steam cleaning’ intervention. Subsequent to the cleaning intervention, viable indoor fungal levels in the test homes remained below pre intervention levels, whereas fungal levels were wide-ranging in the control homes. Penicillium, Cladosporium, Alternaria, Aspergillus, Botrytis and yeast were the most common and widespread fungal taxa recovered indoors and outdoors. Wet extraction cleaning in conjunction with regular dry vacuuming benefits the indoor environment by maintaining not only established fungal levels indoors but also a stable indoor fungal spora.

4.7-4 Error research on a HEPA filter media testing system of MPPS (most penetration particle size) efficiency
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Referring to the Europe Standard En1822, we design a MPPS (most penetration particle size) efficiency testing system for HEPA filter media. This Standard is based on particle counting methods with optical particle counter. It also allows ULPA (ultra low penetration air) filters media to be tested, which is not possible with the previous test methods because of their inadequate sensitivity. In our error analysis, we analyses the data from the testing result and study the possible reason to produce error in the procedure. First, we determine that the mainly error sources lie in the three part of testing procedure, viz. particle counting, flow rate determining and dilution system. Then, the stochastic errors’ effect is considered to the testing system. Last, we draw the conclusion that our testing equipment has good stability and the testing data can repeat well.

4.7-5 Effective cleaning methods for reducing biocontaminant levels
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Clean surfaces are a key element in lowering personal exposure to fine dust by reducing resuspension. However, it is not known which methods effectively remove fine dust from surfaces whilst not resuspending it. Our objective was to find such methods.

We allowed about 0.3 g/m² Arizona test dust to settle onto desk top materials. Dust removal was studied microscopically. Dry wiping (e.g. with paper tissue, electrostatic cloth) removes less than 75% of the fine dust. Efficacy decreases within the first 10 cm of cleaning movement. Damp wipers, that use water or mineral oil to bind the particles, completely remove the dust. Dust resuspension measured by PVI showed that roughly a few percent of the settled dust is resuspended by cleaning. Dry methods and at higher cleaning velocity increase resuspension. For optimum protection of office and cleaning staff to fine dust, damp cleaning at a low velocity is preferred.

4.7-6 Development of air purification system in air-conditioned spaces
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Indoor air purification becomes a popular topic since the outbreak of Severe Acute Respiratory Syndromes (SARS) in 2003. Bacteria and viral contamination in indoor air has become a serious concern in
healthcare facilities. In addition, there was a market boom in air purification products during the outbreak. This paper reviews major technologies available for bacteria removal, including ultraviolet (UV) light, photo-catalytic oxidation, HEPA filters; and describes the testing results of an air purification system in a University clinic. The system was installed with UV lamps and titanium dioxide honeycomb section for photo-catalytic oxidation. Total bacteria count was measured to test the effectiveness of the system. Without the use of purifier, the bacteria count could reach 500–600 cfu/m³ when there are 18 persons or more in the clinic waiting area. The air purifier can reduce the bacteria count to 400–450 cfu/m³ under similar occupancy condition. In addition, two bacteria decay profiles were measured after clinic service hour. The one with the use of air purifier could achieve a decay rate of 4.72 hr⁻¹, comparing with the natural decay rate of 0.95 hr⁻¹.

4.7-7 Floor coverings in schools: particle buildup and resuspension potential based on preliminary field and chamber studies

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Over 70 data sets from 5 school districts in Oklahoma, USA, have been analyzed to examine the buildup of particulate contaminants in carpeted and textured flooring systems and the subsequent degree of vacuuming required for removal. In addition, representative floor covering materials (available for use in school environments) were studied under controlled chamber conditions to study both the particle removal characteristics with vacuuming, and the degree of resuspension of particulates as a function of floor covering type. Both flow through and non flow through (also known as vinyl cushion tufted textile (VCTT)) carpeted surfaces were studied in the chamber environment. The study demonstrates that carpeted floor covering used in school is not a homogeneous medium and physical characteristics vary based on the type of backing, carpet tufted type, face weight, gauge (including stitches/ inch), and adhesive requirements. In addition, the data suggest that reduction in particulate matter harbored on flooring material may present a decreased risk of airborne exposure to children, dependent on the individual flooring type.

4.7-8 Mould disinfection – effect of surface cleaning

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Through last years, there has been an increased focus on how mould growth should be removed sufficiently effective. Various companies have developed methods for using direct measurements (e.g. with damp, mechanical treatment and different chemical products) or treatment of the air (e.g. ionisation, filtration, heating and chemical products). The efficiency of such methods has been proved to be poor, they are not necessary well documented and the often increases the costs significantly. Moreover, discussions about different techniques also take away the focus from practical measurements in protection the personnel that carry out the remediation work and surrounding areas in the building. In many cases those methods also increase the costs of mould remediation. In order to find out what surface treatment that has to be carried out in order to accomplish a satisfactory effect, a laboratory test was performed. Various mould fungi was inoculated on different wooden materials, e.g. massive wood, wooden particleboard, oriented strand board and plywood. The results clearly showed that already a careful, mechanically treatments by hand with an ordinary clothe and warm water gave a very clean surface. Practically all superficial fungal growth and spores were relatively easy removed from the contaminated surfaces. On some materials, a remaining discolouration of the wooden surface was visible, but there was no significant residue of the mould fungi. This shows that a careful cleaning of massive materials is sufficient treatment in order to remove mould fungi.
4.8 Policy, standards and guidelines

4.8-1 Residential indoor air quality, ventilation, and building-related health effects: critical review of scientific literature
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The scientific literature on residential indoor air quality (IAQ), ventilation, and building-related health effects was reviewed to define gaps where further research is needed. Representative ranges of pollutant concentrations were identified for benzene, carbon monoxide, formaldehyde, nitrogen dioxide, fine particles, and total volatile organic compounds. Building-related health effects, including asthma, were found for bioaerosols, pollutants associated with dampness, combustion-related pollutants, and volatile organic compounds. A limited number of studies on the effectiveness of prevention and remediation of IAQ problems in homes were identified. Major areas recommended for further attention were: exposure studies; research addressing carbon monoxide; damp buildings and respiratory disease; temperature and perceived air quality; mitigation investigations; and translation of research into guidelines and standards. Priorities from these recommendations were: a residential building assessment survey and evaluation (BASE) similar to the earlier commercial building BASE project; exposure studies; and ventilation rates and health effects investigations.

4.8-2 The risk management for indoor air pollution caused by formaldehyde in housing: the historical perspectives on early warnings and actions
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When addressing a broad range of hazards due to environmental pollutants linked to public health or the environment, there were some cases that the regulatory actions were delayed due to scientific uncertainty, ambiguity or complexity of causes inherent in the consequences of risk assessment regardless of early warnings on hazards. As the result, the hazards were expanded in these cases. Indoor air pollution caused by formaldehyde in housing have been conducted many investigations or regulatory actions in Europe and North America. We implemented the case studies of historical perspectives on early warnings and actions concerning health hazard due to formaldehyde in Germany, USA, Canada and Japan. We showed the ranges of actions that may be taken in response to risk from indoor air pollutants, which would be one of the risk management model for indoor air pollution.

4.8-3 Round robin test of general ventilation filters according to EN 779 standard
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Air filters used in general ventilation are tested in laboratory according to EN 779 standard which has been revised in 2002. Loading of the filter with the synthetic dust has proven to be not representative of the behaviour of the filter in real life. The objective of the tests described in EN 779 Annex A is to determine if the efficiency of the filter material is based on the electrostatic effects and to measure the efficiency of the filter before and after these effects have been removed. Results obtained on the occasion of a round robin test decided by EUROVENT/CECOMAF organization has allowed to assess the discharging procedures proposed in EN 779 Annex A and to know more about the performances of air filters in real life.

4.8-4 Rationale for IAQ regulations in Scandinavia – similarities and differences
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Most ventilation regulations and standards are descriptive, meaning that they require ventilation flow rates which are assumed to dilute pollutants to acceptable concentrations. The required ventilation flow rates differ considerably between regulations and standards worldwide. This paper compares regulations in Scandinavia. These countries should be quite similar with respect to culture, building tradition, climate etc. In spite of similarities, the difference in required or recommended outdoor air flow rates is significant between the countries. A possible explanation may be uncertainties about indoor air quality and the necessary level of ventilation, in combination with different views on the balance between indoor air quality and energy use.

4.8-5 Standard and guideline requirements for UVGI air treatment systems
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Ultraviolet Germicidal Irradiation (UVGI) systems for air disinfection are coming into increasing use for indoor air quality, disease control, and biodefense applications. However, there are currently no consensus standards for the design, application, or testing of UVGI systems. Several agencies are currently investigating development of guidelines, including the U.S. National Institute of Occupational Safety and Health (NIOSH), American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), American Refrigeration Institute (ARI), and the International Ultraviolet Association (IUA). Such documents will ultimately provide a basis for the development of consensus standards that will support the rapid adoption and advancement of UVGI technology. This paper reviews the requirements for guide-
lines and standards needed to ensure successful UVGI applications as proposed by IUVA.

4.8-6 Evaluation of health and comfort in office buildings (HOPE project): analysis of Italian results

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The EU project HOPE (Health Optimisation Protocol for Energy-efficient buildings) aimed to characterise building performance in both energy efficiency and occupant health and comfort.

The first phase of fieldwork in this project involved the assessment, by building checklist and occupant questionnaire, of 71 office buildings and 98 residential buildings at European level. The second phase involved environmental measurements in a subset of buildings, with measurement plans based on the outcome of the first stage. This paper presents results obtained from the Italian office building sample (4 office buildings located in Milan). Although the investigated office buildings were built or converted and retrofitted recently, taking care of health and comfort issues, all the buildings were classified as ‘unhealthy buildings’. The main problems found were: non complete smoking policy, high levels of radon, particulate matter, carcinogenic VOCs, CO and NOx, and possible presence of biological pollutants. The environmental measurements performed in a subset of two buildings led to a final classification and showed in general a good agreement with phase 1 assessment, indicating the effectiveness of phase 1 tools in selecting measurement plans and assessing health and comfort hazards in buildings.

4.8-7 Performance criteria for healthy and energy efficient buildings: definition, assessment and building classification

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One of the aims of the HOPE project is to develop a method to assess healthiness and energy efficiency of buildings and strategies to optimise their performance towards health and energy efficiency. In this project, a building is defined ‘Healthy and Energy Efficient’ if: it does not cause or aggravate illnesses of the building occupants; it assures a high level of comfort for the building occupants; it minimises the use of non-renewable energy taking into account available technology. Health and comfort performance criteria for buildings have been defined. They include a set of measurable parameters related to indoor air pollutants or physical characteristics of the indoor environment. Compliance with this set is expected to assure, with a high degree of confidence, the provision of acceptable performance of buildings and zones within them. Target values of the selected parameters have been set taking as reference the WHO air quality guidelines, when available. Health classification of buildings is based on health risk analysis from checklist data, if necessary integrated with measurements, and health and comfort-related questionnaire data. To this purpose, health hazards have been divided into 3 groups and acute building-related symptoms are evaluated through the Building Symptom Index (BSI), a numeric indicator that considers the frequency of symptoms related to the Sick Building Syndrome (SBS) perceived by the occupants. In the end, the building is ranked according to the health status in one of 3 classes. Energy efficiency is evaluated by means of the energy index, i.e. the yearly total energy use per gross heated floor area, and the building is ranked accordingly. Combining the health and energy evaluation, the buildings are finally classified as optimal, medium, or low.

4.8-8 Principles and new developments of the emission classification of building materials in Finland

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The first version of the Emission Classification was developed by the Finnish Society of Indoor Air Quality and Climate (FISIAQ) in 1995 as part of Classification of Indoor Climate, Construction, and Finishing Materials. The publication includes measurable target values, cleanliness requirements and emission criteria for building materials. New revised edition was published in 2001. The Emission Classification of Building Materials has been the most successful part of the IAQ classification. The first M1-label was granted in 1996 and in February 2005 there were over 850 M1-labelled products from over 110 companies. The largest groups are plastic sheet flooring, paint and varnishes, plaster and leveling agents, mineral wools, gypsum boards and adhesives. The scope of this classification has been extended to the cleanliness classification of air-handling components year 2001. It includes ducts, fittings, air and fire dampers and also supply air filters. Results and experiences of this well functioning Emission Classification of Building Materials and air-handling components will be presented. In order to improve the IAQ in real conditions other sources of odours and emissions have to take into consideration. Strong sources of harmful chemicals are furniture and cleaners, waxes and other conditioners used for example for floors. There have been discussions to extend the scope of the Emission Classification. The principles for these new requirements and the criteria of the classification will be presented. It would be better, if the Emission Classification of Construction Materials could be international. The requirements for such system will be proposed in this paper based on the Finnish experiences on the Emission Classification.

4.8-9 US EPA's program needs for indoor environments research (PNIER)

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Indoor pollution ranks among the top five environmental risks to public health. The US Environmental Protection Agency (EPA) has recently developed a strategic document outlining EPA's research needs for the indoor environment, Program Needs for Indoor Environments Research (PNIER). PNIER was developed with strong collaboration across several EPA offices. This paper presents the criteria used to develop PNIER and describes the needs identified. The needs are extensive and range from basic research on sources and emissions (including biological, chemical and particulate matter), through exposure characterization, health effects and mitigation techniques. It is anticipated that PNIER will: articulate EPA’s indoor environments research needs, for both internal and external uses; identify where knowledge gaps exist; help establish a more well-defined indoor environments research presence at EPA; facilitate collaboration between EPA’s program offices and research laboratories; and possibly serve as EPA’s foundation towards a larger federal cross-agency research strategy on indoor environments research.
4.8-10 HVAC inspection and maintenance, an important industry standard

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For many years, the aftermarket maintenance of HVAC systems has been a much-discussed subject. Many investigations of IAQ problems suggest that dirty or improperly operating HVAC systems are a contributing cause. Numerous articles and speeches cite deferred or neglected maintenance as leading to premature system failure and inefficient operation. Many over the years have suggested that ASHRAE should develop a standard practice to address proper maintenance. Some ASHRAE members have resisted, noting that as a design oriented society, operations and maintenance falls outside of ASHRAE scope. At the winter ASHRAE meeting in Anaheim, California, the Board of Directors of the society approved the establishment of a project committee to develop such a standard. Since this will be an ANSI Standard, rigorous and well-defined procedures will govern the conduct of the committee and the entire developmental process. Twenty eight committee members have been approved, a formal work plan has been approved by the ASHRAE Technical Council, five meetings have been held and a public review draft will have been released by the time of the conference. This presentation will explain the work plan which includes the title, purpose and scope of the proposed Standard. In addition, it will provide an overview of the latest version of the draft Standard document.

4.8-11 Education programme related to healthy buildings

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A multi-scientific adult education programme (30 credit units) was planned in 1996 for the persons who inspect or design buildings either for the reason that buildings are suspected to be damaged and need to be repaired or for the building trade. Common people, authorities and insurance companies considered that consultants or various authorities performing the building inspections needed more thorough knowledge. Expert inspection was believed to save costs and to increase credibility. In addition, legislation concerning building inspections should be developed. Thus, the fifth programme was launched in August 2004. The students of the latest programme are from various educational backgrounds: construction or air conditioning engineering, microbiology or environmental hygiene. In addition to the whole programme 'Expert of Healthy Buildings' (30 credit units), the students can also accomplish minor grades such as Indoor Air Surveyor (16 credit units) or Moisture and Mould Damage Investigator (20 credit units). Experts of Healthy Buildings can apply for personnel certification from VTT in Finland. The board of the certification includes members representing authorities, municipalities, educational and research institutes, societies, companies and VTT.

4.8-12 Modeling the IAQ impact of HHI interventions in inner-city housing

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The U.S. Department of Housing and Urban Development’s Healthy Homes Initiative is addressing a wide range of indoor air quality (IAQ) concerns to improve urban housing conditions and protect the health of children. To evaluate the impact of potential interventions on indoor contaminant concentrations and occupant exposures, a simulation study was conducted using the multi-zone IAQ model CONTAM. The model was used to predict ventilation rates, contaminant concentrations of carbon dioxide, carbon monoxide, nitrogen dioxide, water vapor, particles, radon, and volatile organic compounds and occupant exposures for a baseline case and for eight different interventions, which included source control, filtration, local exhaust ventilation and dilution ventilation. While source control interventions were always the most effective on an individual contaminant basis, not all sources of indoor contaminants can be removed. On the other hand, interventions impacting air change rates, such as ventilation and envelope tightening, can either increase or decrease contaminant concentrations depending on the origin of the contaminants.

4.8-13 Causes and prevention of symptom complaints in office buildings: distilling the experience of indoor environmental quality investigators

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The goal of this project was to recommend empirically based strategies to prevent building-related symptoms in office buildings, for owners and managers. Ideas from six experienced building investigators were gathered and prioritized in a multi-day workshop. The top ranked problems identified were: in priority order: excessive building moisture, inadequate outdoor air, excessive dust, pollutant gases and odors, inadequate thermal control, and inadequate attention by management to indoor environments. Available findings in the scientific literature were generally consistent with these recommendations. The highest priority strategies recommended for preventing building-related symptoms were: managing water at building exteriors, operating ventilation systems per design intent, providing at least minimum ventilation rates, and maintaining indoor temperatures at 22°C ± 1° (72°F ± 2°). Despite the range of climates in which they worked, IEQ investigators showed considerable agreement, including top-ranking managing of water at building exteriors as a prevention strategy. Efficacy of these empirically based strategies generally has not been confirmed.
The European Directive for Energy Performance of Buildings was approved in the beginning of 2003. The transitional period is 3–6 years depending on the article. The European Organization for Standardization (CEN) has drafted several standards to help the member countries implement the Directive. One of these is the ‘Criteria for the indoor environment including thermal environment, indoor air quality (ventilation), light and noise’. The standard specifies design values of the indoor environment, values to be used in energy calculations, and methods for verifying specific indoor environments in buildings. This paper describes some of the principles applied in the standards, and includes examples that are presented in the above-mentioned standard. The standard covers all building types but the paper focuses on office buildings. International review of the draft standard is in progress during the writing of this paper and the standard is thus subject to change.

4.8-15 Developing successful partnerships to improve indoor air quality in schools using the US EPA indoor air quality tools for schools
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The United States Environmental Protection Agency’s (EPA) Indoor Air Quality Tools for Schools (TIS) Program is a voluntary program designed to help the nation’s schools improve indoor air quality conditions in school buildings. It is well documented (1) that over 50% of schools have reported indoor quality problems in classrooms ranging from poor ventilation, the presence of asthma triggers, lack of maintenance, moldy carpeting, exposure to dust during renovation, radon, etc. Since the publication of TIS in 1995, EPA has developed a number auxiliary tools to enhance the implementation of this national program by producing instructional videos, training modules, as well as guidance on mold in schools, benefits of improving IAQ in the classroom, asthma triggers, IAQ and productivity, etc. The New England Regional EPA office (2) has gone a step further by assisting in the formation of statewide partnerships with a variety of organizations which have yielded impressive results and which can arguably be called national model programs. Perhaps the most outstanding of these has been the Connecticut State Indoor Environment Resource Team. Another factor influencing the effectiveness of TIS implementation is state legislation which, together with dedicated partnerships, paves the way for ultimately having TIS fully implemented in every state.

4.8-16 Investigation of environment and ventilation amount of classrooms at school in Japan
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Decrease of ventilation and generation of the VOC from indoor construction materials have been pointed out as problems of the air contaminations in Japan. Therefore, the indoor measurement of ‘Formaldehyde and VOC’ was obligated by the law. Since the air contamination has become a problem also in classrooms at school, the investigation of ventilation amount in classrooms has been proceeded with using a simple method of measurement (constant concentration attenuation method). According to the result of the measurement at 11 schools (14 classrooms) with using CO2 as a tracer gas, the averaged rate of air circulation in a classroom was about 0.47 times/hour. And effective results were also obtained by the tests of the ventilation amount at schools where Energy Recovery Ventilators are installed for the purpose of energy saving. The VOC concentration measurement was also executed while investigating an accurate ventilation amount.

4.8-17 Volatile organic compounds: guidelines from the Austrian working group on indoor air
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An indoor air working group at the Austrian Ministry of the Environment has developed guidelines for the evaluation of exposure to Volatile Organic Compounds (VOC). Due to the variability in the composition of the VOC spectrum and diverse effects of different components, a procedure has been recommended based on specified ranges of VOC concentrations, derived from characteristic indoor levels and evaluation of effects observed in epidemiological and experimental studies. Broad ranges take the limited evidence about the impact of VOC into account as well as the uncertainty resulting from sampling and analytical procedure. Furthermore, in contrast to single air pollutants for which exposure standards can be derived, rather an integrated situation dependent evaluation is advocated: Assessment of VOC mixtures requires a case by case analysis that should include considerations of specific compounds, observed reactions and health problems in exposed individuals.

4.8-18 A new national design code for indoor air environment of sports buildings
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A new Chinese design code of indoor air environment for sports building is presented. Based on requirements of international sports federations and characteristics of indoor airflow of sports building of China, the parameters of indoor air environment of gymnasium and natatorium, include air velocity, temperature, humidity and fresh air volume, are determined. And some illuminations and considerations are described. The contents could be the design keys in heating, ventilating and air conditioning system of sport hall and other assistant rooms in sports building.
4.8-19 Risk assessment of airborne allergens – an example of the exposure assessment protocol for laboratory animal allergens
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Risk assessment of allergen exposure is difficult because the relationship between exposure concentration, sensitisation, and symptoms has not been fully established. Laboratory animal allergens belong to important occupational health risk factors; 10–32% of those working with laboratory animals develop allergic diseases. This paper introduces a comprehensive assessment protocol established for the evaluation of the risk due to exposure to laboratory animal allergens. The protocol includes questionnaires to the management and employees, hazard identification (i.e., observation and measurements in the workplace), and a summary of generally recommended methods to reduce allergen exposure. Based on these, the synopsis on the critical points needing implementation of effective control measures is then presented. The protocol encompasses several elements applicable to risk assessment of allergens generally, and, therefore, it can be applied wider in risk assessment than merely for laboratory animal allergens.

4.8-20 An integrated evaluation of indoor air pollution based on health risks and greenhouse gas emissions in AP, India
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Background Emissions from biomass use in household stoves can contribute to greenhouse gases (GHGs) and adverse health impacts. Initial results on emissions, concentrations, exposures and burden of disease attributable to solid fuel use are presented from a study in Andhra Pradesh, a southern state in India that applies comparative health risk assessment (CRA) procedures to evaluate the effectiveness of various interventions on the basis of potential to reduce both health risks and emissions.

Methods A district level emission profile for particulate matter (PM) and GHGs was generated, using district level fuel use information and emission factors for specific fuel stove combinations. District level concentration / exposure profiles for PM (used as an indicator pollutant for health damaging pollutants) were generated using background primary data from 420 households across three districts. Burden of disease (BOD) attributable to solid fuel use was calculated using methods developed by the WHO.

Results Biomass contributes the most to emissions of GHGs and PM across all districts. Quantity of fuel rather than differences in emission factors contributed the most to total emissions indicating the need for emission reduction interventions to focus on substantial reductions in quantity of biomass use. The average concentrations/exposures/BOD were not significantly different across districts, but there were differences in the proportions of households in various concentration/exposure categories indicating potential for interventions other than fuel substitution to reduce health risks.

Conclusions Various intervention options are currently being evaluated for potential to reduce both GHG emissions and health risks. Study results will aid priority setting for indoor air pollution mitigation in Southern India.

4.8-21 The practical IAQ control strategy in building renovation process in Taiwan office buildings
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The Indoor Air Quality (IAQ) issues were coming serious in decades. Concerning the National Policy on Sustainable Development, good and healthy living environment is a key issue that must be emphasized. This study focused on the management strategy of IAQ in office buildings and clarified the matchpoint of the pollutants control and the ventilation control. 17 office buildings, including 43 compartments with HVAC systems, were conducted to be the significant samples of the standard operating procedure of environmental sampling made by Taiwan EPA. The factors included physical conditions, chemical pollutants and building characteristics for indoor materials, workers’ density, and HVAC operating. Different target control modulators were conducted to correspond life-cycle assessment procedure for office space diagnosis by the mass balance model revalidation and statistic regression method approaching. The final control strategy of IAQ were combined with both ‘environmental diagnosis’ and ‘predicting simulation’ for remodel design and ordinary management.

4.8-22 Indoor climate – status and perspectives
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Humans spend 80–90% of their life in buildings. The quality of the indoor climate has a tremendous impact on people’s health, productivity and well being. In order to guide both research efforts and more direct governmental interventions, the Danish Environmental Protection Agency has asked the authors to provide a state of the art concerning indoor climate and health. New or modified construction products are introduced at a high rate and construction technology is in rapid development. Knowledge is needed regarding the impact on building occupants of the many new products. At the same time problems with moisture accumulation in structures and consequent mould growth, accelerated degradation of materials and proliferation of house dust mites is a major reason for sickness and annoyance in many schools and dwellings. There is a need for operation manuals for homes with directions on how to maintain proper moisture control. There is also a need for more rapid intervention when failing installations or structures cause moisture problems. Exposure to particles and chemicals measured as PM10 and TVOC has been significantly reduced during the last decade. Fine and ultrafine particles, SVOC, pesticides and other problematic chemicals such as phthalates and PCBs continue to cause concern. The prevalence of asthma and allergy is rising and basically the reason for this is unknown. The indoor climate is considered to have an impact. Many of the health problems of the indoor climate may be caused by the interaction of several conditions including gene/environment, allergens/chemical compounds and behaviour/building design. There is a need for large national study focused on possible adverse health impacts of the indoor climate. The study should focus on possible explanations to the rice in allergy and also include the impact of particles, moisture and problematic chemical emissions.
4.8-23 Air pollution, population and health importance of environment protection

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In recent decades there is increased population concern for environment quality, for it is, after life style, the second risk factor for disease appearance. Environmental exposure affects human health in various ways, including chronic carcinogenic or noncarcinogenic toxic effects. Medical interest for environment protection lies in the prevention of toxic effects. A correct assessment of health risks is of the most important role. The modern model of environmental health risk assessment means a process, with four separated sections (hazard identification, dose/response assessments, exposure and risk assessments). Other models of risk assessment apply safety or uncertainty factors (i.e. NOEL), which can be standardized, and can be rapidly conducted. Every risk assessment model includes some degree of uncertainty in scientific conclusions. Risk assessment has to be included in national health policy. Particular problem is that the great deal of serious harms of health appears after the second latent period, so it isn’t always possible to find the clear linkage with environmental factors. It is considered today that over 40% of lethal cases are due to polluted environment in various ways, while in 5% of diseases environment is the most important etiologic factor. Problems that appear due to environmental pollution are the most frequently related to air pollution: indoor/outdoor. EPA recommends new standards for some pollution substances. In the paper they are reviewed and comment is given to their implementation in our surrounding. New Law on environment protection, should be helpful to experts at the level of subtle diagnostics and recommendation of adequate measures, aiming to improve quality of life.