Indoor Environments: Design, Productivity and Health

Report Number: 2001-005-B FINAL REPORT, Volume 2, Literature Database

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Research Program B
Sustainable Built Environments

Project 2001-005-B
Indoor Environments: Design, Productivity And Health

May 2004

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Introduction

In a typical large office block, by far the largest lifetime expense is the salaries of the workers – 84% for salaries compared with: office rent (14%), total energy (1%), and maintenance (1%). The key driver for business is therefore the maximisation of the productivity of the employees as this is the largest cost. Reducing total energy use by 50% will not produce the same financial return as a 1% productivity improvement.

The aim of the project which led to this review of the literature was to understand as far as possible the state of knowledge internationally about how the indoor environment of buildings does influence occupants, and the impact this influence may have on the total cost of ownership of buildings.

Therefore one of the main focus areas for the literature has been identifying whether there is a link between productivity and health of building occupants and the indoor environment. Productivity is both easy to define – the ratio of output to input – but at the same time very hard to measure in a relatively small environment where individual contributions can influence the results, in particular social interactions. Health impacts from a building environment are also difficult to measure well, as establishing causal links between the indoor environment and a particular health issue can be very difficult. All of these issues are canvassed in the literature reported here.

Humans are surprisingly adaptive to different physical environments, but the workplace should not test the limits of human adaptability. Physiological models of stress, for example, accept that the body has a finite amount of adaptive energy available to cope with stress. The importance of, and this projects' focus on, the physical setting within the integrated system of high performance workplaces, means this literature survey explores research which has been undertaken on both the physical and social aspects of the built environment.

The literature has been largely classified in several different ways, according to the classification scheme shown below. There is still some inconsistency in the use of keywords, which is being addressed and greater uniformity will be developed for a CD version of this literature, enabling searching using this classification scheme.

Classifier	Keywords	Notes
Geographic Location (Custom 1)	Australia, State Europe, Country USA, State Asia, Country	If a study is restricted to a specific city, (eg London) then the complete classifier will be: **Europe, UK, London**
Building Type (Custom 2)	Office, Low Rise Office, High Rise Domestic, Low Rise Domestic, High Rise Domestic, House Commercial, Retail Commercial, Industrial School University	All appropriate identifiers are used – eg for a study which includes Low Rise and High Offices, both are used.
Data Type (Custom 3)	Quantitative Qualitative Survey Interview Questionnaire, on-site Questionnaire, off-site Measurements, on-site Measurements, laboratory Guide Observations Case Study	For a study which considered measurements in a building and surveys of occupants, with quantitative analysis and correlation of date the classifier is: **Quantitative, Survey, Interview, Measurements, on-site**
Outcome Focus (Custom 4)	Occupant, Health Occupant, Productivity Occupant, Well-being Occupant, comfort Occupant, Response Operation, Energy Operation, Maintenance Operation, Environmental	This identifies the outcome for the **occupants** or the **building** which is the focus of the paper/document. The focus of the project is on the occupants, but technology and design impacts cross-over.
Building Attribute (Custom 5)	Indoor Air Quality Daylight Lighting Thermal Comfort Noise Architecture	This identifies the attribute of the indoor environment which is the focus of the study. Could be multiple.
Detailed Attributes (Custom 6)	Non-specific keywords	This is to be more descriptive and details specific items considered. Under daylight for example, it might consider: view glare lighting control occupant control etc

The author index lists all authors of papers, but has attempted to use a single form of the name, eg Bell, J.M. is used even when some publications might give authorship details as Bell, J. or John Bell.

Author Index

Literature

Abdou, O. A. (1997). Effects of Luminous Environment on Worker Productivity in Building Spaces. Journal of Architectural Engineering. **3:** 124-132.
Geographical Location: USA
Building Type: office; industrial
Data Type: survey; measurement laboratory; review
Outcome Focus: occupant, productivity

Abstract

This paper is based in part, on the results of a survey undertaken by the writer for an industrial client. The purpose was to collect and systematize information on quantitative relations between the indoor environment and worker productivity. Office workers strongly believe that lighting conditions are an extremely important aspect of their workspace environment. Unfavorable conditions may hamper productivity. Daylighting is of particular importance. It is further shown that lighting conditions have a strong impact on worker performance in industrial facilities. Certain lighting strategies can contribute to an enhancement in worker productivity while cutting down on energy consumption. The influence on worker productivity of different characteristics of illumination are described. These include spectral distribution, color rendition, glare, daylight versus artificial light, and others. The presence or absence of windows on worker comfort and perception is also discussed. It is shown that improving lighting conditions is a highly cost-effective method of increasing worker productivity in office spaces as well as in manufacturing facilities.

Abel, E., J. Andersson, et al. (2002). The Swedish Key Action "The Healthy Building" Research Results Achieved During the First Three-Years Period 1998 – 2000. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate:**
Geographical Location: Europe; Sweden
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Achilles, C., J. Prout, et al. (2001). Serendipitous Policy Implications from Class-Size-Initiated Inquiry: IAQ? Paper Presented at the Annual Meeting of School Administrators. Orlando, Florida**:** 1-19.
Geographical Location: USA
Building Type: School; Secondary
Data Type:
Outcome Focus:

Abstract

The level of carbon dioxide in a classroom can have a significant negative effect on teaching and learning. Carbon dioxide (CO2) level is affected by class size and time of day. Six urban schools were studied to characterize the effects of these three factors on different class sizes. Carbon monoxide, CO2, temperature, and relative humidity readings were taken in 32 rooms in 6 buildings at approximately 90-minute intervals during the school day. Statistical analyses show a steady increase in CO2 levels with time. Class-size and time-of-day effects are evident. All classes started approximately the same (600-700 parts per million [PPM]) , but by day's end, the average CO2 level for small classes was 2,836 PPM and the average for larger classes was 4,181 PPM. Study results show a direct relationship between the amount of cubic feet of air per student and classroom performance of both students and teachers. Given the deteriorating condition of many schools, the increasing numbers of students, more reports of "sick building syndrome," increasing child asthma, and claims of low test scores, these results are important in matters of school health policy and practice. This report concludes with tables and appendices providing raw data and supplementary information on indoor air quality (IAQ).

Acliciems, A. and R. de Dear (1986). Airconditioning in Australia 1 - Human Thermal Factors. Architectural Science Review. **29:** 67-75.
Geographical Location: Australia
Building Type: office
Data Type: survey; quantitative analysis
Outcome Focus: artificial airconditioning

Abstract

The result of large sample surveys of airconditioning criteria and practices in office buildings in Darwin, Brisbane, and Melbourne are reported with reference to prevailing theories of human response. Constancy of indoor warmth is found to be inappropriate to climate conditions.

Ahman, M., A. Lundin, et al. (2000). Improved Health after Intervention in a School With Moisture Problems. Indoor Air. **Vol. 10:** 57-62.
Geographical Location: Europe; Sweden, Stockholm
Building Type: School
Data Type:
Outcome Focus:

Abstract

In a school with floor moisture problems, the personnel had complaints consistent with the sick-building syndrome (SBS). Interventive measures including the laying of a ventilated floor were undertaken to eliminate the emissions. To examine if the intervention resulted in positive health effects, 34 personnel and 336 pupils were interviewed just before the intervention and also 7 months after. Also were interviewed 21 personnel and 224 pupils at an adjacent school serving as a control. Compared with the control school, the problem school showed more complaints, more general symptoms and more symptoms from the eyes, airways and skin, both among the personnel and the pupils. In the post-intervention examinations, the

excess of symptoms among the personnel had almost disappeared. Among the pupils, the frequency of eye irritation was reduced but a general improvement of the other symptoms was not as obvious. However, after adjustment for a recent common cold, atopy and stress among the pupils, only one symptom ("stuffy nose") remained significantly elevated. In conclusion, the intervention was followed by positive health effects, supporting the hypothesis that emissions from building material had contributed to the excess of symptoms. A recent common cold was highly related to the symptoms and should be considered in future SBS studies.

Ahrentzen, S. (1981). The environmental and social context of distraction in the classroom. EDRA: Environmental Design Research Association. **12:** 241-250.
Geographical Location:
Building Type: school
Data Type: qualitative; interview; observations
Outcome Focus: occupant, productivity

Abstract

Presents a conceptual perspective of distraction in the classroom, focusing on (a) 2 dimensions of distraction (distraction-occurrence and distraction-prevention), (b) physical features, and (c) the social context. Teachers and 65 9-23 yr olds from 13 classrooms were interviewed. Observations of class activities were also made. Environmental influences of distraction were different between teachers and students. Teachers in classrooms with a greater percentage of nonpermanent walls expressed a tendency to restrict or eliminate certain class activities in efforts to prevent disturbing others. These Ss generally worked by themselves and preferred to work in secluded areas when they needed to concentrate. (25 ref) (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Ahrentzen, S. and G. W. Evans (1986). Distraction, privacy, and classroom design. Environment & Behavior. **16:** 437-454.
Geographical Location:
Building Type: school
Data Type: qualitative interviews
Outcome Focus: occupant, productivity

Abstract

Examined environmental features of elementary school classrooms in relation to distraction and privacy and explored teachers' adjustments of their activities to make their settings less distracting. Classrooms were measured on interior spaciousness, degree of open perimeter, and amenities for private study. 65 4th-6th graders and 13 teachers from 5 schools were interviewed. Environmental influences on distraction, both positive and negative, were particularly prominent among teachers. Teachers' adjustments of curricular activities to prevent distraction were associated with the amount of nonstructural walls in the classroom. Few architectural features were associated with student distraction. Students in classrooms with amenities for private study actually reported lower levels of privacy than those students without such classroom amenities. This unexpected finding may be due to limited access to these amenities even when present in the classroom. When they wanted to be alone, students preferred to be in secluded study areas or corners. (21 ref) (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Aiello, J. R., D. T. DeRisi, et al. (1977). Crowding and the role of interpersonal distance preference. Sociometry. **40:** 270-282.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Aizlewood, C., S. Coward, et al. (2002). The Impact of Humidity on Health and Comfort in an Office Building. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: UK
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The aim of this study was to test whether changes in relative humidity (RH) over the range 30-40% RH would affect acute symptoms or comfort. The study was carried out in an airconditioned office building, during the heating season (when the risk of low humidity was greatest). Temperature and RH were monitored, and occupants completed weekly health and comfort questionnaires. During the study, the humidity set point in an experimental area was reduced compared to a control area. Occupants were blind to the intervention. The achieved change in RH was not as great as had been hoped, and did not have a significant effect on symptom prevalence or comfort. There was a slight reduction of building-related symptoms at higher RH. In considering the desirability of humidification, the modest potential benefits indicated in this study must be weighed against the potential long-term disadvantages, such as biological contamination, and the economic/energy cost.

Altman, I. (1975). The environment and social behavior: Privacy, personal space, territoriality and crowding. Monterrey, CA, Brooks/Cole.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

American Society of Interior Designers (1998). Productive Workplaces. How Design Increases Productivity: Expert Insights. Washington D. C, ASID.
Geographical Location: USA
Building Type: office
Data Type: Qualitative; survey
Outcome Focus: occupant, productivity; occupant, well-being

Abstract

This paper is based on the results of an independent research survey commissioned by ASID. management consultants, university researchers and leading office designers were asked about keys to improving productivity and how iffice design contributes to the process.

American Society of Interior Designers (2001). Designing the Workplace for High Performance. Ziff Davis Smart Business. **14:** 32, 2p.
Geographical Location: USA
Building Type: office
Data Type: qualitative; survey
Outcome Focus: occupant, productivity; occupant, well-being

Abstract

Reports the importance of physical work environment on employee performance in the United States. Perceptions on management and employees functional efficiency; Effect of the environment on job satisfaction; Suggestions for a workplace design.

American Society of Interior Designers (2001). Workplace Values. How Employees Want to Work. Washington, D. C., ASID.
Geographical Location: USA
Building Type: office
Data Type: qualitative; survey; interview, phone; questionnaire, off-site
Outcome Focus: architecture; lighting; indoor air quality; noise

Abstract

Phone interview of office workers

Andersson, K., L. Bodin, et al. (2002). The Perceived Physical and Psychological Climate in Swedish Schools from 1989 to 2000 – A Database Analysis. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Sweden
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

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

Andersson, K., G. Stridh, et al. (2002). Comparison of the Perceived Indoor Climate and Symptoms Reported by Students and Personnel in 16 Senior High Schools in Sweden. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Sweden
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

In school investigations the prevalence of complaints and symptoms often differ between the school personnel and students. To study this 1 023 personnel and 8 853 students from 16 senior high schools answered the same questions about the perceived indoor climate and SBS symptoms. Both personnel and students reported

high prevalence of annoying indoor air quality, dust and dirt and temperature problems. The symptom prevalence was strongly related to sex and allergic constitution. The students reported much higher prevalence of general symptoms compared to the personnel, while the personnel reported somewhat higher prevalence of mucous membrane irritations and skin symptoms. In conclusion it is important to be aware of all factors influencing the results from a questionnaire study to do a correct interpretation. Proper use of relevant reference values is essential.

Anonymous (1999). EPA: Bad Air in Schools Hinders Student Learning. What Works in Teaching and Learning. **31:** 5-7.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Anonymous (2000). Dehumidification Improves Air Quality in Florida School. Air Conditioning, Heating & Refrigeration News. **209:** 114-115.
Geographical Location: USA, Florida, Okeechobee
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

School officials at the Okeechobee (Florida) School District became concerned about poor air quality and humidity in the classrooms after high humidity levels started causing structural damage, threatening costly computer equipment, and making classroom work practically unbearable for students and teachers. High humidity levels can have a profound effect on building occupants, woodwork, machinery, and other property. It also can lead to Sick Building Syndrome, which often increases sick time for building occupants and lowers their productivity.

Apte, M., W. J. Fisk, et al. (2000a). Associations Between Indoor CO2 Concentrations and Sick Building Syndrome Symptoms in U.S. Office Buildings: An Analysis of the 1994 – 1996 BASE Study Data. Indoor Air. **10:** 246-257. .
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Higher indoor concentrations of air pollutants due, in part, to lower ventilation rates are a potential cause of sick building syndrome (SBS) symptoms in office workers. The indoor carbon dioxide (CO2) concentration is an approximate surrogate for indoor concentrations of other occupant-generated pollutants and for ventilation rate per occupant. Using multivariate logistic regression (MLR) analyses, we evaluated the relationship between indoor CO2 concentrations and SBS symptoms in occupants from a probability sample of 41 U.S. office buildings. Two CO2 metrics were constructed: average workday indoor minus average outdoor CO2 (dCO2, range 6-418 ppm), and maximum indoor one-hour moving average CO2 minus outdoor CO2 concentrations (dCO2MAX). MLR analyses quantified dCO2/SBS symptom associations, adjusting for personal and environmental factors. A dose-response relationship ($p<0.05$) with odds ratios per 100 ppm dCO2 ranging from 1.2 to 1.5 for sore throat, nose/sinus, tight chest, and wheezing was observed. The dCO2MAX/SBS regression results were similar. Implications: large increases in

ventilation rate or improvements in ventilation effectiveness and/or indoor pollutant source control would be expected to decrease the prevalence of selected symptoms by up to 70-85%.

Apte, M., W. J. Fisk, et al. (2000b). Indoor Carbon Dioxide Concentrations and SBS in Office Workers. Healthy Buildings 2000 Conference. Espoo Finland. **1:** 133-138.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Relationships between indoor carbon dioxide (CO2) levels and mucous membrane and lower respiratory sick building syndrome (SBS) symptoms are explored in 41 office buildings from the US EPA BASE study. Elevated indoor CO2 concentrations may indicate inadequate ventilation per occupant and elevated indoor pollutant concentrations, leading to SBS symptoms. Two CO2 metrics were constructed: average workday indoor minus average outdoor CO2 (dCO2, range 6-418 ppm), and maximum indoor one-hour moving average CO2 minus outdoor CO2 concentrations (dCO2MAX). Multivariate logistic regressions quantified dCO2/SBS symptom associations, adjusting for personal and environmental factors. A dose-response relationship ($p<0.05$) with odds ratios per 100 ppm dCO2 ranging from 1.2 to 1.5 for sore throat, nose/sinus, tight chest, and wheezing was observed. The dCO2MAX/SBS regression results were similar. Implications: large increases in ventilation rate or improvements in ventilation effectiveness and/or indoor pollutant source control would be expected to decrease the prevalence of selected symptoms by up to 70-85%.

Apte, M. and C. Erdmann (2002). Indoor Carbon Dioxide Concentrations, VOCs, Environmental Sensitivity Association with Mucous Membrane and Lower Respiratory Sick Building Syndrome Symptoms in the BASE Study: Analyses of the 100 Building Dataset. Indoor Environment Department. Berkeley, CA, Lawrence Berkeley National Laboratory.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Using the 100 office-building Building Assessment Survey and Evaluation (BASE) Study dataset, we performed multivariate logistic regression analyses to quantify the associations between indoor minus outdoor CO2 (dCO2) concentrations and mucous membrane (MM) and lower respiratory system (Lresp) Sick Building Syndrome (SBS) symptoms, adjusting for age, sex, smoking status, presence of carpet in workspace, thermal exposure, relative humidity, and a marker for entrained automobile exhaust. Using principal components analysis we identified a number of possible sources of 73 measured volatile organic compounds in the office buildings, and assessed the impact of these VOCs on the probability of presenting the SBS symptoms. Additionally we included analysis adjusting for the risks for predisposition of having SBS symptoms associated with the allergic, asthmatic, and environmentally sensitive subpopulations within the office buildings. Adjusted odds ratios (ORs) for statistically significant, dose-dependant associations ($p<0.05$) for dry eyes, sore throat, nose/sinus congestion, and wheeze symptoms with 100-ppm increases in dCO2 ranged from 1.1 to 1.2. These results suggest that increases in the ventilation rates per person among typical office buildings will, on average significantly reduce the prevalence of several SBS symptoms, up to 80%, even when these buildings meet

the existing ASHRAE ventilation standards for office buildings. VOC sources were observed to play an role in direct association with mucous membrane and lower respiratory irritation, and possibly to be indirectly involved in indoor chemical reactions with ozone that produce irritating compounds associated with SBS symptoms. O-xylene, possibly emitted from furniture coatings was associated with shortness of breath (OR at the maximum concentration = 8, $p < 0.05$). The environmental sensitivities of a large subset of the office building population add to the overall risk of SBS symptoms (ORs ranging from 2 to above 11) within the buildings.

Arens, E. A. and A. Baughman (1996). Indoor Humidity and Human Health - Part 2: Buildings and Their Systems. ASHRAE Transactions. **102:** 212-221.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This paper continues a review of the humidity effects on health as addressed in indoor ventilation and environmental standards. Part I identified a number of health-related agents that are affected by indooor humidity, common sites of contamination within buildings, and common remediation measures.
Part II discusses the physical causes of moisture-related health problems in buildings, subdividing them by climate and mechanical system type. It examines studies done on moisture problems in these differing environments, showing that in most, if not all, cases the causes of the problem are only indirectly related to indoor humidity in the space. To do a better job of controlling such problems, the building- and system-specific causes of the problems should be studied. A number of specific research needs are identified.

Aries Human Lighting Demands ? IEA SHC 31.
Geographical Location: Netherlands
Building Type: unknown
Data Type: theory
Outcome Focus: occupant, well-being

Abstract

Arnetz, B., M. Berg, et al. (1997). Mental Strain and Physical Symptoms Among Employees in Modern Offices. Archives of Environmental Health. **52:** 63–67.
Geographical Location: Europe, Sweden
Building Type: Office, High Rise
Data Type:
Outcome Focus:

Abstract

A comprehensive questionnaire that assessed both physical and psychosocial work environments, as well as personal health and lifestyle, was answered by 133 (92%) employees. In addition, we assessed the physical/chemical and psychosocial environments of 8 randomly selected employees, of whom some had environmentally related health complaints. Environmental factors most often associated with poor work environments were improper room temperature, light reflexes (i.e., glare and reflection of light), dust, and dry air. Emission products from traffic pollution and 1, 1, 1-trichloroethane levels were also detected. The electromagnetic fields in both the low and the extremely low frequencies spectra were close to background levels. Individuals who had environmentally associated health symptoms worked mainly in

the customer support division, and they perceived higher work demands. Their computer environment was also worse ergonomically. There were no differences with respect to objective skin signs or disease between those with and without symptoms, respectively. The results of this study point to the importance of looking at both the psychosocial and physical environments when health complaints arise in modern offices.

Auliciems, A. (1969). Effects of Weather on Indoor Thermal Comfort. International journal of biometeorology. **13:** 147-162.
Geographical Location: UK, England, Reading
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

Since many of the bodily functions involved in thermoregulation have been found to be affected by the meteorological environment, it would seem feasible that the physiological changes resulting from exposure to outdoor weather could exert considerable influence on subsequent thermal sensations. The present investigation was designed to test this hypothesis, together with others relating to work efficiency as measured by tests of performance.

Auliciems, A. (1969). Thermal Requirements of Secondary Schoolchildren in Winter. Journal of Hygiene (Lond). **67:** 59-65.
Geographical Location: UK, England, Reading
Building Type: School, Secondary
Data Type: observations
Outcome Focus: occupant, comfort; occupant, health

Abstract

Although winter thermal comfort requirements in Great Britain have been investigated for adults in light industry (Bedford, 1936), offices (Black, 1954), and lecture halls (Angus & Brown, 1957), no inquiry appears to have been conducted with respect to schoolchildren. Suggestions for desirable classroom temperatures have been largely based on considerations of the relatively higher metabolic rate of children and in consequence recommended temperatures have been appreciably lower than those considered optimum for adults. Clay (1929) advocated air temperatures of 55-60°F, Vernon, Bedford & Warner (1930) 'not much below 60° F.', and Seymour (1939) 55-57° F. equivalent temperature. However, Post War Building Studies No.27, on heating and ventilating of schools (1947), suggested somewhat higher values with 57-60° F. equivalent temperature, while the Building Bulletin No.2 (1950) specified an air temperature of 62° F. This is the present legal requirement (Statutary Instruments 1954), which stipulates 62° F. air temperature with six air changes per hour (20-40 ft./min. air movement). Although the latter is regarded by the Institute of Heating and Ventilating Engineers (The Heating and Ventilation of Schools, 1951) as the minimum requirement, the reasons for and indeed the desirability of this temperature may be open to question since no experimental data have yet been presented. The present investigation was designed to determine the optimum conditions and limits for the thermal comfort of secondary schoolchildren.

Auliciems, A. (1972). Classroom Performance as a Function of Thermal Comfort. International journal of biometeorology. **16:** 233-246.
Geographical Location: Europe, England, Reading
Building Type: School, Secondary
Data Type:
Outcome Focus:
Abstract

On reporting his now classical experiment, Mackworth (1950, p. 149) commented that "..a rise of 5oF has no effect at all on human ability at ordinary atmospheric temperatures". This somewhat unwarranted assumption appears to have been perpetuated, since most subsequent studies relating work efficiency to thermal environments have employed broad temperature steps at which performances are compared. In all such cases, one thermal level has been chosen only roughly approximating thermal neutrality of the subjects in question, with the next levels beyond comfort limits. While this method has enabled the demonstration of "critical temperature ranges" beyond which work efficiency deteriorates (Carpenter, 1950; Mackworth. 1950; Pepler, 1958; Watkins, 1956), little or no information has been forthcoming as regards to more precise optimum temperatures, or to possible changes of performance levels within the comfort zone. Apart from attempting to gain information relating to "ordinary temperatures", the present investigation was designed to answer a number of questions, including the following:
(1) Do optimum thermal environments exist for work, or can any point within the comfort zone be considered as satisfactory?
(2) If work optima do exist, what is their relation to subjective thermal sensations ?

Auliciems, A. (1972). Some Observed Relationships between the Atmospheric Environment and Mental Work. Environmental Research. **5:** 217-240.
Geographical Location: UK, , England, Reading
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

Since the early part of this century , and the writings of climatic determinists such as Ellsworth Huntington, little has been done in relating the meteorological environment directly to man's working capacity. Research into nonpathological effects has recently gained momentum, but interest has chiefly centered on adaptation within the relatively stressful conditions encountered in the developing areas of the world. Within the temperate climatic zone however, some evidence has been presented to suggest direct causality between "weather phases" and such quantifiable dimensions of human performance as accident rates and reaction times. With rapid development of indoor microclimatic regulation and the future possibility of climatic control on a larger scale, it would seem that much more information is needed on the environmental influences affecting man, in order that he may capitalize on his technological innovations and achieve optimum atmospheric conditions. The present study was undertaken to gain more insight into the relationships of the outdoor meteorological and indoor micro climatic environments to human comfort and efficiency in the temperate climatic zone. In particular this report deals with the outdoor meteorological environment in relation to mental efficiency.

Auliciems, A. (1973). Thermal Sensations of Secondary School Children in Summer. Journal of Hygiene (Lond). **71:** 453-458.
Geographical Location: Europe
England, Reading
Building Type: School, Secondary
Data Type: observations
Outcome Focus: occupant, comfort; occupant, health

Abstract

Summer thermal sensations of secondary schoolchildren in England are compared with those earlier published for winter. Heat stress, contrary to expectation, is seen to decrease during the warm months, and neutrality is found to increase by some 6 deg F. (3.5 deg C) air temperature, which is more than double the increases observed for adults under similar circumstances.

Auliciems, A. (1975). Warmth and Comfort in the Subtropical Winter: a Study in Brisbane Schools. Journal of Hygiene (Lond). **74:** 339-343.
Geographical Location: Australia, Queensland, Brisbane
Building Type: School, Secondary; Primary
Data Type: qualitative, survey
Outcome Focus: occupant, comfort

Abstract

Winter thermal sensations of secondary and primary school-children in Queensland are related to air temperature. Neutrality is estimated by regression analysis of over 6000 assessments and a lower comfort limit is suggested to include 80% of the children. Cold discomfort is seen as the main problem, and comparison is made to an earlier study in England.

Auliciems, A. and S. V. Szokolay (1997). Thermal Comfort. Passive and Low Energy Architecture Notes, University of Queensland.
Geographical Location: Australia
Building Type: various
Data Type: Theory
Outcome Focus: Occupant, comfort

Abstract

Australian Greenhouse Office (1999). Australian Commercial Building Sector Greenhouse Gas Emissions 1990–2010. Canberra, Commonwealth of Australia**:** 16.
Geographical Location: Australia
Building Type: Commercial
Data Type: Review
Outcome Focus: Performance - energy

Abstract

This study estimates energy consumption and greenhouse gas emissions in the commercial buildings sector over the period 1990 to 2010. The primary aim is to provide a basis for the determination of an equitable contribution by the building sector to greenhouse gas emission reductions. The analysis uses existing databases from previous work within the industry by such bodies as ABARE, DPIE, and the Property Council of Australia. EMET's own databases and models are used heavily in the analysis.

The use of electricity is responsible for 89% of commercial buildings' greenhouse gas emissions. Specific operational energy applications principally responsible for

greenhouse gas emissions are cooling (28%), air handling (22%), lighting (21%) and heating (13%). Heating, ventilation and air conditioning (HVAC) and lighting thus account for 84% of commercial building sector greenhouse emissions.

Australian Standards (1990). Interior Lighting: Recommendations for specific tasks and interiors, Standards Australia. **1680.2**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract
Aylward, C., P. Harrison, et al. (2002). Analysis of Topics and Trends in Indoor Environment Research in Europe. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe
Building Type:
Data Type:
Outcome Focus:

Abstract

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

Bachmann, M. and J. Myers (1995). Influences on Sick Building Syndrome Symptoms in Three Buildings. Social Science Medicine. **40:** 245-251.
Geographical Location: South Africa, Capetown
Building Type: Office, High Rise
Data Type:
Outcome Focus:

Abstract

Relationships between symptoms typical of sick building syndrome, musculoskeletal symptoms, and reported indoor environmental exposures, psychological state, work stress and interpersonal relationships at work, were investigated among 624 office workers in three buildings. Symptom prevalences were similar in the three buildings, and were slightly lower in the two buildings characterized by its inhabitants as 'sick' than in the one building not considered to be 'sick'. Women were more likely than were men to complain of most symptoms in all three buildings. Multiple regression showed psychological symptoms and sex to be significant independent predictors of symptoms. Reported odours, and uncomfortable humidity and temperature were also independently associated with symptoms. The study indicates that sex and psychological symptoms are important predictors of perceived building related illness.

Bailey, J. M. and R. S. Bhagat (1987). Meaning and measurement of stressors in the work environment. Stress and Health: Issues in Research Methodology. S. V. K. a. C. L. C. (eds). Chichester, Wiley.

Baker, N. and K. Steemers (2000). Energy and Environment in Architecture. UK, E & FN Spon.
Geographical Location: England
Building Type: various
Data Type: case study; theory
Outcome Focus: operation, design

Abstract

Bakke, J. V. (2000). Economy and Indoor Climate. National Conference on Indoor Climate. Oslo.
Geographical Location: Europe, Sweden
Building Type:
Data Type:
Outcome Focus:

Abstract

Bakke, J. V., E. Falck, et al. (2001). Creation of healthy indoor environment in schools. ISIAQ Task Force on schools - A Nordic approach, National Institute of Public Health, Sweden.
Geographical Location: Europe, Sweden
Building Type: School
Data Type:
Outcome Focus:

Abstract

Bakke, J. V. (2002). Requirements for Good Indoor Environments in Schools, International Knowledge/Attitude (ISIAQ/WHO). Outsourcing - Alternative to Public Remediation? Norwegian Engineers Associations Meeting. Trondheim.
Geographical Location: Europe, Sweden
Building Type: School
Data Type:
Outcome Focus:

Abstract

Baughman, A. V. and E. A. Arens (1996). Indoor Humidity and Human Health - Part 1: Literature Review of Health Effects of Humidity-Influenced Indoor Pollutants. ASHRAE Transactions: Research. **102:** 193-211.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Standards for indoor thermal conditions and ventilation include upper limits for relative humidity (RH) that typically are in the range of 60% to 80% RH. Although the reasons for the limits are often not explicitly stated. It is generally known that they were set out of concern for the health effects that might occur should the humidity become too high. The primary health effects of high humidity are caused by the

growth and spread of biotic agents, although humidity interactions with non biotic pollutants, such as formaldehyde, may also cause adverse effects. This literature review identifies the most important health issues associated with high humidities and presents humidity requirements, typical contamination sites within buildings, and remediation measures for each pollutant. Part two of the paper addresses the physical causes of moisture-related problems in buildings.

Bauman, F. S., D. Faulkner, et al. (1992). Air Movement, Ventilation, and Comfort in a Partitioned Office Space. ASHRAE Transactions. **98:** 756-780.
Geographical Location: USA
Building Type: Office, Laboratory
Data Type:
Outcome Focus:

Abstract

Results are presented from a research project to investigate the effects of office partition design on air movement, worker comfort, and ventilation in workstations. The objectives of the study were to evaluate the comfort and ventilation conditions produced by a conventional ceiling supply-and-return air distribution system in workstations separated by (1) solid partitions of different height (75 in. [1.9 m], 65 in. [1.65 m], 42 in. [1.1 m], and 0 in. [partitions removed]) and (2) partitions containing a gap positioned at the bottom of the partition. The project consisted primarily of experiments performed in a full-scale controlled environment chamber (CEC) in which a typical modular office environment was set up. The range of partition configurations and environmental parameters investigated included (1) partition height, (2) solid vs. airflow partitions, (3) airflow gap size, (4) supply air volume, (5) supply/room temperature difference, (6) supply diffuser location, (7) heat load density, (8) workstation size, and (9) cooling vs. heating mode. Under steady-state conditions , multipoint measurements were made of air velocities , air temperatures, and radiant (globe) temperatures to characterize the key environmental variables affecting thermal comfort , and tracer gas methods using multipoint sampling locations were employed to determine the ventilation performance within the test chamber. The results indicated that variations in solid partition height produce only small differences in overall thermal and ventilation performance. Results also showed that while the existence of an airflow opening at the bottom of office partitions can, in some cases, produce slight increases in air velocities near the floor, there are no significant improvements in comfort conditions or ventilation efficiency within the workstations compared to results obtained for solid partitions. Test parameters that were found to have a more substantial impact on air movement and comfort included heat load density and distribution, supply air temperature, and supply diffuser location.

Bauman, F. S., T. G. Carter, et al. (1997). Field Study of the Impact of a Desktop Task/Ambient Conditioning System in Office Buildings. ASHRAE Transactions: Symposia. **11:** 1153 - 1171.
Geographical Location: USA, California, San Francisco
Building Type: Office, High Rise
Data Type:
Outcome Focus:

Abstract

A field study was carried out to assess the impact of installing a desktop task/ambient conditioning (TAC) system at 42 selected workstations within three San Francisco office buildings occupied by a large financial institution. In this study field measurements, including subjective surveys and physical monitoring were performed both before and after the TAC system installation to evaluate the impact of the TAC system on occupant satisfaction and thermal comfort, as well as the thermal

environments within the office buildings. For comparative indoor environments within each building, a control group, consisting of workers who did not receive a desktop TAC unit, was studied concurrently. During the follow-up field tests, performed three months after the TAC system installation, measurements were repeated under three different room temperature setpoint conditions (normal, set-up, and set-down) to investigate the ability of the occupants to use the desktop TAG units to control their local environment in response to a wider range of ambient temperatures. Survey results show that among the six building assessment categories investigated, installation of the desktop TAC system provided the largest increases in overall occupant satisfaction for thermal quality, acoustical quality and air quality. In terms of specific environmental factors, increased occupant satisfaction levels among the TAC group were strongly significant in comparison to changes within the control group for both temperature and temperature control. A large majority of the workers in the control group indicated a preference for higher air movement at operative temperatures of 73 F (23 C) and above. The percentage preferring higher air movement within the TAC group was lower. Workers in the TAC group had the ability to use their own TAC units to adjust the air movement in their workstations in response to changes in the ambient temperature. Over the range of operative temperatures covered by this field study, air movement preference and thermal sensation votes by workers in the control group indicated that they were more than twice as sensitive to changes as those in the TAC group.

Bayer, C., S. Crow, et al. (1999). Causes of Indoor Air Quality Problems in Schools: Summary of Scientific Research. Springfield, Virginia, National Technical Information Service.

Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

In the modern urban setting, most individuals spend about 80% of their time indoors and are therefore exposed to the indoor environment to a much greater extent than to the outdoors (Lebowitz 1992). Concomitant with this increased habitation in urban buildings, there have been numerous reports of adverse health effects related to IAQ ("sick buildings"). Most of these buildings were built in the last two decades and were constructed to be energy-efficient. The quality of air in the indoor environment can be altered by a number of factors: release of volatile compounds from furnishings, floor and wall coverings, and other finishing materials or machinery; inadequate ventilation; poor temperature and humidity control; re-entrainment of outdoor volatile organic compounds (VOCs); and the contamination of the indoor environment by microbes (particularly fungi). Armstrong Laboratory (1992) found that the three most frequent causes of IAQ are (1) inadequate design and/or maintenance of the heating, ventilation, and air-conditioning (HVAC) system, (2) a shortage of fresh air, and (3) lack of humidity control. A similar study by the National Institute for Occupational Safety and Health (NIOSH 1989) recognized inadequate ventilation as the most frequent source of IAQ problems in the work environment (52% of the time). Poor IAQ due to microbial contamination can be the result of the complex interactions of physical, chemical, and biological factors. Harmful fungal populations, once established in the HVAC system or occupied space of a modern building, may episodically produce or intensify what is known as sick building syndrome (SBS) (Cummings and Withers 1998). Indeed, SBS caused by fungi may be more enduring and recalcitrant to treatment than SBS from multiple chemical exposures (Andrae 1988). An understanding of the microbial ecology of the indoor environment is crucial to ultimately resolving many IAQ problems. The incidence of SBS related to multiple chemical sensitivity versus bioaerosols (aerosolized microbes), or the contribution of

the microorganisms to the chemical sensitivities, is not yet understood. If the inhabitants of a building exhibit similar symptoms of a clearly defined disease with a nature and time of onset that can be related to building occupancy, the disease is generally referred to as "building-related illness." Once the SBS has been allowed to elevate to this level, buildings are typically evacuated and the costs associated with disruption of the building occupants, identification of the source of the problem, and eventual remediation can be significant. Understanding the primary causes of IAQ problems and how controllable factors-proper HVAC system design, allocation of adequate outdoor air, proper filtration, effective humidity control, and routine maintenance-can avert the problems may help all building owners, operators, and occupants to be more productive (Arens and Baughman 1996). This paper provides a comprehensive summary of IAQ research that has been conducted in various types of facilities.

However, it focuses primarily on school facilities because, for numerous reasons that will become evident, they are far more susceptible to developing IAQ problems than most other types of facilities; and the occupants, children, are more significantly affected than adults (EPA 1998).

Bayer, C., S. Crow, et al. (2000). Causes of Indoor Air Quality Problems in Schools: Summary of Scientific Research, Revised Edition. Springfield, Virginia, National Technical Information Service.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Understanding the primary causes of indoor air quality (IAQ) problems and how controllable factors--proper heating, ventilation and air-conditioning (HVAC) system design, allocation of adequate outdoor air, proper filtration, effective humidity control, and routine maintenance--can avert problems may help all building owners, operators, and occupants to be more productive. This revised report provides a comprehensive summary of IAQ research that has been conducted in various types of facilities. It focuses primarily on school facilities because, for numerous reasons, they are far more susceptible to developing IAQ problems than most other types of facilities, and the occupants--children--are more significantly affected than adults are. This revised report contains summaries of more recent IAQ articles, with So new items added to the references. In addition, it expands the discussion of carbon dioxide in response to concerns about this section in the first version of the report.

Beard, D. W. (1993). Indoor Air Quality and HVAC Systems.
Geographical Location: unknown
Building Type: office
Data Type: ?
Outcome Focus: operation, maintenance

Abstract

Beckenhauer, L. L. (2000). Indoor Air Quality and Health. Washington and Lee University.
Geographical Location: USA, Washington university
Building Type: office
Data Type: review
Outcome Focus: occupant, health

Abstract

Indoor Air Quality, commonly abbreviated "IAQ", has become a major health issue in

the past 3 decades. Since many of the people concerned about health and the environment concentrate on the severity of pollution problems affecting our outdoor air, few people understand that the indoor environment may be as much as 100 times more hazardous to human health than an outdoor environment. This fact arises for two major reasons: 1) many of the substances to which we are exposed in an indoor environment are more harmful and 2) according to EPA studies, concentrations of some harmful pollutants may be anywhere from 25 to 100 times higher in an indoor setting than outdoors. These statistics become more alarming when considering the fact that the average person spends from 80-90% of his/her time indoors (Clean and Green, The Ecological Janitor; Healthy Building International, 2000). In addition, the American College of Allergists reports that poor indoor air quality either causes or aggravates 50% of all illness. In total, to the U.S. Occupational Safety and Health Administration estimates that one out of every three Americans who currently work in non-industrial buildings may be exposed to poor indoor air quality sufficient to cause illness. While a portion of this effect may result from second hand smoke, radon, and asbestos, another portion falls under the classification of Sick Building Syndrome

Becker, F. D. (1981). Workplace: Creating Environments in Organizations. New York, Praeger.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Becker, F. D. (1990). The Total Workplace. New York, van Nostrand Reinhold.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Becker, F. D. and F. Steele (1995). Workplace by design : mapping the high-performance workscape. San Francisco :, Jossey-Bass Publishers,**:** xvi, 228 p. :.
Geographical Location: 658.23 21
Building Type: 940804s1995 caua b 00100 eng dcam a
Data Type:
Outcome Focus:

Abstract

Begemann, Beld, et al. (1997). Daylight, artificial light and people in an office environment, overview of visual and biological responses. International Journal of Industrial Ergonomics. **20:** 231-239.
Geographical Location: Netherlands
Building Type: office
Data Type: measurement, lab
Outcome Focus: occupant, response operation, environment

Abstract

Long-term behaviour/response of people has been studied in standard window zone offices during daytime working hours. Regular cell-offices were equipped with experimental lighting systems delivering lighting conditions that are known to influence human physiology. The results show that most people prefer to follow a

daylight cycle instead of a constant level. Preferred lighting levels are significantly higher than today's indoor lighting standards and correspond to levels where biological stimulation can occur. The results strongly suggest that meeting biological lighting needs is very different from meeting visual needs. Results of two permanent occupants show striking differences in lighting settings, which correspond to individual circadian cycles and performance. This strengthens that present indoor lighting levels (and standards) are too low for biological stimulation. Medical research has shown that a prolonged lack of `light vitamin' can cause health problems ranging from minor sleep and performance difficulties to major depressions. This inevitably suggests that `poor' indoor lighting is the underlying cause of many of the health and performance problems. By naming this the `ill-lighting syndrome' we may well have identified the fundamental mechanism that can result in many different negative health/performance effects. Creating healthy indoor lighting can be a simple form of preventive medicine and providing a new challenge for the lighting community.

Berglund, L. G. (1998). Comfort and Humidity. ASHRAE Journal. **40:** 35-41.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Humidity affects our comfort in numerous ways both directly and indirectly. It is a factor in our energy balance, thermal sensation, skin moisture, discomfort, tactile sensation of fabrics, health and perception of air quality.

Berlin, G. (2001). Humidity Control, IAQ, and You. Engineered Systems**:** 78–89.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The author focuses on how humidity control affects the IAQ of the modern workplace environment. Studies cited show the effect that controlled relative humidity levels has on absenteeism and productivity. Overall benefits of hvac renovation to improve IAQ are reviewed, as well as current humidity control technologies and their applications.

Berry, M. A. (2001). Educational Performance, Environmental Management, and Cleaning Effectiveness in School Environments. **2003**.
Geographical Location: USA, North Carolina
Building Type: School
Data Type:
Outcome Focus:

Abstract

This paper briefly discusses research on the negative impact of indoor air environments within educational facilities and the positive impact of a scientifically based cleaning process. Included is a form for calculating the environmental performance for a school environment and definitions of relevant terms. Final sections discuss building management and cleaning and list the principles of cleaning effectiveness in school environments.

Berry, M. A. (2002a). The Contribution of Restoration and Effective Operation and Maintenance Programs on Indoor Environmental Quality and Educational Performance in Schools. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA, North Carolina
Building Type: School
Data Type:
Outcome Focus:

Abstract

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

Berry, M. A. (2002b). Healthy School Environment and Enhanced Educational Performance - The Case of Charles Young Elementary School Washington, DC. **Carpet and Rug Institute**.
Geographical Location: USA, Washington, DC
Building Type: School, Primary
Data Type: case study
Outcome Focus: occupant, well-being

Abstract

The 1997 renovation of the Charles Young Hill Top Academy in the District of Columbia is a classic illustration of how an improved school environment contributes to higher levels of educational performance. This case illustrates the connection between environmental quality, comfort, health and well-being, positive attitudes and behavior, and higher levels of educational performance. This case shows that aging city schools do not have to be abandoned; they can be successfully revitalized and made contribute effectively to the process of education. Regardless of where a school is located, a healthy school environment is comfortable and secure from danger radiates a “sense of wellbeing” and a sends a caring message. These healthy school environments are the key to a high performance educational institution.

Bholah, R., I. Fagoonee, et al. (2000). Sick Building Syndrome in Mauritius: Are Symptoms Associated with the Office Environment? Indoor and Built Environment. **9:** 44-51.
Geographical Location: Mauritius
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A cross-sectional study was carried out to Investigate the occurrence of the sick building syndrome (SBS) among office workers in Mauritius. A walk-through inspection and a questionnaire survey were carried out in 21 office building complexes to evaluate the prevalence of risk indicators for SBS symptoms among 302 office workers. Indoor climatic variables monitored were: carbon dioxide, carbon monoxide, nitrogen dioxide, air temperature, relative humidity, air movement, noise and light. All data collected were analysed using the EPI-info software. Results showed that symptoms of SBS were significantly higher among occupants of buildings with mechanical ventilation than those of the naturally ventilated buildings. Among personal factors assessed, there were generally consistent findings associating increased symptoms with age and female gender. The results also

revealed that certain SBS symptoms such as a headache across the forehead, nervousness, nausea, irritated sore eyes and sneezing were more widespread among women in these offices. However, measurements of the selected indoor variables were not found to be reliable predictors of the symptoms.

Biggerman, T. (2000). Bibliography: Lighting and Productivity, EnergyIdeas Clearinghouse.
Geographical Location: various
Building Type: various
Data Type: bibliography
Outcome Focus: occupant, productivity

Abstract

Biner, P. M., D. L. Butler, et al. (1989). An Arousal Optimization Model of Lighting Level Preferences. An Interaction of Social Situation and Task Demands. Environment and Behavior. **21:** 3-16.
Geographical Location: United States
Building Type: University
Data Type: Qualitative survey questionnaire
Hypothetical situations
Outcome Focus: Occupant, response

Abstract

Biner, P. M., D. L. Butler, et al. (1991). Inside Windows: An Alternative to Conventional Windows in Office and Other Settings. Environment and Behavior. **23:** 359-382.
Geographical Location: USA, Midwest
Building Type: Office
Data Type: Qualitative survey questionnaire,
off-site subjects. administrative university office workers, students
Outcome Focus: occupant, well-being
occupant, preferences

Abstract

Biner, P. M., D. L. Butler, et al. (1993). Windowless in the Workplace: A Reexamination of the Compnsation Hypothesis. Environment and Behavior. **25:** 205-227.
Geographical Location: USA. Midwest
Building Type: office
Data Type: qualitative questionnaire, off-site
questionnaire, on-site
Outcome Focus: occupants, response

Abstract

A series of studies was performed to explore the hypothesis that employees in windowless offices compensate for the lack of windows. In Experiment 1 students rated the degree to which they perceived various offcie features to be subtitutes for windows. Analyses revealed four general categories of potential window substituetes: other apertuers (e.g., skylights), paintings/art, living things (e.g., plants), and panels (e.g., light panels). Experiment 2 supported the external validity of the data in Experiment 1 in that full-time office workers produced virtually identical ratings of window substitutability. Experiment 3 was a field study of 173 offices. Measurements were made of the number and size of windows, number and size of all potential window substitues, and size of wall space availbale for pictures. Size was measured in degrees of visual angle from the office workers' chairs. No evidence was obtained to indicate that any of the feature measured were more prvalent or larger in offices

without windows. Furthermore, power analyses indicated that the study had sufficient power to find such effects. Experiment 4 was designed to investgate other potential reasons for the use of the items that were examined in Experiment 3. Several reasons, such as space personalization, were found to be perceived by office occupnats as more important than the desire to compensate for lack of windows.

Bischof, W., S. Brasche, et al. (2002). Do Building-Related Complaints Reflect Expectations. Indoor Air 2002. Monterey, California, ProKlima Study Group. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe
Germany
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Expectations confound the interaction between environment and human perception. Assuming expectations have an important impact on well-being and behaviour, identifying predictors of expectations might be a needful task concerning prevention. Thus, data of 4,596 office workers investigated in phase I of the ProKlimA project have been analysed by multiple logistic regression to find associations between expectations and potential impact variables.
Women, subjects working in buildings with air conditioning and employees identified as SBS cases are characterised by consistently higher expectations towards indoor humidity , temperature, air velocity and ventilation quality. Adjusted odds ratios (OR) for 'SBS cases' range between 1.61 and 2.52. The risk of having higher expectations ranges between 1.45 and 1.93 for office workers in spaces with air conditioning compared to naturally ventilated rooms. With OR from 1.45 to 1.78, women report higher expectations than men. Building design and facility management should consider related expectations.

Bluyssen, P. M., E. de Oliveira Fernandes, et al. (1996). European Indoor Air Quality Audit Project in 56 Office Buildings. Indoor Air. **6:** 221-238.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A European project started at the end of 1992, in which, in addition to current methods, trained sensory panels were used to investigate office buildings all over Europe. The main aim of this EC-Audit was to develop assessment procedures and guidance on ventilation and source control, to help optimize energy use in buildings while assuring good indoor air quality. In each of nine countries, six or more office buildings were selected. Measurements were performed at five selected locations in each building. The buildings were studied while normally occupied and ventilated to identify the pollution sources in the spaces and to quantify the total pollution load caused by the occupants and their activities, as well as the ventilation systems. The investigation included physical and chemical measurements, assessment of the perceived air quality in the spaces by a trained sensory panel, and measurement of the outdoor air supply to the spaces. A questionnaire for evaluating retrospective and immediate symptoms and perceptions was given to the occupants of the buildings. The building characteristics were described by use of a Check-list. The annual energy consumption of the buildings and the weather conditions were registered. This paper presents results and conclusions of the audit in 56 buildings in Europe. However, the analysis and discussions of the results are a summary of the work

done, and are focused mainly on comparison between sensory assessments and the other measurements performed. Furthermore. this paper brings the results of the study based on a two-factor analysis. A paper dealing with results on a multifactorial analysis is in preparation.

Bluyssen, P. M. and C. Cox (2002). Indoor environment quality and upgrading of European office buildings. Energy and Buildings. **34:** 155-162.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Indoor environmental quality (IEQ) is an important quality aspect of office buildings, which is acknowledged in a new European methodology and software for office building refurbishment (TOBUS). In TOBUS, an inventory of complaints from occupants about IEQ is made as well as an inventory of characteristics of building and HVAC-system. Based on relations between characteristics of buildings and systems and the use of the building, different possible causes for the problems can be identified and possible actions for improvement can be selected. A relation scheme is provided with relations between objects and types, complaints of occupants in an office building, possible causes of those complaints and actions that should take away those complaints. Furthermore, a relation scheme is provided with causes and actions that cannot be related to an object. A procedure to qualify and quantify the IEQ performance of a building is given. This article describes the results of the field investigations in 12 European buildings focused on the IEQ part. Discussions and conclusions from this field study with respect to IEQ and with respect to the methods and procedures used are also presented.

Boerstra, A., S. Kurvers, et al. (2002). Thermal Comfort in Real Live Buildings: Proposal for a New Dutch Guideline. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Netherlands
Building Type: Office
Data Type: theory
Outcome Focus: occupant, comfort

Abstract

In practice the commonly used criteria for thermal comfort in Dutch buildings (weighted factor method) often lead to confusion. The criteria are hard to understand for non-experts, and many doubt the validity of the present criteria. A project was initiated in order to formulate alternative ways to predict, evaluate and communicate thermal comfort performance of buildings. The result: a draft version for a new Dutch guideline for design and evaluation purposes. Properties of the new guideline are: - It distinguishes between requirements for centrally controlled and for occupant controlled indoor environments. - Limits are set in terms of maximum allowable operative indoor temperatures. These increase with increasing average outdoor temperature, anticipating on adaptation effects. - A building's performance is characterized by '% of working time that the allowable (floating) maximum indoor temperature is exceeded' and the 'average amount of degrees that the upper-limit is exceeded during those exceeding hours'.

Bordass, B., R. Cohen, et al. (1997). Energy and Engineering Probe Technical Review. Building Services Journal.
Geographical Location: England
Building Type: office; non commercial
Data Type: measurement on-site; case study
Outcome Focus: operation, energy

Abstract

Eight buildings were studied under the PROBE research project - four offices and four non-commercial buildings. In the penultimate article in this PROBE series, we focus on the engineering and energy issues of all the study buildings to draw some conclusions on building perfomance. How well do lighting controls work? Are energy efficiency targets being met, and how important is the quality of construction to delivering good comfort conditions?

Bordass, B. (2000). Cost and Value: fact and fiction.
Geographical Location: England
Building Type: building
Data Type: qualitative study
Outcome Focus: operation, energy occupant, well-being

Abstract

Assessing the costs and benefits of any building - let alone a green one - can be elusive. This paper considers the triple bottom line of economic, human and environmental costs and benefits. It identifies inertia in the system; perceived and actual risks; areas in which value can most easily be added or subtracted at various stages in the process; and where improvements might be made. Much of the supporting information comes from recent studies of occupied UK buildings, and may not represent the situation in other countries. However, there appears to be growing similarities in today's globalising market.

Bordass, B., A. Leaman, et al. (2001). Walking the Tightrope: The Probe team's response to comments in BR&I.
Geographical Location: England
Building Type: building
Data Type: case study review survey
Outcome Focus: operation, energy occupant, response

Abstract

The Probe team is delighted that BRI's Special Issue on Post-Occupancy Evaluation (POE) has led to these important contributions from world experts in building performance. Monitoring and feedback are essential to learning and improvement. When innovating, you need to know how well you have done, to find out what you need to improve and if there are any unintended consequences. Even if what you are doing is completely routine, feedback is essential to quality control. There are high costs in NOT undertaking effective feedback.

Bornehag, C., G. Blomquist, et al. (2001). Dampness in Buildings and Health, Nordic Interdisciplinary Review of the Scientific Evidence on Associations between Exposure to ‘‘Dampness’’ in Buildings and Health Effects (NORDDAMP). Indoor Air. **11:** 72-86.
Geographical Location: Europe, Sweden
Building Type: Office, School
Data Type:
Outcome Focus:

Abstract

Several epidemiological investigations concerning indoor environments have indicated that "dampness" in buildings is associated to health effects such as respiratory symptoms, asthma and allergy. The aim of the present interdisciplinary review is to evaluate this association as shown in the epidemiological literature. A literature search identified 590 peer-reviewed articles of which 61 have been the foundation for this review. The review shows that "dampness" in buildings appears to increase the risk for health effects in the airways, such as cough, wheeze and asthma. Relative risks are in the range of OR 1.4-2.2. There also seems to be an association between "dampness" and other symptoms such as tiredness, headache and airways infections. It is concluded that the evidence for a causal association between "dampness" and health effects is strong. However, the mechanisms are unknown. Several definitions of dampness have been used in the studies, but all seems to be associated with health problems. Sensitisation to mites may be one but obviously not the only mechanism. Even if the mechanisms are unknown, there is sufficient evidence to take preventive measures against dampness in buildings.

Boubekri, M., R. Hulliv, et al. (1991). Impact of window size and sunlight penetration on office workers' mood and satisfaction. A Novel way of Assessing Sunlight. Environment & Behavior. **23:** 474-493.
Geographical Location: USA. Texas
Building Type: Office
Data Type: qualitative, quantitative questionnaire, on-site measurements, laboratory field experiments, office module
Outcome Focus: occupants, well-being

Abstract

Sunlight or direct-gain passive solar strategies let sunlight penetrate the living space. In environments where the well-being of the building occupant is a salient concern to the designer, this intrusion of sunlight ought to be controlled so that it does not impede the perfomance of the occupant. This study investigates the impact of window size and different amounts of sunlight penetration on occupant emotional response and degree of satisfaction. Unlike previous sunlight requirements studies, sunlight penetration is measured not in terms of duration, but rather in therms of size of sunlit areas, and therefore as a visual stimulus. The study was perfomred in an office room of a typical size. It was found that window size did not significanly affect the occupant emotional state or the degree of satisfaction. Sunlight penetration significantly affected the feeling of relaxation when the observer was sitting sideways to the window and the relationshop had an inverted u-shpace. The study stresses the validiy of this novel way of assessing sunlight penetration in terms of size of the sun patches inside the room and its importance as a significant environmental attribute and design parameter that ought to be accounted for during the design of windows in sulighting or direct-gain passive solar strategies.

Brasche, S., M. Bullinger, et al. (2001). Why do Women Suffer from Sick Building Syndrome more often than Men? – Subjective Higher Sensitivity versus Objective Causes. Indoor Air. **11:** 217-222.
Geographical Location: Europe, Germany
Building Type: Office
Data Type: quantitative, statistical, self-reporting
Outcome Focus: occupant, health

Abstract

Office workers often report so-called sick building syndrome (SBS) symptoms affecting the skin, mucous membranes and nervous system. The recurring higher prevalence of SBS in women was investigated using questionnaire and ergonomic data from the German ProKlimA-Project. The hypothesis that working conditions and job characteristics for women are inferior to those of men was tested for groups of risk factors. Finally, gender-specific multiple logistic regression models were compared. It was found that 44.3% of women (n=888) and 26.2% of men (n=576) suffer SBS with significant differences between men and women for many variables. Considering sub-groups - supposing the same circumstances in psycho-social and work-related conditions - gender-specific SBS prevalence rates differ as for the whole sample, e.g. 35.9% of women with the most favourable job characteristic suffer SBS (men: 19.4%), 53.0% of women with the most unfavourable job characteristic suffer SBS (men: 33.3%). These results show that women suffer more SBS than men independent of personal, most work-related and building factors. Multiple logistic models define self-reported acute illness, job satisfaction, software quality and job characteristics as significant gender-independent risk factors. Number of persons/room, selfreported allergy and smoking are characteristic female risk factors. Age is a significant risk factor only in men.

Brennan, T. M. and P. E. Turner (1999). Indoor Air Quality Primer. Contracting Business. **Ventilation Guide Spring:** 5 - 20.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

What factors and conditions cause indoor air quality problems and what can you do to stop them?

Brightman, H. S., L. A. Wallace, et al. (1999). Comparing Symptoms in United States Office Buildings. Indoor Air '99. G. Raw, C. Aizlewood and P. Warren. Edinburgh, Scotland London, England, Construction Research Communications Ltd. **Proceedings of Indoor Air '99 The 8th International Conference on Indoor Air Quality and Climate:** 847-852.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Brill, M., S. Margulis, T, et al. (1981). Using Office Design to Increase Productivity. Buffalo, NY, Buffalo Organization for Social and Technological Innovation (BOSTI). **1**.

Geographical Location: USA
Building Type: office
Data Type: qualitative surveys self rating and supervisory ratings of job performance questionnaires (6,000 workers, 70 organizations) design guidelines
Outcome Focus: occupant, productivity
occupant, well-being

Abstract

Table of Contents
Introduction (Office design and the national interest, Reconceptualizing the office as a tool, Economics of the office as a tool, the best criteria for design)
The research program described how best to read the results
summary of the results
office workers described
Detailed results (the work space, ambient conditions, psychophysical constructs, facilities design and management)
The dollar value of appropriate office design
appendices

Brown, S. K. (1997a). Indoor Air Quality. Australia: State of the Environment Technical Paper Seriers (Atmosphere), Environment Australia**:** 68.

Geographical Location: Australia
Building Type: commercial, domestic, non industrial workplaces
Data Type: survey, theory, case study
Outcome Focus: occupant, health
occupant, well-being

Abstract

The objective of this paper was 'the preparation of an analysis of the current state of air quality in a range of indoor environments in Australia, the identification of human induced pressures on indoor air quality and the assessment of responses to pressure on indoor air quality'. The term indoor air was taken to include the air inside residential buildings and accessible public indoor areas of workplaces. This paper focuses on non-industrial workplaces and industrial workplaces are discussed only in relation to the operation and enforcement of occupational exposure standards for air. The scope of the paper was specified by the State of the Environment Atmosphere Reference Group.

Brown, S. K. (1997b). Indoor Air Pollutants: Sources, Health Effects and Measurement. Managing Indoor Air Quality – A Practical Approach, Australian Institute of Refrigeration, Air Conditioning and Heating.

Geographical Location: Australia
Building Type: Office
Data Type: survey
Outcome Focus: occupant, health

Abstract

It is a popular misconception that indoor air pollutants are just ambient air pollutants that get drawn into buildings with ventilation air. While it is certainly true that ambient air pollutants do get into buildings, it is also true that the major pollutant species are different between outdoor and indoor air and that the outdoor pollutants are partially lost (eg. deposition of particles, lead or sulfur dioxide, irreversible reaction of ozone or nitrogen dioxide) by the time they get into buildings. The main indoor air pollutants

arise from a diverse range of indoor materials and products that emit pollutants and have no relationship to outdoor air pollution. As a result, it is commonly found for most air pollutants that indoor air concentrations are far in excess of those outdoors. When combined with the fact that we spend over 90% of our lives indoors (even here in sunny Australia) our exposure to air pollutants is far greater from breathing indoor air than outdoor air. International effort is now directed to dealing with the problem on two fronts:

* eliminating or controlling sources of indoor pollutants
* ensuring building ventilation rates are sufficient to remove pollutants for which source control is limited. This presentation will focus on the first of these factors from the following perspectives, each of which will be addressed for specific pollutants:
* major indoor air pollutants and their sources (especially in Australia)
* health effects of indoor air pollutants (and exposure standards)
* procedures to sample and analyse pollutants.

Brown, S. K. (1997c). Indoor Air Quality, Australia: State of the Environment Series (Atmosphere), Environment Australia, Department of the Environment, Commonwealth of Australia.

Geographical Location: Australia
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The objective of this paper was 'the preparation of an analysis of the current state of air quality in a range of indoor environments in Australia, the identification of human-induced pressures on indoor air quality and the assessment of responses to pressures on indoor air quality'. The term indoor air was taken to include the air inside residential buildings and accessible public indoor areas of workplaces. This paper focuses on non-industrial workplaces and industrial workplaces are discussed only in relation to the operation and enforcement of occupational exposure standards for air. The scope of the paper was specified by the State of the Environment Atmosphere Reference Group.

Brown, R., J. Bell, et al. (2002). Low Energy Cooling Systems for Queensland Schools. Queensland University of Technology**:** 94.

Geographical Location: Australia
Building Type: school
Data Type: case study, review
Outcome Focus: operation energy

Abstract

This project has been commissioned by BERU as a preliminary scoping investigation for a full research project into the development of low-energy cooling systems for educational buildings. A survey of alternative low energy and passive technologies is presented which may be able to improve the indoor thermal environment in educational buildings located in the humid and temperate climatic regions of Australia. Gaps in existing technology, which are needed to develop cost-effective, low energy cooling systems, are identified.

Browning, W. D. (1997). Giving Productivity an Energy-Efficient Boost. Consulting-Specifying Engineer**:** 40 - 44.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Although the indoor environment's effects on health and well being have been the subject of headlines and news reports in recent years, hard evidence of such relationships has been lacking. Tying visual acuity, thermal comfort and indoor-air quality to worker productivity is a difficult research proposition. However, a recent study isolating these factors illustrates their importance to a facility's bottom line. In fact, the report indicates productivity gains resulting from a well-designed efficiency upgrade can be more important than energy savings to the project's pay-back schedule.

Building Research Establishment Productivity.
Geographical Location: various
Building Type: various
Data Type: literature
Outcome Focus: occupant, productivity

Abstract

Burge, H. A., M. D.K., et al. (1998). Final Report: Bioaerosols, Health, and Productivity in Large Office Buildings, Harvard School of Public Health.
Geographical Location: USA
Building Type: Office, High Rise
Data Type:
Outcome Focus:

Abstract

Building-related illnesses are of increasingly common concern. However, the causes and cures remain obscure. This project was designed to longitudinally evaluate the role of environmental factors on reported symptoms and measured working efficiency in a group of office workers. Although a single large building was to be the focus, difficulties in obtaining access forced the use of working spaces in five different buildings. This slowed the project and increased the difficulties involved in gathering data, but expanded the range of environmental conditions available for study. Overall we collected continuous data on CO2, RH, and temperature from 28 sites in 5 buildings over a period of 18 months. We collected environmental samples (air samples for fungi and bacteria, dust samples for estimation of 'dustiness', culture of fungi and bacteria, and assay of allergens) on a total of 17 occasions from these sites. We also recruited 180 individuals, and recovered 729 six-week questionnaires, and 4103 weekly questionnaires. Measures of working efficiency were collected from 171 individuals, with an average of about 2 tests/person/week, and a total of 2176 tests overall. Methods evaluations revealed that Andersen conversions were not necessary for the data set, and that MEA and DG-18 culture media produced very similar results so that the resulting data could be combined. Using Principal Component Analysis (PCA), airborne fungal recoveries grouped into four factors which explained 53% of the variance. Airborne fungal concentrations varied seasonally with the highest median value in August and the lowest in January. Total airborne fungal concentrations were negatively correlated with CO2 and positively related to relative humidity. PCA factors 1 and 2 were negatively correlated with CO2 and positively correlated with RH Similar studies for dustborne fungi. These

populations clustered into three factors using PCA. Concentrations of dust fungi were related to temperature and CO2 levels. Cat and dust mite allergens were consistently present in dust in all buildings.

Butler, D. L. and P. M. Biner (1989). Effects of Setting on Window Preferences and Factors Associated with those Preferences. Environment and Behavior. **21:** 17-31.
Geographical Location: USA. Ball State University
Building Type: office, university, domestic
Data Type: Qualitative Survey questionnaire, off-site subjects: students
Outcome Focus: occupant, well being
occupant, preferences

Abstract

Butler, D. L. and P. M. Biner (1990). A Preliminary Study of Skylight Preferences. Environment and Behavior. **22:** 119-140.
Geographical Location: USA. Midwest
Building Type: office, University, domestic
Data Type: qualitative, survey, questionnaire
off-site subjects: university students
Outcome Focus: occupant, well-being
occupant, preferences

Abstract

Butler, D. L. and B. L. Steuerwald (1991). Effects of view and room size on window size preferences made in models. Environment and Behavior, Sage Publications. **23:** 334-358.
Geographical Location: USA
Building Type: office
Data Type: qualitative, quantitative, survey , questionnaire, on-site scale models
Outcome Focus: occupant, well-being

Abstract

Window size preferences were studied in two experiments using a 1/12 scale model. In the first experiment, subjects viewed small- to medium-sized offices. The experiment showed that window preferences are affected by room size. Preferred window size is not a constant proportion of a wall size. Rather, a larger proportion is preferred for smaller rooms. Second, the experiment showed that scenes perceived as more beautiful lead to larger preferred windows. Third, office work experience of subjects had no effect on preferences. Experiment 2, which incorporated several changes, confirmed all three of these findings. In addition, this experiment showed that window size preferences are also affected by the type of the room. Subjects viewing the same model preferred smaller windows for a computer work room than for an office.

Butler, T. and J. Woldroop (1999). "Job Sculpting, The Art of Retaining your best People." Harvard Business Review: 140-152.

Cain, W. S. (2002). The Construct of Comfort: A Framework for Research. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA, California
Building Type:
Data Type:
Outcome Focus:

Abstract

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

California Department of Health Services (1998). Indoor Environmental Quality in California Schools: Critical Needs, An Assessment by the California Interagency Working Group on Indoor Air Quality,, Indoor Air Quality Branch, Environmental Health Laboratory Branch, California Department of Health Services.
Geographical Location: USA, California
Building Type: School
Data Type:
Outcome Focus:

Abstract

Poor indoor environmental quality (IEQ) in California public schools is causing detrimental effects on staff and students, including health impacts and reduced educational effectiveness, plus the degradation of communities' investments in school infrastructure.

Carlopio, J. R. and D. Gardner (1992). Direct and interactive effects of the physical work environment on attitudes. Environment and Behavior. **24:** 579-601.
Geographical Location: Australia, New South Wales
Building Type: office
Data Type: qualitative, questionaires, on site
Outcome Focus: Occupant, health
Occupant, well-being
Occupant, response

Abstract

This study examined the direct and interactive relationships among several elements of the physical work environment (i.e. type of office, personal computer (PC) use, and ergonomic furniture), types of work (i.e., clerical, professional, and managerial, and supervisory versus non-supervisory), and employee attitudes (i.e, satisfaction and environmental perceptions). Two-hundred and twenty-eight employees of a large bank completed questionnaires. Analyses of variance revealed both direct and interactive effects. Differences were found across those with and without PCs and ergonomic furniture on various attitudes and perceptions. Differences were also found across office types, as were interactive effects among work types and office types. These results support the hypothesis that relationships among these variables are complex and interactive, and illustrate that perceptions of the physical environment

are moderated by the job level and the type of work people perform.

Carrer, P., M. Maroni, et al. (2001). Allergens in Indoor Air: Environmental Assessment and Health Effects. The Science of the Total Environment. **270:** 33-42.
Geographical Location: Europe, Italy
Building Type: Office, School
Data Type:
Outcome Focus:

Abstract

It has been suggested that the increase in morbidity and mortality for asthma and allergies may also be due to an increase in exposure to allergens in the modern indoor environment. Indoor allergen exposure is recognised as the most important risk factor for asthma in children. House dust mites, pets, insects, plants, moulds and chemical agents in the indoor environment are important causes of allergic diseases. House dust mites and their debris and excrements that contain the allergens are normally found in the home in beds, mattresses, pillows, carpets and furniture stuffing, but they have also been found in office environments. Domestic animals such as cats, dogs, birds and rodents may cause allergic asthma and rhinoconjunctivitis. The exposure usually occurs in homes, but also in schools and kindergartens where domestic animals are kept as pets or for education; moreover, cat and dog owners can bring allergens to public areas in their clothes. Allergy to natural rubber latex has become an important occupational health concern in recent years, particularly among healthcare workers; when powdered gloves are worn or changed, latex particles get into the air and workers are exposed to latex aerosolised antigens. To assess the environmental risk to allergen exposure or to verify if there is a causal relationship between the immunologic findings in a patient and his/her environmental exposure, sampling from the suspected environment may be necessary.

Carsia, T. (2002). Designing Workspaces for Higher Productivity. Occupational Health & Safety. **71:** 192-195.
Geographical Location: USA
Building Type: office
Data Type: literature review
Outcome Focus: occupant productivity

Abstract

Some companies are using the open office plan to support a business philosophy that encourages communication and a collaborative environment. When open offices are designed correctly, the space became a powerful business tool, enabling the company to save money while facilitating communication and encouraging teamwork. Yet companies adopting open offices run the risk of hindering business success for the sake of saving money.

Castells, M. (2001). The Internet Galaxy, Reflections on the Internet, Business and Society, Oxford University Press.

Cena, K. and R. de Dear (1998). Field Study of Occupant Comfort and Office Thermal Environments in a Hot Arid Climate, Institute for Environmental Science, Murdoch University, Sydney.

Geographical Location: Australia; Kalgoorlie-Boulder
Building Type: Office
Data Type: measurements, on-site; survey
Outcome Focus: occupant, comfort

Abstract

This report presents the findings of ASHRAE research project RP-921; a field study of occupants' comfort and office thermal environments in 22 mechanically ventilated office buildings in Kalgoorlie-Boulder, Western Australia, a location characterized by a hot-arid climate. This study is the fourth in a series of ASHRAE projects (RP-462, 702 and 821) which investigated office environments in temperate, hot-humid and cold climatic regions. A total of 935 subjects provided 1,229 sets of data for winter and summer. The study used the original San Francisco questionnaires with minor adaptations to local conditions. Indoor climatic data were collected by a light and portable mobile cart carrying laboratory-grade instrumentation fully compliant with ANSI/ASHRAE Standard 55 and ISO 7726 in terms of accuracy and response times. Clothing insulation levels recorded in Kalgoorlie-Boulder were 0.49 clo in summer and 0.69 in winter. Office chairs were estimated to add 0.15 clo to the clothing insulation. Metabolic rates were estimated to be on average 77 W/m2 or 1.3 met for both seasons and for both sexes. Over 80% of subjects lived (for over 5 years), travelled and worked in air-conditioning spaces. Thermal neutrality, according to responses on the ASHRAE seven-point sensation scale, occurred at 20.3 oC in winter and at 23.3 oC in summer. Preferred temperature, defined as a minimum of subjects requesting temperature change, was 22.2 oC for both seasons. The values of thermal neutrality were in general agreement with predictions from models by Humphreys (1981) and Auliciems (1983). After the effect of chair insulation was accounted for, the PMV index adequately predicted optimum summer-time indoor temperatures for the Kalgoorlie-Boulder subjects, whether defined in terms of thermal neutrality or thermal preference. The PMV predictions of neutrality and preference for winter were less useful. Nearly 65 % of the indoor measurements fell within the ANSI/ASHRAE Standard 55a summer comfort zone; 85 % in the winter. Over 75 % of the combined project's workstations had indoor climates complying with the ASHRAE Standard 55 – 1992 comfort zone, and 86% of the occupants considered their thermal conditions acceptable. Draft or unwanted local cooling subjective responses did not correlate with the subjects' perception of thermal environments. It is likely that the levels of air movement and turbulence encountered in offices were too small to significantly influence the subjects' responses, although they were Standard 55a and also ISO 7730 compliant. Group mean thermal sensations in Kalgoorlie-Boulder showed a reduced sensitivity to indoor temperature, changing approximately one unit on the ASHRAE scale per 4oC change in operative temperature. There was little difference between the sexes in terms of thermal sensations, although there were significantly more expressions of thermal dissatisfaction from the females. Subjects who expressed a below-average level of job satisfaction on a 15-question index were 50% more likely to express dissatisfaction with their thermal environment than subjects with above-average job satisfaction. The effects of Kalgoorlie-Boulder hot-dry/cold-dry seasonality on thermal comfort responses of office workers was significant, amounting to a 3 oC shift in neutrality and was within the range expected on the basis of the clothing insulation differences of approximately 0.2 clo between seasons. Suggestions for future work include metabolic rate, chair insulation, and clothing perception estimates, and air movement preferences. Recommendations also include specifications for occupant survey questionnaires.

Cena, K. and R. de Dear (1999). Field Study of Occupant Comfort and Office Thermal Environments in a Hot, Arid Climate. ASHRAE Transactions: Research. **105:** 204-217.
Geographical Location: Australia, Kalgoorlie-Boulder
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This paper presents the main findings of ASHRAE research project RP-921, a field study of occupant comfort and office thermal environment in 22 air-conditioned office buildings in Kalgoorlie-Boulder, Western Australia, a location characterized by a hot and arid climate. A total of 935 subjects provided 1,229 sets of data for winter and summer, each accompanied by a full set of indoor climatic measurements with laboratory-grade instrumentation. Clothing insulation estimates for seated subjects (0.5 clo in summer and 0,7 in winter) were supplemented by the incremental effect of chairs (0,15 clo). Thermal neutrality, according to responses on the ASHRAE seven-point sensation scale, occurred at 20.3°C in winter and at 23.3°C in summer. Preferred temperature, defined as a minimum of subjects requesting temperature change, was 22.2 degrees C for both seasons. Nearly 65% of the indoor measurements fell within the ANSI/ASHRAE Standard 55a-1992 summer comfort zone and 85% in the winter. Over 85% of the occupants considered their thermal conditions acceptable. Subjects who expressed a below-average level of job satisfaction on a 15-question index were 50% more likely to express dissatisfaction with their thermal environment than subjects with above-average job satisfaction.

Cena, K. and R. de Dear (2001a). Thermal Comfort and Behavioural Strategies in Office Buildings Located in a Hot-Arid Climate. Thermal Biology. **26:** 409-414.
Geographical Location: Australia, Kalgoorlie-Boulder
Building Type:
Data Type:
Outcome Focus:

Abstract

The effects of indoor climates on thermal perceptions and adaptive behaviour of office workers during a large field study in Kalgoorlie-Boulder, located in a hot-arid region of Western Australia, are discussed. Clothing insulation levels were 0.5 clo in summer and 0.7 in winter. Thermal neutrality, according to responses on the American Society of Heating, Refrigerating and Air-Conditioning Engineers seven-point sensation scale, occurred at 20.31C in winter and at 23.31C in summer. The effect of hot-dry/cool-dry seasonality on thermal comfort responses of office workers was significant. Future research into how the overcooling of office buildings in hot-dry climates can be reduced is called for.

Cena, K. and R. de Dear (2001b). Thermal comfort and behavioural strategies in office buildings located in a hot-arid climate. Journal of Thermal Biology. **26:** pp409-414.
Geographical Location: Australia, Western Australia
Building Type: office
Data Type: questionnaire, interview; quantitative, measurement
Outcome Focus: occupant

Abstract

The effects of indoor climates on thermal perceptions and adaptive behaviour of office workers during a large field study in Kalgoorlie-Boulder, located in a hot-arid region of Western Australia, are discussed. Clothing insulation levels were 0.5 clo in summer and 0.7 in winter. Thermal neutrality, according to responses on the American Society of Heating, Refrigerating and Air-Conditioning Engineers seven-point sensation scale,

occurred at 20.3°C in winter and at 23.3°C in summer. The effect of hot-dry/cool-dry seasonality on thermal comfort responses of office workers was significant. Future research into how the overcooling of office buildings in hot-dry climates can be reduced is called for.

Challenge, G. (1999). Toowoomba Foundry Re-roofing Project.
Geographical Location: Australia, Queensland
Building Type: industrial
Data Type: case study
Outcome Focus: operation, energy; occupant, well-being

Abstract

Toowoomba Foundry has substantially completed the re-roofing of its foundry buildings an area of two hectares - resulting in a 400 per cent increase in the availability of natural light. This equates to a 60 per cent saving in energy consumption, or a reduction of 200 tonnes of CO2 per annum.

Chan, D. W. T., J. Burnett, et al. (1998). A Large-Scale Survey of Thermal Comfort in Office Premises in Hong Kong. ASHRAE Transactions:Symposia. **104:** 1172-1180.
Geographical Location: Hong Kong
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Hong Kong is a densely populated city in which the service sector dominates. The significant outdoor noise pollution and subtropical climate severely restrict the opportunity for office premises to be naturally ventilated. The high energy consumption for space cooling and the demand for improved indoor thermal comfort conditions stimulated a large-scale survey of thermal comfort conditions in Hong Kong office premises. The neutral temperatures and preferred temperatures are found to be lower than those found in other studies in the tropics, with 60% of the surveyed subjects preferring a change of the thermal conditions in summer. The outcome provides for a better notion of thermal comfort, which can be imposed on design criteria. The results also add weight to the concern about the validity in the field of the traditional chamber test data presented by ASHRAE Standard 55-1992. It further suggests the potential for adopting an adaptive control algorithm for thermal comfort.

Chen, A. and E. L. Vine (1999). A Scoping Study on the Costs of Indoor Air Quality Illnesses: An Insurance Loss Reduction Perspective. Environmental Science Policy. **2:** 457-464.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The number of indoor air quality (IAQ)-related health complaints in commercial buildings, and the frequency of litigation over the effects of poor IAQ is increasing. These increases have ramifications for insurance carriers, which pay for many of the costs of health care and general commercial liability. However, little is known about the actual costs to insurance companies from poor IAQ in buildings. This paper reports on the results of a literature search of buildings-related, business and legal databases, and interviews with insurance and risk management representatives aimed at finding information on the direct costs to the insurance industry of poor building IAQ, as well as the costs of litigation. The literature search turned up little

specific cost information, but indicated that there is a strong awareness and growing concern over the "silent crisis" of IAQ and its potential to cause large industry losses. The source of these losses includes both direct costs to insurers from paying health insurance and professional liability claims, as well as the cost of litigation. In spite of the lack of data on how IAQ-related health problems affect their business, the insurance industry has taken the anecdotal evidence about their reality seriously enough to alter their policies in ways that have lessened their exposure.

Cheong, K. W. and K. Y. Chong (2001). Development and Application of an Indoor Air Quality Audit to an Air-Conditioned Building in Singapore. Building and Environment. **36:** 181–188.
Geographical Location: Singapore
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Good indoor air quality (IAQ) enhances occupant health, comfort and workplace productivity. This issue has become more critical in a country like Singapore that has no other natural resources except manpower. In addition, Singapore is located in the tropical region with a hot and humid climate and a large number of the buildings are served by air-conditioning and mechanical ventilation (ACMV) systems to maintain a thermally comfortable indoor environment. The provision of a thermally comfortable indoor environment for the occupants is only one aspect in achieving better indoor air quality. Chemical pollutants, dust particles and microbials are other factors that have impact on the quality of indoor air. Pollutant emissions from people, building materials, air handling units, etc. in the form of both living and dead material take place continuously in any type of buildings, i.e., residential, commercial, industrial, institutional, etc. An IAQ audit methodology developed is adopted to establish the IAQ profile of the building. In this paper, a case-study is used to demonstrate the application of the IAQ audit and evaluate its comprehensiveness and usefulness to the building owners or facility managers. This audit was conducted in the administration offices of a hospital building. The audit consists of examination of the air exchange rate, ventilation effectiveness and age of air. Thermal comfort parameters, microbial counts, dust particles and the concentrations of carbon dioxide (CO2), carbon monoxide (CO), formaldehyde (HCHO) and total volatile organic compounds (TVOC) were also monitored. In addition, a questionnaire was completed by the staff in order to provide a subjective assessment of indoor air quality.

Cheong, K. W. D., E. Djunaedy, et al. (2003). Thermal comfort study of an air-conditioned lecture theatre in the tropics. Building and Environment. **38:** 63-73.
Geographical Location: Singapore
Building Type: university
Data Type: quantitative; qualitative
Outcome Focus: occupant, well-being

Abstract

This paper evaluates the current thermal comfort conditions of an air-conditioned lecture theatre in a tertiary institution using objective measurement, computational fluid dynamics (CFD) modelling and subjective assessment. A CFD tool was used to simulate the indoor comfort parameters, such as temperature, airflow rate and relative humidity. Corroboration between results from the field measurements and predicted values was conducted.

It was found that the measured air temperatures, air velocities and relative humidities

were within the limits of thermal comfort standards, although temperature and relative humidity were located at the extreme of the limits. The predicted results showed good distributions of airflow characteristics and temperature gradients, and these were in fair agreement with empirical measurements. The overall comfort vote, predicted mean vote and predicted percentage dissatisfied indices found the occupants to be slightly uncomfortable and dissatisfied. Additionally, recommendations were made to improve the thermal comfort condition and reduce the build-up of concentration of carbon dioxide in the lecture theatre.

Chiang, C.-M. and C.-M. Lai (2002). A study on the comprehensive indicator of indoor environment assessment for occupants' health in Taiwan. Building and Environment. **37:** 387-392.
Geographical Location: Taiwan
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This paper presents the methodology of developing the comprehensive indicator for indoor-environment assessment. It intends to provide the occupants with the measures of indoor-environment quality. These indicators were drawn up by literature review based on the practicability, economic and feasible aspects. The categories we considered included acoustics, vibrations, illumination, thermal comfort, indoor air quality, water quality, greens and electromagnetic fields. The purpose is to derive the essential indicators through expertise consultation for quantitative assessment on existing buildings. The analytic hierarchy process (AHP) method was used to carry out the weighting among the categories and these indicators in the same category respectively. The consistency ratio was also calculated to filter out the null questionnaire. Finally, a comprehensive index, indoor environment index (IEI(AHP)), composed of the filtered indicators, is proposed to assess the indoor-environment in the built buildings.

Chiang, C.-M. and C.-M. Lai (2002). "A study on the comprehensive indicator of indoor environment assessment for occupants' health in Taiwan." Building and Environment **37**(4): 387-392.

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CIBSE (1999). Environmental factors affecting office worker performance: A summary review of evidence. CIBSE Technical Memoranda. Great Britain, The Chartered Institution of Building Services Engineers. **TM24:1999**.
Geographical Location: various
Building Type: office
Data Type: review
Outcome Focus: occupant, productivity

Abstract

This report aims to present a state-of-the-art review of literature which provides evidence of how the physical environment affects productivity in the workplace, in particular white-collar (knowledge-based) workers in offices. This review is based on published research data rather than anecdotal evidence.
Some of the studies provide convincing evidence to show that environmental factors do affect work performance. In particular, organisational issues affect motivation and in turn performance. Studies of the physical environment show that, although short-term exposure to discomfort can improve the performance of simple tasks, in general optimum conditions for comfort are the most appropriate for performance. Several researchers have estimated that improving physical conditions produces approximately 15% increase in productivity.

Clausen, G., S. Alm, et al. (2002). The Impact of Air Pollution from Used Ventilation Filters on Human Comfort and Health. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe
Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Clements-Croome, D. (2000a). Indoor Environment and Productivity. Creating the Productive Workplace. D. Clements-Croome. London, E & FN Spon**:** 3-17.
Geographical Location: UK, England
Building Type: Office
Data Type: theory
Outcome Focus: occupant, productivity

Abstract

In the journal of the British Council for Offices entitled Office (Summer 1997) it is reckoned that 'advanced building intelligence' should increase the productivity of occupants by 10 per cent annually as well as improving efficiency to satisfy owner occupiers. In contrast, 'standard intelligence' can improve efficiency by 8 per cent annually and improve efficiency which results in a payback within two to four years. The argument is that in an intelligent building there is less illness and absenteeism. Intelligent buildings do not mean that masses of technology are necessary. Simple adaptable building forms combined with appropriately specified building services and technologies should result in a high-quality business value intelligent building. Three

major UK studies were carried out in 1997-98 on productivity: by SBS Business Solutions and the Building Research Establishment; by the Post Office Property Holdings Policy Planning and Development Group; and by the University of Reading in conjunction with several industrial partners.

Clements-Croome, D. J. (2000b). Influence of social organisation and environmental factors and well-being in the office workplace. CLIMA 2000. Naples.
Geographical Location: UK, England
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Commission, N. O. H. S. Comfort at work - too hot? Too cold?, Commonwealth of Australia.
Geographical Location: Australia
Building Type: office, commercial, industrial
Data Type: information
Outcome Focus: occupant, well-being

Abstract

Comfort at work is an important issue whether you work in an office or factory. The best temperature for the workplace is the temperature most people find comfortable without particularly discomforting the few people who have unusual temperature preferences. In office environments the best temperature is around 23°C and it is common for air conditioning systems to be in the range 20°C to 26 °C. However, even this best temperature satisfies only 75-80% of people as personal preferences vary according to the clothing you wear and the work you are doing.

Comnes, L. (2002). Is School Making Your Students Sick? Clearing. **111:** 10-14.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Reviews environmental hazards within schools. Identifies indoor air pollution, asbestos, lead poisoning, and pesticides as the leading hazards. Forms of indoor air pollution include radon carbon dioxide, carbon monoxide, volatile organic compounds, and various allergens such as mould and animal dander. Presents some guiding principles for the environmental quality of schools along with curriculum and assessment resources. (DLH)

Cooper, C. L. (1985). The stress of work: an overview. Aviation, Space and Environment Medicine**:** 627-632.
Geographical Location: Europe, UK
Building Type: Commercial, industrial
general
Data Type: literature review
Outcome Focus: occupant, well-being
occupant, health

Abstract

This paper looks at a number of potential occupational stressors found to predict job dissatisfaction and ill health (both mental and physical) in a variety of different occupational settings. Factors intrinsic to the nature of the job, role ambiguity and

conflict, poor relationships at work, lack of career development, inadequate organisation structure/climate, and problems associated with the interface between work and home life are the focal points of attention. Many of these sources of occupational stress are prevalent in the field of aviation, and may be exacerbated by the move toward deregulation and increasing commercial competition within the industry.

Cooper, B. A., S. Ahrentzen, et al. (1991). Post-occupancy evaluation: an environment-behaviour technique for assessing the built environment. Canadian Journal of Occupational Therapy. Revue Canadienne d'Ergotherapie. **58:** 181-188.
Geographical Location: Canada
Building Type: domestic, hospitals
Data Type: case studies
Outcome Focus: occupants, well-being

Abstract

This paper reviews the development, structure and process of post-occupancy evaluation (POE) as an environment-behaviour approach to assessing built environments of all sizes and types. It illustrates the use of POEs with three examples from the Health Care sector: The Canadian Hospital Evaluation Program, the Weiss Institute, and 18 independent-living apartment units. A comparison is made between POEs and the approach currently used by occupational therapy (OT) for environmental assessments. Recommendations suggest that OT's approach could be extended and strengthened through 1) incorporating POE methods and existing data from environment-behaviour studies; 2) the use of standard assessment procedures and well-validated measures; and 3) the development of a data bank on OT environmental assessments. [Journal Article; In English; Canada]

Cowling, I., S. Coyne, et al. (1990). Light in Brisbane Office Buildings - A Survey. School of Physical Sciences, QUT.
Geographical Location: Australia
Building Type: office
Data Type: survey
Outcome Focus: occupant

Abstract

Cox, T., M. Thirlaway, et al. (1983). The nature and assessment of general well-being. Journal of Psychosomatic Research. **27:** 353-359.
Geographical Location: Europe, UK
Building Type: office
Data Type: Qualitative, questionnaire, on-site
Outcome Focus: occupant, well-being

Abstract

Data on self-reported symptoms of ill-health were collected from 1500 respondents, and factor analysed. The results of this analysis suggested a two factor orthogonal model of well-being: one factor refecting fatigue, emotional fragility and confusion (worn-out) and the other tension, anxiety and agitation (up-tight), The reliability and validity of the model were tested and appeared acceptable, and scales were constructed for the assessment of the two factors. It is suggested that the model and the associated scales could offer new information in studies of occupational stress and health

Cox, T. (1985). The nature and management of stress. Ergonomics. **28:** 1155-1163.
Geographical Location: Europe, UK
Building Type: note: the paper speaks of working places therefore the following are included, although the study is not specific on:
office
commercial
Data Type: literature review, measurement of stress
Outcome Focus: occupant, health
occupant, well-being
occupant, response

Abstract

This paper considers why asking what physiological measures of stress there are, is not a sensible question. In doing so, it examines the nature of stress as described by contemporary theories and explores their implications for measurement. It concludes that there cannot be direct physiological measures of stress, only physiological correlates. The measurement of stress must focus on the individual's psychological state, as related to their perception of the environment and emotional reaction to it (mood) In discussing the question of measurement, the paper introduces the issues of reliability, validity and fairness, and emphasizes that they should be raised in relation to all types of measure, not just those that are subjective.

Cox, T. and E. Ferguson (1994). Measures of the Subjective Work Environment. Work and Stress. **8:** 98-109.
Geographical Location: Europe, UK
Building Type: Note: the paper relates to work environment in general, therefore it is inferred that the following are included: commercial; office
Data Type: literature review
review of measurement and study models, research methodology
Outcome Focus: occupant, health
occupant, productivity
(performance)

Abstract

This paper considers the various issues that frame the development and use of measures of the subjective work environment. it begins by questioning the role of the work environment in determining occupational health, and explores the possible mechanisms by which that environment might exert it influence. It concludes that one of the important final common pathways is psycho-physiological in nature and is rooted in individual perception and cognition and the experience of stress. Important for this model are the concepts of mediation and moderation. The measurement of the subjective work environment has often been idiosyncratic to the study in hand, and there are few well-established measures in common use. It is argued that researchers should be careful when deciding not to use established measures and effectively 'invent' their own. In developing new measures, decisions have to be made concerning the nature of the measure along with its 'granularity' and complexity. It is also argued that it is important that researchers should follow good phsychometric practice in the development of those measures. Suggestions for 'good practice' are discussed. Attention is drawn to the issues of reliability and validity, and this paper discusses the role of triangulation in the planning and execution of data collection and analysis. The paper ends by reviewing the recommendations made towards the development and use of measures of the subjective work environment.

Crouch, A. and U. Nimran (1989). Perceived Facilitators and Inhibitors of Work Performance in an Office Environment. Environment and Behavior. **21:** 206-226.
Geographical Location: Australia, Melbourne
Building Type: office . Closed office. Open plan office
Data Type: qualitative, survey, questionnaire, off-site
Outcome Focus: occupants, productivity

Abstract

A descriptive model is presented that identifies characteristics of office surroundings that senior managers believe facilitate an inhibit their work performance. Data for the presented study were obtained from a survey of 65 managers asked to name three inhibitory and three facilitative features of their offices.

Cuijpers, C. E., G. M. Swaen, et al. (1995). Adverse Effects of the Indoor Environment on Respiratory Health in Primary School Children. Environmental Research. **68:** 11-23.
Geographical Location: Europe, Netherlands
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

Exposure to various factors from the indoor environment on respiratory health of 470 Dutch primary school children was studied. We investigated which of the factors, such as home dampness, passive smoking, unvented kitchen geysers, or pets, affected children's respiratory health the most, and whether airway sensitivity to these indoors exposures differed between boys and girls. Information on respiratory morbidity and characteristics of the housing was obtained by a written questionnaire, completed by the parents of the children. Lung function of the children was measured at school, by forced oscillation technique (FOT) and spirometry. In boys, all investigated lung function parameters were significantly affected by exposure to passive smoking during the child's entire life. Although mostly non-significant, all of the reported asthma-like symptoms were related especially to maternal smoking, with a trend of a dose-response relationship. Furthermore, damp stains ($P < 0.05$) and mould growth (ns) were associated with chronic cough and with small but significant impairments in part of the lung function parameters. No consistent patterns were observed with unvented kitchen geysers and pets. Although passive smoking (cumulative dose) in girls was also associated with lung function impairments, the effects were smaller than those in boys and not all significant. Associations between the asthma-like symptoms and the dose of maternal and paternal smoking also were less consistent. Furthermore, no associations were found with the dampness indicators and with pets, but unvented kitchen geysers were significantly related to impairments in some of the impedance indices. This study shows detrimental effects of several indoor factors on the prevalence of chronic respiratory symptoms and lung function in children, which are most pronounced for passive smoking, and somewhat less pronounced for dampness and the presence of unvented kitchen geysers. Airway sensitivity to these exposures appeared to be higher in boys than in girls.

Cullen, S. (2002). Clearing the air: Your office may be hazardous to your health. Office Solutions. **19:** 18.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Indoor air pollution is estimated to be two to five times worse than outdoor air

pollution. One does not have to look far to find potential sources of toxic pollutants in an office. According to research, rarely is a single pollutant present in unhealthy amounts within a sick building. Rather, it is an array of pollutants circulating through an office, which cumulatively produce a volatile mixture. Among the most notorious pollutants are: 1. biological agents, 2. carbon monoxide, 3. formaldehyde, 4. secondhand smoke, and 5. volatile organic compounds. Cost-effective solutions for clearing the air include: 1. eliminate tobacco smoke, 2. provide adequate ventilation, 3. maintain the ventilation system, and 4. remove sources of pollution.

Czubaj, C. A. (2002). School Indoor Air Quality. Journal of Instructional Psychology. **29:** 317–321.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Indoor air quality is affected by emittance of various sources and air movement dynamics. Indoor air pollutants can be natural and anthropogenic materials. Indoor sources of these pollutants are small pools of water in the heating/ventilation/air/ conditioning system. Outdoor pollutants are also brought indoors via the ventilation system. The pollutants are believed to be contributing to the high number of students suffering from asthma. An effective air quality program begins with a "Principles of Conduct." The ventilation system is then evaluated for efficiency. Activities, such as carpet care, must be performed routinely and with appropriate equipment. The Environmental Protection Agency offers seven suggestions to improve indoor air quality. The "green school" design eliminated air pollutants. The Environmental Protection Agency is conducting a study in an attempt to establish indoor air quality standards.

Daft, R. L. (1999). Leadership: Theory and Practice. Fort Worth, Texas, The Dryden Press.
Geographical Location: not applicable
Building Type: not applicable
Data Type: theory
Outcome Focus:

Abstract

Daisey, J. M. and W. J. Angell (1998). A Survey and Critical Review of the Literature on Indoor Air Quality, Ventilation and Health Symptoms in Schools, IEQ Strategies. Washington, D.C; Sacramento, California, Department of Energy
California State Environmental Protection Agency.
Geographical Location: USA
Building Type: School
Data Type: literature review
Outcome Focus: occupant, health

Abstract

A survey and critical review were undertaken of existing published literature and reports on indoor air quality (IAQ), ventilation, and IAQ- and building-related health problems in schools, including California schools. Over 450 relevant publications were obtained and reviewed. Including papers published in the archival peer-reviewed scientific literature, proceedings of scientific meetings, government reports, 77 NIOSH Health Hazard Evaluation Reports (HHER) and 70 reports on investigations of problem schools in California; Most of the reviewed literature was for complaint or problem schools. The types of health symptoms reported in schools

were very similar those defined as "sick building syndrome" (SBS) symptoms, although this may be due, at least in part, to the type of health symptom questionnaires used. Some of the symptoms, e.g., wheezing, are indicative of asthma. In the studies in which complaint and non-complaint buildings or areas were compared, complaint buildings generally had higher rates of health symptoms. Formaldehyde, total VOCs, CO and microbiological pollutants were the most commonly measured air pollutants in schools. Most of the formaldehyde measurements made in the U.S. were made in complaint schools but were generally below 0.05 ppm. Measurements of other pollutants were too limited to make conclusions as to the prevalence of indoor concentrations above levels of concern, even in problem schools. However, there is some evidence indicating that microbiological pollutants may be of particular concern. The few scientific studies on causes of symptoms in complaint schools indicate that exposures to moulds and to allergens in schools contribute to asthma. SBS and other respiratory symptoms. Other indoor air pollutants, such as VOCs, aldehydes, etc., have been investigated to only a very limited extent, although there are reasons to suspect they may also contribute to health symptom prevalences in schools. The major building-related problem identified was "inadequate ventilation with outside air." Several lines of evidence indicate that inadequate ventilation with outside air is a fairly common problem in schools in general, including those in California. However, "inadequate ventilation" can only be considered an indicator, not the causal agent(s) for health symptoms reported in problem schools. Water damage to the building shells of schools, leading in turn to mould contamination and growth, was the second most frequently reported building-related problem. The root causes of many of the ventilation and water-damage problems in the schools was inadequate' and/or deferred maintenance of school buildings and HV AC systems. However, in most studies, neither the building and ventilation systems problems nor specific pollutants have been clearly and unambiguously demonstrated to be causally related to the symptoms. Although there is now considerable qualitative information on health complaints, ventilation and IAQ problems in complaint schools, we do not know what fraction of schools is experiencing IAQ and ventilation problems, and related health symptoms. There is also a lack of scientifically rigorous and quantitative information on the causal relationships between health symptoms, exposure, and dose response relationships that are needed to establish health standards for the protection of children in schools. Finally, the effectiveness and the costs and benefits of various remedial actions, undertaken to solve problems in specific schools, remain largely unknown. Recommendations to address these issues are made in this report.

Daisey, J. M., W. J. Angell, et al. (2003). Indoor air quality, ventilation and health symptoms in schools: an analysis of existing information. Indoor air. **13:** 53-64.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

We reviewed the literature on Indoor Air Quality (IAQ), ventilation, and building-related health problems in schools and identified commonly reported building-related health symptoms involving schools until 1999. We collected existing data on ventilation rates, carbon dioxide (CO2) concentrations and symptom-relevant indoor air contaminants, and evaluated information on causal relationships between pollutant exposures and health symptoms. Reported ventilation and CO2 data strongly indicate that ventilation is inadequate in many classrooms, possibly leading to health symptoms. Adequate ventilation should be a major focus of design or remediation efforts. Total volatile organic compounds, formaldehyde (HCHO) and microbiological contaminants are reported. Low HCHO concentrations were unlikely

to cause acute irritant symptoms (<0.05 ppm), but possibly increased risks for allergen sensitivities, chronic irritation, and cancer. Reported microbiological contaminants included allergens in deposited dust, fungi, and bacteria. Levels of specific allergens were sufficient to cause symptoms in allergic occupants. Measurements of airborne bacteria and airborne and surface fungal spores were reported in schoolrooms. Asthma and 'sick building syndrome' symptoms are commonly reported. The few studies investigating causal relationships between health symptoms and exposures to specific pollutants suggest that such symptoms in schools are related to exposures to volatile organic compounds (VOCs), molds and microbial VOCs, and allergens.

Darmawan, A. (2001). DRESS SENSE: Controlling and Adapting to Thermal Environment in the Intelligent Building Era.1 Based on an Observational Study of User Thermal Acceptance and Response in the Library of the University of New South Wales.
Geographical Location: Australia
Building Type: library
Data Type: survey; case study
Outcome Focus: occupant, response

Abstract

Clothing is the most prevalent and convenient way to respond to a certain activity and thermal condition. It is the traditional strategy of individually controlling thermal comfort. Unlike opening windows, which means changing the environment, and other natural behaviour which responds to thermal conditions, such as shivering and sweating, dressing sensibly is a way of providing suitable thermal resistance in order to reach individual thermal comfort.

de Dear, R. J. and G. S. Brager Developing an Adaptive Model of Thermal Comfort and Preference. ASHRAE. **RP-884**.
Geographical Location: various
Building Type: office
Data Type: questionnaire, on-site, measurements, on-site
Outcome Focus: occupant, well-being

Abstract

The adaptive hypothesis predicts that contextual factors and past thermal history modify buildings occupants' thermal expectations and preferences. One of the predictions of the adaptive hypothesis is that people in warm climate zones prefer warmer indoor temperatures than people living in cold climate zones. This is contrary to the static assumption underlying the current ASHRAE comfort standard 55-92. To examine the adaptive hypothesis and its implications for Standard 55-92, the ASHRAE RP-884 project assembled a quality-controlled database from thermal comfort field experiments worldwide (circa 21000 observations from 160 buildings). Our statistical analysis examined the semantics of thermal comfort in terms of thermal sensation, acceptability, and preference, as a function of both indoor and outdoor temperature. Optimum indoor temperatures tracked both prevailing indoor and outdoor temperatures, as predicted by the adaptive hypothesis. The static predicted mean vote (PMV) model was shown to be partially adaptive by accounting for behavioural adjustments, and fully explained adaptation occurring in HVAC buildings. Occupants in naturally ventilated buildings were tolerant of a significantly wider range of temperatures, explained by a combination of both behavioural adjustments and psychological adaptation. These results formed the basis of a proposal for a variable indoor temperature standard.

de Dear, R. and M. E. Fountain (1994). Field Study of Occupant Comfort and Office Thermal Environments in a Hot-Humid Climate. **2:** 457-475.
Geographical Location: Australia
Building Type: office
Data Type: measurements, on-site
Outcome Focus: operation, environment; occupant, comfort

Abstract

This paper presents the main findings of ASHRAE research project RP-702, a field investigation of indoor climates and occupant comfort in 12 air-conditioned office buildings in Townsville, located in Australia's tropical north.

de Dear, R. and M. E. Fountain (1995). Field Experiments on Occupant Comfort and Office Thermal Environments in a Hot-Humid Climate. ASHRAE Transactions: Research.
Geographical Location: Australia, Townsville
Building Type: Office
Data Type: questionnaire
Outcome Focus: occupant, comfort

Abstract

This paper presents the main findings of ASHRAE research project RP-702, a field investigation of indoor climates and occupant comfort in 12 air-conditioned office buildings in Townsville, located in Australia's tropical north. The project replicates an earlier ASHRAE investigation in San Francisco (RP-462). A total of 836 subjects provided 1,234 sets of questionnaire responses, each accompanied by a full set of physical indoor climatic measurements from laboratory-grade instrumentation. Clothing insulation estimates for seated subjects included the incremental effect of chairs. Thermal environmental results are compared with ASHRAE Standard 55-1992 prescriptions. Thermal neutrality, preference, and acceptability results are compared with laboratory-based models and standards. Gender and seasonal effects were minor, and many of the differences from the earlier San Francisco data were explicable in terms of clothing patterns. Most of the thermal dissatisfaction expressed within the Standard 55 comfort zone was associated with requests for higher air velocity.

de Dear, R., G. Brager, et al. (1997). Developing an Adaptive Model of Thermal Comfort and Preference. Final Report ASHRAE RP-884, Macquarie Research Ltd, Macquarie University, Sydney.
Geographical Location: USA, UK, Europe, Australia, Asia
Building Type: Office
Data Type:
Outcome Focus:

Abstract

One of the more contentious theoretical issues in the applied research area of thermal comfort has been the dialectic between “adaptive” and “static” models. Apart from having disparate methodological bases (the former laboratory-experimental, the latter field-based), the two approaches have yielded starkly differing prescriptions for how the indoor climate of buildings should be managed. These prescriptions carry implications for the types of permissible building designs, the means by which their thermal environments are controlled, and the amounts of energy they consume in the production of habitable indoor climates. Static models have led to indoor climate standards that have been universally applied across all building types, are characterised by minimal recognition of outdoor climatic context, and are contributing to an increased reliance on mechanical cooling. In contrast, proponents of adaptive models have advocated variable indoor temperature standards that more fully

exercise the adaptive capabilities of building occupants. This approach potentially leads to more responsive environmental control algorithms, enhanced levels of occupant comfort, reduced energy consumption, and the encouragement of climatically responsive building design.

de Dear, R. (1998). A Global Database of Thermal Comfort Field Experiments. ASHRAE Transactions. **104:** 1141-1152.
Geographical Location: USA, UK, Australia, Europe, Asia
Building Type: Office
Data Type: questionnaire; measurements
Outcome Focus: occupant, comfort

Abstract

ASHRAE Research Project 884 on adaptive thermal comfort required a large database of field observations. Approximately 21,000 sets of raw thermal comfort data were collected from research groups around the world for this purpose. They included thermal comfort questionnaire responses plus coincident indoor and outdoor climatic observations. Before assimilation into the database, raw data were subjected to various "cleaning" and standardization processes. Clo values were converted to their ASHRAE Standard 55 equivalents, and thermal comfort indices were recalculated using ASHRAE-sponsored software. The database has numerous potential applications extending well beyond the initial scope of adaptive thermal comfort modelling, including empirical thermal index development and field validation of laboratory-based comfort models and standards. The database has been put in the public domain and is readily available in a variety of formats via a site on the World Wide Web. This paper describes the background and content of the database and serves as a manual for its end-users.

de Dear, R. and G. Brager (1998). Developing an Adaptive Model of Thermal Comfort and Preference / Discussion. ASHRAE Transactions: Research. **104:** 145-167.
Geographical Location: USA, UK, Europe, Australia, Asia
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The adaptive hypothesis predicts that contextual factors and past thermal history modify building occupants' thermal expectations and preferences. One of the predictions of the adaptive hypothesis is that people in warm climate zones prefer warmer indoor temperatures than people living in cold climate zones. This is contrary to the static assumptions underlying the current ASHRAE comfort standard 55-92. To examine the adaptive hypothesis and its implications for Standard 55-92, the ASHRAE RP-884 project assembled a quality controlled database from thermal comfort field experiments worldwide (circa 21.000 observations from 160 buildings). Our statistical analysis examined the semantics of thermal comfort in terms of thermal sensation, acceptability, and preference, as a function of both indoor and outdoor temperature. Optimum indoor temperatures tracked both prevailing indoor and outdoor temperatures, as predicted by the adaptive hypothesis. The static predicted mean vote (PMV) model was shown to be partially adaptive by accounting for behavioural adjustments, and fully explained adaptation occurring in HVAC buildings. Occupants in naturally ventilated buildings were tolerant of a significantly wider range of temperatures, explained by a combination of both behavioural adjustment and psychological adaptation. These results formed the basis of a proposal for a variable indoor temperature standard.

de Dear, R. (1999). Adaptive Thermal Comfort in Natural and Hybrid Ventilation. HybVent Forum '99. Sydney, Australia**:** 1-10.
Geographical Location: Australia
Building Type: Office
Data Type: literature survey
Outcome Focus: occupant, comfort

Abstract

Current thermal comfort standards and the models underpinning them purport to be equally applicable across all types of buildings, ventilation systems, occupancy patterns, and climate zones. A recent ASHRAE-sponsored research project (RP-884) critically evaluated this by statistically analysing a large thermal comfort field research database from 160 buildings scattered all over the would (n=22,000). The results suggest several significant changes for the next revision of ASHRAE's comfort standard (ASHRAE Std 55), particularly as they relate to buildings with natural and hybrid ventilation systems.

de Dear, R. and G. S. Brager (2002). Thermal comfort in naturally ventilated buildings: revisions to ASHRAE Standard 55. Energy and Buildings. **34:** 549-561.
Geographical Location: various
Building Type: building
Data Type: quantitative; measurements, on-site
Outcome Focus: occupant, well-being

Abstract

Recently accepted revisions to ASHRAE Standard 55—thermal environmental conditions for human occupancy, include a new adaptive comfort standard (ACS) that allows warmer indoor temperatures for naturally ventilated buildings during summer and in warmer climate zones. The ACS is based on the analysis of 21,000 sets of raw data compiled from field studies in 160 buildings located on four continents in varied climatic zones. This paper summarizes this earlier adaptive comfort research, presents some of its findings for naturally ventilated buildings, and discusses the process of getting the ACS incorporated into Standard 55. We suggest ways the ACS could be used for the design, operation, or evaluation of buildings, and for research applications. We also use GIS mapping techniques to examine the energy-savings potential of the ACS on a regional scale across the US. Finally, we discuss related new directions for researchers and practitioners involved in the design of buildings and their environmental control systems.

Department of Health and Aged Care (2000). Indoor Air Quality: A Report on Health Impacts and Management Options. Canberra, Australia, Department of Health and Aged Care, Commonwealth of Australia.
Geographical Location: Australia
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The Greater part of people's lives is spent indoors. Consequently, most of the air people breathe is from the indoor environment. While much focus has been placed on outdoor air quality and pollution measurements and management, the air we are exposed to indoors has a greater potential to have more impact on our health.
This report was commissioned to describe the state of knowledge about indoor air and the potential for adverse health impacts as well as indicating potential mitigation/remediation strategies. The authors include independent practicing experts from a broad range of backgrounds involved with the scientific and administrative

aspects of indoor air quality. The report is intended to stimulate informed debate and raise issues on which to base future policy directions and decisions.

Dickens, K. V. (2003). IAQ in DC. Engineered Systems. **20:** 38.
Geographical Location: USA, Washington D.C.
Building Type: School
Data Type:
Outcome Focus:

Abstract

Focuses on the design of school buildings in Washington D.C. Importance of school environments on the performance of students and teachers; Call of the U.S. Senate Environment and Public Works Committee for environmental standards for green schools; Ability of school officials to improve indoor air quality.

Djukanovic, R., P. Wargocki, et al. (2002). Cost Benefit Analysis of Improved Air Quality in an Office Building. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA, Miami, Chicago, Canada, Winnipeg
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A cost-benefit analysis of measures to improve air quality in an existing air-conditioned office building (11581 m2, 864 employees) was carried out for hot, temperate and cold climates and for two operating modes: Variable Air Volume (VAV) with economizer; and Constant Air Volume (CAV) with heat recovery. The annual energy cost and first cost of the HVAC system were calculated using DOE 2.1E for different levels of air quality (10-50% dissatisfied). This was achieved by changing the outdoor air supply rate and the pollution loads. Previous studies have documented a 1.1% increase in office productivity for every 10% reduction in the proportion of occupants entering a space who are dissatisfied with the air quality. With this assumption, the annual benefit due to improved air quality was always at least 10 times higher than the increase in annual energy and maintenance costs. The payback time of the HVAC first costs involved in improving the air quality was always less than 4 months.

Donnini, G. (1997). Field Study of Occupant Comfort and Office Thermal Environments in a Cold Climate. ASHRAE Transactions: Research. **103:** 205-220.
Geographical Location: Canada, Quebec
Building Type: Office
Data Type: measurements, on-site; survey
Outcome Focus: occupant, comfort

Abstract

This paper presents the findings of ASHRAE research project RP-821, a field study of occupant comfort and office thermal environments in 12 mechanically ventilated office buildings in southern Quebec. A total of 877 subjects were surveyed during hot and cold months. Each interview provided a set of responses to a questionnaire and a set of physical indoor climatic measurements. The incremental effect of chairs was included in the estimates of clo values. The observed temperature optima were somewhat consistent with the predictions of comfort models and standards based on mid-latitude climate chamber experimental data. The Montreal subjects' thermal sensation and acceptability ratings were much less accepting of non-neutral temperatures than either the PPD index or ANSI/ASHRAE Standard 55 predicted.

There was a consistent request for higher air velocity, indicating that air movement guidelines may be too restrictive as set out by ANSI/ASHRAE Standard 55 and ISO 7730. Job satisfaction, general health status, and perceived levels of personal control were moderately correlated with overall generalized assessments of the workplace physical environment. Lighting levels and exposure to humidifiers outside the workplace had some relationship to specific environmental conditions occurring at the time of the interviews. There was little difference between the sexes in terms of thermal sensation, although there were significantly more frequent expressions of thermal dissatisfaction from the females in the sample, despite their thermal environment being no different from that of the males.

Donnini, G., J. Molina, et al. (1997). Field study of occupant comfort and office thermal environments in a cold climate. ASHRAE. **RP-821:** 205-220.
Geographical Location: Canada, Quebec
Building Type: office
Data Type: questionnaire, on-site; measurements, on-site
Outcome Focus: occupant, comfort

Abstract

This paper presents the findings of ASHRAE research project RP-821, a field study of occupant comfort and office thermal environments in 12 mechanically ventilated office buildings in southern Quebec. A total of 877 subjects were surveyed during hot and cold months. Each interview provided a set of responses to a questionnaire and a set of physical indoor climatic measurements. The incremental effect of chairs was included in the estimates of clo values. The observed temperature optima were somewhat consistent with the predictions of comfort models and standards based on mid-latitude climate chamber experimental data.

The Montreal subjects' thermal sensation and acceptability ratings were much less accepting of non-neutral temperatures than either the PPD index or ANSI/ASHRAE Standard 55 predicted. There was a consistent request for higher air velocity, indicating that air movement guidelines may be too restrictive as set out by ANSI/ASHRAE Standard 55 and ISO 7730. Job satisfaction, general health status, and perceived levels of personal control were moderately correlated with overall generalised assessments of the workplace physical environment. Lighting levels and exposure to humidifiers outside the workplace had some relationship to specific environmental conditions occurring at the time of the interviews. There was little difference between the sexes in terms of thermal sensation, although there were significantly more frequent expressions of thermal dissatisfaction from the females in the sample, despite their thermal environment being no different from that of the males.

Dorgan, C. B., C. E. Dorgon, et al. (1998). Health and Productivity Benefits of Improved Indoor Air Quality. ASHRAE Transactions. **104:** 658–666.
Geographical Location: USA, Europe
Building Type: Office, School
Data Type: review
Outcome Focus: occupant, productivity

Abstract

This paper is a summary of two studies completed for a national contractor's association on the health costs and productivity benefits of improved IAQ. The original study documented the general health costs and productivity benefits of improved IAQ. The second study expanded the scope to include medical cost reductions for specific illnesses from improved IAQ. General information on the objectives, assumptions. definitions, and results of the studies are presented, followed by detailed information on research methodology, building inventory and

wellness categories, health and medical effects of poor IAQ, health cost benefits, productivity benefits, recommended improvements, and conclusions and future improvements.

Dorgan, C., S. O. Hanssen, et al. (2000). Evaluation of association between indoor air climate, well-being and productivity. Healthy Buildings 2000 Workshop Summaries. O. Seppanen, M. Tuomainen and J. Sateri. Espoo, Finland**:** 49–52.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Duvall-Early, K. and J. O. Benedict (1992). The relationship between privacy and different components of job satisfaction. Environment and Behavior. **24:** 670-679.
Geographical Location: USA
Building Type: Office
Data Type: Qualitative, survey, questionnaire, on-site
Outcome Focus: occupants, well-being

Abstract

The level of workplace architectural privacy has previously been found to relate to overall job satisfaction. It was hypothesized that because privacy may serve particular functions, only particular facets of job satisfaction will be related to it, both in the short term (less than 1 year). One hundred thirty professional secretaries assessed their level of privacy and their level of job satisfaction as measured by the Minnesota Satisfaction Questionnaire. The results supported the hypotheses and showed that the environment in which one works affects some but not all facets of job satisfaction.

Ebbehoj, N. E., M. O. Hansen, et al. (2002). Building-Related Symptoms and Moulds: A Two-Step Intervention Study. Indoor Air. **12:** 273-277.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Abstract Aims: To evaluate the relation between mould growth and symptoms in an intervention study design. Methods: The building was examined by a walk-through and microbiological testing from surfaces and ventilation canals before and after each of two steps of the renovation. The examination program for the 25 employees comprised questionnaire, clinical examination,2-w eek peak-flow monitoring, and blood samples, and in six persons also a bronchial challenge. Results: Initially the building had severe moisture problems with growth of Trichoderma and Phoma as dominating microfungi. The total number of symptoms from a nine-item building-related symptom score was 66%,peak-flow variability was 20%. After the first renovation, no visible mould growth was seen, but samples showed that the building was still contaminated. Symptoms decreased to 33%. After further cleaning the mould levels decreased on surfaces, and the number of symptoms decreased to 4%. Mean peak-flow variability fell to 15%. Discussion: In a poorly maintained building with moisture problems and mould growth, the staff had a number of irritative and general symptoms. The first renovation eradicated most visible signs of moulds and gave a decreased number of symptoms. The second renovation sufficiently cleaned the building, and the rate of symptoms and peak-flow variability fell to normal levels. A thorough cleaning after renovation seems necessary for the eradication of

symptoms.

Education Queensland (2001). Education Queensland Statistics.
Geographical Location: Australia, Queensland
Building Type: school
Data Type: survey
Outcome Focus: occupant, response; occupant, well-being

Abstract
Table of data

Education Queensland Survey (1999). HOW SATISFIED ARE SCHOOL STAFF WITH STATE SCHOOLS AS A WORKPLACE?, Education Queensland.
Geographical Location: Queensland
Building Type: Schools
Data Type: Survey
Outcome Focus: Occupant, satisfaction

Abstract

Edwards, B. (1999). Sustainable Architecture, European Building Design. UK, Reed Educational and Professional Publishing Ltd.
Geographical Location: Europe
Building Type: various
Data Type: case study
Outcome Focus: operation

Abstract

Edwards, L. and P. Torcellini (2002). A Literature Review of the Effects of Natural light on Building Occupants. NREL Technical Report, NREL**:** 58.
Geographical Location: various
Building Type: office, school
Data Type: literature review
Outcome Focus: occupant, well-being

Abstract
This paper presents summary information from a non-critical literature review on daylighting in buildings. It is by no means exhaustive, and no attempt has been made to determine the scientific nature of the studies that are cited. It was the goal of this document to compile a listing of the literature that is commonly cited for showing the impacts of daylighting in buildings. NREL does not endorse any of the findings as the citations have not been critically reviewed.

Eley Associates (2001). High Performance Schools Best Practices Manual, Volume 1 Planning. San Francisco, Eley Associates. **1**.
Geographical Location: California
Building Type: Schools
Data Type: survey, measurements, on-site
Outcome Focus: occupant, comfort
occupant, productivity
performance, energy

Abstract
This is a unique period in California history. The state, already educating 1 out of every 8 students in America, has seen historical enrolment rates four times higher

than national averages. Hundreds of schools a year are being built to house the 100,000 new students per year moving into the system and to accommodate state-mandated class-size reductions. The current infrastructure is aging and over 30% of existing facilities are in need of major renovation. At the same time, California schools are spending nearly $450 million per year on energy1 in a time of rising concern over energy supplies and tight school budgets. These figures illustrate an enormous opportunity for our state's school districts to build the next generation of school facilities that improve the learning environment while saving energy, resources, and money.

The goal of this Best Practices Manual is to create a new generation of high performance school facilities in California. The focus is on public schools and levels K-12, although many of the design principals apply to private schools and higher education facilities as well. High performance schools are healthy, comfortable, energy efficient, resource efficient, water efficient, safe, secure, adaptable, and easy to operate and maintain. They help school districts achieve higher test scores, retain quality teachers and staff, reduce operating cost, increase average daily attendance (ADA), reduce liability, while at the same time being friendly to the environment.

Engelhart, S., H. Burghardt, et al. (1999). Sick Building Syndrome in an Office Building Formerly Used by a Pharmaceutical Company: A Case Study. Indoor Air. **9:** 139-143.
Geographical Location: Europe, Germany, Bonn
Building Type: Office
Data Type:
Outcome Focus:

Abstract

In the past two decades, a group of health problems related to the indoor environment -generally termed sick building syndrome (SBS) -has emerged. We present an investigation of SBS in employees of a ministry working in a naturally ventilated office building that formerly had been used by a pharmaceutical company. A preceding environmental monitoring had failed to identify the cause(s) for the complaints. We conducted a questionnaire-based investigation and categorized the building sections and rooms according to their renovation status and their former use, respectively. The highest level of complaints was found among the employees working in rooms that in the past had been used for the production or storage of various pharmaceutical products suggesting that pharmaceutical odors may be a risk factor for SBS. Clinical laboratory tests did not show any unusual results. We concluded that the former use of a building for production and storage of pharmaceutical products should be considered as a possible risk factor for complaints about indoor air quality, e.g., when advising about or planning for renovations of buildings formerly used for production, handling, or storing of chemicals.

Environment Management Industry Association of Australia (1998). Cleaner Production - Lighting Improvements Increase Staff Productivity - NCI Plastics (Australia) Pty Ltd. Eco-Efficiency and Cleaner Production Case Studies. Victoria, Australia, Environment Australia.
Geographical Location: Australia, Victoria
Building Type: Factory
Data Type: Case Study
Outcome Focus: occupant, productivity; operation, energy

Abstract

NCI Plastics, an injection moulding company based in Victoria, improved factory lighting, resulting in greater productivity, and making workers feel better about their surroundings. An added benefit was reduced energy costs.

EPA-402-F-94-003 (1990). Fact Sheet: Ventilation and Air Quality in Offices. **Office of Air and Radiation**.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Millions of Americans work in buildings with mechanical heating, ventilation, and air conditioning (HVAC) systems; these systems are designed to provide air at comfortable temperature and humidity levels, free of harmful concentrations of air pollutants. While heating and air-conditioning are relatively straightforward operations, the more complex processes involved in ventilation are the most important in determining the quality of our indoor air .

While many of us tend to think of ventilation as either air movement within a building or the introduction of outdoor air, ventilation is actually a combination of processes which results in the supply and removal of air from inside a building. These processes typically include bringing in outdoor air, conditioning and mixing the outdoor air with some portion of indoor air, distributing this mixed air throughout the building, and exhausting some portion of the indoor air outside. The quality of indoor air may deteriorate when one or more of these processes is inadequate. For example, carbon dioxide (a gas that is produced when people breathe), may accumulate in building spaces if sufficient amounts of outdoor air are not brought into and distributed throughout the building. Carbon dioxide is a surrogate for indoor pollutants that may cause occupants to grow drowsy, get headaches, or function at lower activity levels. There are many potential sources of indoor air pollution, which may singly, or in combination, produce other adverse health effects. However, the proper design, operation and maintenance of the ventilation system is essential in providing indoor air that is free of harmful concentrations of pollutants.

EPA_402-F-00-009 (2000). Indoor Air Quality and Student Performance. Washington, D.C., Office of Air and Radiation, United States Environmental Protection Agency**:** DC 20460, USA.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Poor indoor air quality (IAQ) can cause illness requiring absence from school, and can cause acute health symptoms that decrease performance while at school. In addition, recent data suggest that poor IAQ can reduce a person's ability to perform specific mental tasks requiring concentration, calculation, or memory.

EPA_402-F-00-010A (2000). Case Study - G.W. Carver and Charles Drew Elementary Schools. San Francisco, California, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, California, San Francisco
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010B (2000). Case Study – William Blackstone Elementary School. Boston Public Schools. Massachusetts, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, Massachusetts, Boston
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010C (2000). Case Study – King-Murphy Elementary School. Clear Creek School District. Colorado, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, Colorado, Evergreen
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010D (2001). Case Study – Chicopee Public Schools. Chicopee. Massachusetts, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-3.
Geographical Location: USA, Massachusetts, Chicopee
Building Type: School, Primary, Secondary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010E (2001). Case Study – Little Harbour School. Portsmouth School Department. Portsmouth, New Hampshire, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, New Hampshire, Little Harbour
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010F (2001). Case Study – Shamona Creek Elementary School. Dowingtown Area School District. Dowingtown, Pennsylvania, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, Pennsylvania, Shamona Creek
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010G (2001). Case Study – Burlington School District. Burlington, Massachusetts, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, Massachusetts, Burlington
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010H (2001). Case Study – Robert K. Shafer Middle School. Bensalem Township School District. Bensalem, Pennsylvania, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, Pennsylvania, Bensalem
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010I (2001). Case Study – Okaloosa County School District. Fort Walton Beach, Florida, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-3.
Geographical Location: USA, Florida, Fort Walton Beach
Building Type: School, Primary, Secondary
Data Type:
Outcome Focus:

Abstract

EPA_402-F-00-010J (2001). Case Study – Fairgrounds Junior High School. Nashua School District. Nashua, New Hampshire, Indoor Environments Division, Office of Radiation and Indoor Air, United States Environmental Protection Agency**:** 1-2.
Geographical Location: USA, New Hampshire, Nashua
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

EPA_402-K-01-003 (2001). Healthy Buildings, Healthy People: A Vision for the 21st Century. Washington, DC 20460, Office of Air and Radiation, United States Environmental Protection Agency.
Geographical Location: USA
Building Type: Office, School
Data Type:
Outcome Focus:

Abstract

Americans spend about 90 percent of their time indoors, where concentrations of pollutants are often much higher than those outside. Risk assessments performed for radon, environmental tobacco smoke (ETS), and lead have shown that health risks are substantial. Thousands of chemicals and biological pollutants are found indoors, many of which are known to have significant health impacts both indoors and in other environments. Although much is known or suspected regarding human health risks in the indoor environment, a comprehensive, integrated effort to assess and manage

indoor risks has yet to be undertaken. In 1987, the EPA Comparative Risk Project was conducted to examine the relative risk of environmental problems. In 1990, the Relative Risk Reduction Strategies Committee of EPA's Science Advisory Board conducted a similar, extensive analysis of relative environmental risk. Both resulting reports, Unfinished Business: A Comparative Assessment of Environmental Problems (U.S. EPA 1987) and Reducing Risk: Setting Priorities and Strategies for Environmental Protection (U.S. EPA 1990), ranked indoor air pollution among the top five environmental risks to public health. In 1997, the Presidential and Congressional Commission on Risk Assessment and Risk Management also found that indoor environmental pollution can pose a substantial environmental risk and advised EPA to address those risks. During the release of its report, the Commission chairman highlighted indoor environmental pollution as one of the greatest risks to human health. Americans are concerned about their own health and the health of their children. However, despite efforts by EPA and other private and public groups to conduct research on indoor environmental issues and to communicate the findings of that research, most Americans do not have a clear sense of the significant health risks of indoor pollution. They also do not know what they can do to reduce risk for asthma, cancer, and other serious diseases caused by indoor pollutant exposure. Nor do many building professionals yet understand how to integrate indoor air quality objectives into the design and operation of the Nation's buildings. The economic value of improved health and productivity can be substantial, and can be achieved through integrated building design, commissioning, and operations which may reduce costs or result in only modest cost increases. Thus, indoor air quality promises to become an important part of the movement toward green buildings and green products. Further, any productivity gains will serve to enhance the Nation's competitiveness in the global economy.

EPA_402-K-02-005 (2002). Indoor Air Quality Tools for Schools Program: Benefits of Improving Air Quality in the School Environment. Washington DC 20460, Office of Air and Radiation, United States Environmental Protection Agency.

Geographical Location: USA
Building Type: Schools
Data Type:
Outcome Focus:

Abstract

IAQ is increasingly an important issue in our nation's schools. Approximately 20 percent of the U.S. population — nearly 55 million people — spend their days inside elementary and secondary schools. In 1999, indoor air quality (IAQ) was reported to be unsatisfactory in about one in five public schools in the United States, while ventilation was reported as unsatisfactory in about one-quarter of public schools, according to the National Center for Education Statistics of the Department of Education. The health of students and staff in these schools is a cause for great concern, particularly the negative effects of poor IAQ on asthma and other respiratory illnesses. The U.S. Environmental Protection Agency (EPA) developed the Indoor Air Quality Tools for Schools (IAQ TfS) Program to help schools prevent, identify, and resolve their IAQ problems. Through simple, low-cost measures, schools can:

- Reduce IAQ-related health risks and triggers for asthma.
- Identify sources of mold.
- Improve comfort and performance levels.
- Avoid costly repairs.
- Avoid negative publicity and loss of parent and community trust.
- Avoid liability problems.

Economic data and scientific studies on the health impacts of poor IAQ provide additional evidence of the benefits that may be associated with implementing the IAQ TfS Program.

EPA_R824795 (1999). Final Report: Indoor Air Quality in Large Office Buildings in the Midwest. Iowa, National Center for Environmental Research, U.S. Environmental Protection Agency.
The University of Iowa, College of Public Health.
Geographical Location: USA, Iowa, Minnesota, Nebraska
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This study used standardized methods to characterize indoor air quality (IAQ), building design and operation, psychosocial factors, and human perceptions of IAQ and symptoms in six large office buildings located in the Midwestern U.S. The aims of this study were to: 1. Collect baseline data to characterize: the physical, mechanical, and environmental factors that influence L\Q; human exposures to carbon dioxide, carbon monoxide, temperature, relative humidity, noise, illumination, organic chemicals, respirable particulates, and microorganisms; occupant perceptions of IAQ, psychosocial attributes of the workgroup, and occupant productivity; and 2. To evaluate relationships among these parameters. Six large office buildings in metropolitan areas were selected in Iowa (#1,#2), Minnesota (#4,#5,#6), and Nebraska (#6). Sampling was conducted over a one week period in each building, in each of four seasons. The building design, air handling system, air flow patterns and velocities, and building operation were characterized. Carbon dioxide, carbon monoxide, temperature, relative humidity, light, and noise were monitored using direct reading instruments and data-loggers inside each building. Simultaneous outdoor measurements of these parameters were also made. Airborne concentrations of culturable bioaerosols, volatile organic compounds, formaldehyde, acetaldehyde, and PM10 particulates were also made. Airborne endotoxins and total microorganisms (culturable plus non-culturable bacteria and fungi) were evaluated. In addition to employee perceptions and symptoms, data on the psychological characteristics of employees and the psychosocial characteristics of the work group as a whole were collected using a questionnaire based upon the EPA BASE questionnaire with additions from other standardized questionnaires. Data was entered into the EPA data management program for inclusion in the EPA's national IAQ data base (IADCS).

EPA_R824797 (1998). Final Report: Bioaerosols, Health, and Productivity in Large Office Buildings, National Center for Environmental Research, U.S. Environmental Protection Agency.
Harvard School of Public Health.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Building-related illnesses are of increasingly common concern. However, the causes and cures remain obscure. This project was designed to longitudinally evaluate the role of environmental factors on reported symptoms and measured working efficiency in a group of office workers.

Although a single large building was to be the focus, difficulties in obtaining access forced the use of working spaces in five different buildings. This slowed the project and increased the difficulties involved in gathering data, but expanded the range of environmental conditions available for study. Overall we collected continuous data on CO2, RH, and temperature from 28 sites in 5 buildings over a period of 18 months. We collected environmental samples (air samples for fungi and bacteria, dust

samples for estimation of 'dustiness', culture of fungi and bacteria, and assay of allergens) on a total of 17 occasions from these sites. We also recruited 180 individuals, and recovered 729 six-week questionnaires, and 4103 weekly questionnaires. Measures of working efficiency were collected from 171 individuals, with an average of about 2 tests/person/week, and a total of 2176 tests overall. Methods evaluations revealed that Andersen conversions were not necessary for the data set, and that MEA and DG-18 culture media produced very similar results so that the resulting data could be combined. Using Principal Component Analysis (PCA), airborne fungal recoveries grouped into four factors which explained 53% of the variance. Airborne fungal concentrations varied seasonally with the highest median value in August and the lowest in January. Total airborne fungal concentrations were negatively correlated with CO2 and positively related to relative humidity. PCA factors 1 and 2 were negatively correlated with CO2 and positively correlated with RH. Similar studies for dustborne fungi. These populations clustered into three factors using PCA. Concentrations of dust fungi were related to temperature and CO2 levels. Cat and dust mite allergens were consistently present in dust in all buildings. Analysis of this large data set is continuing, with current emphasis on relationships between weekly and daily symptom reporting and environmental variables. The data are the subject of two doctoral theses, and have stimulated creation of a bioaerosols analysis working group at the School.

Epstein, Y. M., R. L. Woolfolk, et al. (1981). "Physiological, cognitive and non verbal responses to repeated expousure to crowding." Journal of applied Social Psychology **11**: 1-13.

Epstein, B. L. (2001). Childhood Asthma and Indoor Allergens: The Classroom May be a Culprit. Journal of School Nursing. **17:** 253-257.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Asthma has become the most common chronic illness among children. Indoor environments appear to playa substantial role in the development of asthma. Recent studies indicate strong evidence of a causal relationship between exposure to certain indoor environmental pollutants and development and/or exacerbation of asthma in susceptible individuals. Allergens of concern include those produced by dust mites, cockroaches, cats, dogs, and molds. It is important to better understand this relationship and take preventive and corrective steps to reduce or eliminate these sources in schools, homes, and day care centers. Measures include tracking of asthma and allergic response incidents; monitoring for the presence of allergens and molds; effective cleaning procedures; prompt repair of water leaks and/or moisture problems; control of indoor relative humidity; and proper operation of heating, ventilation, and air conditioning (HVAC) systems.

Erdmann, C. A., K. C. Steiner, et al. (2002). Indoor Carbon Dioxide Concentrations and Sick Building Syndrome Symptoms in the Base Study Revisited: Analyses of the 100 Building Dataset. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

In previously published analyses of the 41-building 1994-1996 USEPA Building Assessment Survey and Evaluation (BASE) dataset, higher workday time-averaged indoor minus outdoor CO2 concentrations (dCO2), were associated with increased prevalence of certain mucous membrane and lower respiratory sick building syndrome (SBS) symptoms, even at peak dCO2 concentrations below 1,000 ppm. For this paper, similar analyses were performed using the larger 100-building 1994-1998 BASE dataset. Multivariate logistic regression analyses quantified the associations between dCO2 and the SBS symptoms, adjusting for age, sex, smoking status, presence of carpet in workspace, thermal exposure, and a marker for entrained automobile exhaust. Adjusted dCO2 prevalence odds ratios for sore throat and wheeze were 1.17 and 1.20 per 100-ppm increase in dCO2 ($p < 0.05$), respectively. These new analyses generally support our prior findings. Regional differences in climate and building design and operation may account for some of the differences observed in analyses of the two datasets.

Evans, G. W. and J. M. McCoy (1998). When Buildings don't Work: The Role of Architecture in Human Health. Journal of Environmental Psychology, Academic Press. **18:** 85-94.
Geographical Location: USA
Building Type: Buildings in general
Data Type: literature review
Outcome Focus: occupant, health
occupant, well-being

Abstract

Fang, L., G. Clausen, et al. (1998). Impact of Temperature and Humidity on Perception of Indoor Air Quality. Indoor Air. **8:** 80-90.
Geographical Location: Europe
Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Sensory responses to clean air and air polluted by five building materials under different combinations of temperature and humidity in the ranges 18-28°C and 3O-70% RH were studied in the laboratory. A specially designed test system was built and a set of experiments was designed to observe separately the impact of temperature and humidity on the perception of air quality / odour intensity, and on the emission of pollutants from the materials. This paper reports on the impact on perception. The odour intensity of air did not change significantly with temperature and humidity: however, a strong and significant impact of temperature and humidity on the perception of air quality was found. The air was perceived as less acceptable with increasing temperature and humidity. This impact decreased with an increasing level of air pollution. Significant linear correlations were found between acceptability and enthalpy of the air at all pollution levels tested, and a linear model was established to describe the dependence of perceived air quality on temperature and humidity at different pollution levels.

Fang, L., G. Clausen, et al. (1998). Impact of Temperature and Humidity on Perception of Indoor Air Quality During Immediate and Longer Whole-Body Exposures. Indoor Air. **8:** 276-284.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Acceptability of clean air and air polluted by building materials was studied in climate chambers with different levels of air temperature and humidity in the range~ 18-28"C and 30-70% relative humidity (RH). The acceptability of the air quality immediately after entering a chamber and during the following 20-min whole-body exposure was assessed by 36 untrained subjects who maintained thermal neutrality by modifying their clothing. The results confirm the significant decrement of the acceptability with increasing temperature and humidity, as shown in a previous study with facial exposures. The odour intensity was found to be independent of temperature and humidity. A linear relation between acceptability and enthalpy of air was again observed by this experiment. No significant difference was observed between the immediate acceptability and the acceptability during the following 20-min exposure, i.e., no adaptation took place. Both the immediate assessment of acceptability and the assessments during the 20-min exposure were independent of the air temperature and humidity to which the subjects were exposed before entering the chamber. The results further indicate that a notable decrement of the ventilation requirement may be achieved by maintaining a moderate enthalpy of air in spaces.

Fang, L., P. Wargocki, et al. (1998). Field Study on the Impact of Temperature Humidity and Ventilation on Perceived Air Quality. Indoor Air '99. Edinburgh. **2:** 107-112.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Perceived ail quality was studied in a real office space at different levels of air temperature, humidity and ventilation. The impact of temperature and humidity on perceived air quality was studied in the ranges 20-26°C and 4O-6O%RH in an office polluted by building materials and bioeffluents, with a ventilation rate of 10 L/s per person. In addition, perceived air quality was observed at a low ventilation rate of 3.5 L/s per person, with a room temperature/humidity of 20°C/40%RH. Thirty female subjects participated in the experiment. They were exposed to each environmental condition for 4.6 hours. During occupancy, the subjects performed simulated office work and assessed perceived air quality. The study confirmed the previously observed impact of temperature and humidity on perceived air quality and the linear correlation between acceptability and enthalpy. The impact on perceived air quality of a decrement of the ventilation rate from 10 to 3.5 L/s per person could be counteracted by a decrement of enthalpy from 45 kJ/kg (23°C/50%RH) to 35 kJ/kg (20°C/40%RH).

Fang, L., D. P. Wyon, et al. (2002). Temperature and Humidity: Important Factors for Perception of Air Quality and for Ventilation Requirements. ASHRAE Transactions. **106:** 503-510.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A series of experiments was carried out to study the effect of temperature and humidity on the perception of indoor air quality. The study included both laboratory and controlled field experiments using an untrained sensory panel to judge the air quality at different levels of temperature and humidity. Facial and whole-body exposure for a short tenn (up to 20 minutes) was used in the laboratory study, and long-term whole-body exposure (up to 4.6 hours) was used in the field study. The study found a significant impact of temperature and humidity on the perception of indoor air quality. The air was perceived as less acceptable with increasing temperature and humidity, and the acceptability decreased linearly with increasing enthalpy of the air: Ventilation requirements for comfort can be significantly reduced by decreasing indoor air enthalpy.

Fang, L., D. P. Wyon, et al. (2002). Sick Building Syndrome Symptoms and Performance in a Field Laboratory Study at Different Levels of Temperature and Humidity. Indoor Air 2002. Monterey, California. **Proceedings of the 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Thirty female subjects were exposed for 280 minutes to four conditions in balanced order of presentation: to 20°C/40%, 23°C/50%, 26°C/60% RH at10 L/s/p outside air, and to 20°C/40% RH at 3.5 L/s/p. They performed simulated office work throughout each exposure and repeatedly marked a set of visual-analogue scales to indicate their perception of environmental conditions and of the intensity of SBS symptoms at the time. They were repeatedly reminded to adjust their clothing so as to remain in thermal comfort, and succeeded in doing so. Although perceived air quality improved at lower indoor air temperature and humidity and at the higher ventilation rate, this could not be shown to be associated with any effects on task performance. However, subjects reported significantly more intense SBS symptoms associated with decreased productivity, including fatigue, headache and difficulty in thinking clearly, when they were exposed to raised levels of temperature and humidity.

Fanger, P. O. (1970). Thermal Comfort - Analysis and Applications in Environmental Engineering. Copenhagen, Danish Tehnical Press.
Geographical Location:
Building Type: non-specific
Data Type: theory
Outcome Focus: occupant, comfort

Abstract

Fanger, O., P. (2000a). Indoor Air Quality in the 21st Century: Search for Excellence. Indoor Air. **10:** 68-73.
Geographical Location: Europe, Denmark, Sweden
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Field studies demonstrate that there are substantial numbers of dissatisfied people in many buildings, among them those suffering from sick building syndrome (SBS) symptoms, even though existing standards and guidelines are met. The reason is that the requirements specified in these standards are rather low, allowing a substantial group of people to become dissatisfied and to be adversely affected. A paradigm shift from rather mediocre to excellent indoor environments is foreseen in the 21st century. Based on existing information and on new research results, five principles are suggested as elements behind a new philosophy of excellence: 1) better indoor air quality increases productivity and decreases SBS symptoms; 2) unnecessary indoor pollution sources should be avoided; 3) the air should be served cool and dry to the occupants; 4) "personalized air", i.e. a small amount of clean air, should be served gently, close to the breathing zone of each individual; and 5) individual control of the thermal environment should be provided. These principles of excellence are compatible with energy efficiency and sustainability.

Fanger, O., P. (2000b). Good Air Quality in Offices Improves Productivity. Journal of Mechanical Engineering. **46:** 408-412.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Three recent independent studies have documented that the quality of indoor air has a significant and positive influence on the productivity of office workers. A combined analysis of the results of the three studies shows a significant relationship between productivity and perceived indoor air quality. The impact on productivity justifies a much higher indoor air quality than the minimum levels prescribed ill present standards and guidelines. One way of providing air of high quality for people to breathe, without involving excessive ventilation rates and energy use, is to provide "personalized air" to each individual. The application of this concept is discussed in this paper.

Fanger, O., P. (2001). Human requirements in future air-conditioned environments. International Journal of Refrigeration. **24:** 148-153.
Geographical Location: various
Building Type: office
Data Type: case study, measurement
Outcome Focus: occupant, productivity
operation, energy

Abstract

Although air-conditioning has played a positive role for economic development in warm climates, its image is globally mixed. Field studies demonstrate that there are substantial numbers of dissatisfied people in many buildings, among them those suffering from Sick Building Syndrome (SBS) symptoms, even though existing standards and guidelines are met. A paradigm shift from rather mediocre to excellent

indoor environments is foreseen in the 21st century. Based on existing information and on new research results, five principles are suggested as elements behind a new philosophy of excellence: better indoor air quality increases productivity and decreases SBS symptoms; unnecessary indoor pollution sources should be avoided; the air should be served cool and dry to the occupants; "personalized air", i.e. a small amount of clean air, should be served gently, close to the breathing zone of each individual; individual control of the thermal environment should be provided. These principles of excellence are compatible with energy efficiency and sustainability.

Farrenkopf, T. and V. Roth (1980). The University faculty office as an environment. Environment & Behavior. **12**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Federspeil, C. C., G. Liu, et al. (2002). Worker Performance and Ventilation: Analyses of Individual Data for Call-Center Workers. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate:** 796-801.
Geographical Location: USA
Building Type: Office, Call-Centre
Data Type: quantitative, measurements, on-site
Outcome Focus: occupant, health; occupant, productivity

Abstract

We investigated the relationship between ventilation rates and work performance in a call center. We randomized the ventilation controls and measured ventilation rate, differential carbon dioxide (.CO2) concentration, temperature, humidity, occupant density, degree of under-staffing, shift length, time of day, and time required to complete two different work performance tasks (talk and wrap-up). CO2 concentrations ranged from 13 to 611 ppm. We used multi-variable regression to model the association between the predictors and the responses. We found that agents performed talk tasks fastest when the ventilation rate was highest, but that the relationship between talk performance and ventilation was not monotone. We did not find a statistically significant association between wrap-up performance and ventilation. At high temperatures agents were slower at both the talk and wrap-up tasks. Agents were slower at wrap-up during long shifts and when the call center was under-staffed.

Finnegan, M. and L. Z. Solomon (1981). Work Attitudes in Windowed vs. Windowless envirnoments. The Journal of Social Psychology. **115:** 291-292.
Geographical Location: USA, New York
Building Type: Office
Data Type: qualitative, survey , questionnaire, on-site subjects: 81 worked in windowed settings, 32 in windowless settings
Outcome Focus: occupants, well-being

Abstract

Fisk, W. J. Health and Productivity Gains from Better Indoor Environments and Their Implications for the U.S. Department of Energy.
Geographical Location: USA
Building Type: building
Data Type: survey, theory
Outcome Focus: occupant, health

Abstract

A substantial portion of the US population suffers frequently from communicable respiratory illness, allergy and asthma symptoms, and sick building syndrome symptoms. We now have increasingly strong evidence that changes in building design, operation, and maintenance can significantly reduce these illnesses. Decreasing the prevalence or severity of these health effects would lead to lower

health care costs, reduced sick leave, and shorter periods of illness-impaired work performance, resulting in annual economic benefits for the US in the tens of billion of dollars.

Fisk, W. J., M. J. Mendell, et al. (1993). The California Healthy Building Study, Phase 1: A Summary. Indoor Air. **3:** 246-254.
Geographical Location: USA, California
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Increasing our understanding of the building and environmental factors that result in healthy and productive office workers is the long-term goal of the California Healthy Building Study. The primary objectives of the Phase-1 study were to: (1) test hypotheses about associations between health symptoms and features of the buildings, indoor environments, and jobs; (2) obtain background data on health symptom prevalences and indoor air quality; and (3) gain experience with this type of study. Primary hypotheses were that symptom prevalences, after adjustment for confounders, would be: (a) higher in sealed air conditioned buildings than in naturally ventilated buildings; (b) not related to the total concentrations of volatile organic compounds (VOC), fungi, or bacteria; and (c) higher as the measured thermal comfort decreased. For the study, we selected three naturally ventilated (NV) office buildings; three mechanically ventilated (MV) office buildings; and six air conditioned (AC) office buildings. Information on the prevalences of work-related symptoms, demographics, and work and job factors were determined via a questionnaire completed by 880 occupants. Several indoor environmental parameters were measured. Logistic regression models were used to assess associations between symptom prevalences and features of the buildings, indoor environments, jobs, and occupants. Although symptom prevalences varied within each group of buildings, the occupants of the MV and AC buildings had significantly more symptoms than occupants of the NV buildings. Based on preliminary analyses of the data, none of the measured environmental parameters were clearly associated with symptom prevalence; however, increased prevalences of some symptoms were associated with several job and workspace factors including: presence of carpet , increased use of carbonless copies and photocopiers, space sharing, and distance from a window.

Fisk, W. J., D. Faulkner, et al. (1994). Phase 2 of the California Healthy Building Study: A Status Report. Berkley, Lawrence Berkley National Laboratory, California.
Geographical Location: USA, San Francisco
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The primary goal of the California Healthy Building Study (CHBS) is to identify the major characteristics of buildings, ventilation systems, jobs, and indoor environmental quality that are associated with building-related sick-building health symptoms. The first phase of the CHBS was a cross sectional study of 12 office buildings located in the San Francisco Bay area. Health symptom and job data were collected via a questionnaire, buildings and ventilation systems were characterized, and regression models were used to assess associations between symptom prevalences and factors suspected to be associated with increased symptoms. This report summarizes research activities undertaken during Phase-2 of the CHBS and compiles currently available results. Phase 2 activities were limited to inspections and low cost measurements that yielded additional information that could be used in conjunction

with the Phase-1 symptom data or provided valuable experience or information for future research. Because much of the Phase-2 effort was devoted to evaluation of measurement methodologies or collection of information that will be used in conjunction with the Phase-1 symptom data, this report is intended primarily for internal use by the CHBS research team. The Phase-2 study included the following components: (1) inspections of HVAC systems to identify and, in some cases, quantify potential sources of volatile organic compounds, fibers, and bioaerosols; (2) evaluation of a protocol for measuring the concentration of bioaerosols in the air exiting supply air diffusers; (3) interviews of building operators to assess practices related to HVAC inspection, cleaning, and disinfecting; (4) evaluation of a protocol for measuring the extent of microbiological contamination on floors and on upholstered chairs; (5) quantifying the amount of carpet within each study space in order to allow an improved assessment of associations with worker symptoms; (6) interviews of building operators to determine the quality of office cleaning and the nature of office pest-control practices; (7) measurement of the spatial and temporal variations in sound levels within study areas so that a protocol for sound-level measurements could be designed and used in a future study; and (8) measurement of percent lighting flicker in each study space so the association between percent flicker and symptoms could be evaluated. Regression modeling to evaluate associations between Phase-1 symptom prevalences and Phase-2 data is ongoing and is not described in this document.

Fisk, W. and A. Rosenfeld (1997a). Improved Productivity and Health from better Indoor Environments. CBS Newsletter.
Geographical Location: USA
Building Type: building
Data Type: quantitative, case studies
Outcome Focus: occupant, health

Abstract

Recently completed analyses suggest that improving buildings and indoor environments could reduce health-care costs and sick leave and increase worker performance, resulting in an estimated productivity gain of $30 to $150 billion annually.

Fisk, W. J. and A. H. Rosenfeld (1997b). Estimates of Improved Productivity and Health from Better Indoor Environment. Indoor Air. **7:** 158-172.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The existing literature contains strong evidence that characteristics of buildings and indoor environments significantly influence rates of respiratory disease, allergy and asthma symptoms, sick building symptoms, a11d worker performance. Theoretical considerations, and limited empirical data, suggest that existing technologies and procedures can improve indoor environments in a manner that significantly increases health and productivity. At present, we can develop only crude estimates of the magnitude of productivity gains that may be obtained by providing better indoor environments; however, the projected gains are very large. For the U.S, we estimate potential annual savings and productivity gains of $6 billion to $19 billion from reduced respiratory disease; $1 billion to 54 billion from reduced allergies and asthma, 510 billion to $20 billion from reduced sick building syndrome symptoms, and $12 billion to $125 billion from direct improvements in worker performance that are unrelated to health. Sample calculations indicate that the potential financial benefits

of improving indoor environments exceed costs by a factor of 18 to 47. The policy implications of the findings are discussed and include a recommendation for additional research.

Fisk, W. J. and A. H. Rosenfeld (1998a). Potential Nationwide Improvements in Productivity and Health from Better Indoor Environments. 1998 Summer Study on Energy Efficiency in Buildings. Washington D.C.**:** 8.85-8.97.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Theoretical considerations and empirical data suggest that existing technologies and procedures can improve indoor environments in a manner that significantly increases productivity and health. Existing literature contains moderate to strong evidence that characteristics of buildings and indoor environments significantly influence rates of respiratory disease, allergy and asthma symptoms, sick building symptoms, and worker performance. While there is considerable uncertainty in our estimates of the magnitudes of productivity gains that may be obtained by providing better indoor environments, the projected gains are very large. For the U.S., we estimate potential annual savings and productivity gains of $6 to $19 billion from reduced respiratory disease, $1 to $4 billion from reduced allergies and asthma, $10 to $20 billion from reduced sick building syndrome symptoms, and $12 to $125 billion from direct improvements in worker performance that are unrelated to health. In two example calculations, the potential financial benefits of improving indoor environments exceed costs by a factor of 8 and 14. Productivity gains that are quantified and demonstrated could serve as a strong stimulus for energy efficiency measures that simultaneously improve the indoor environment.

Fisk, W. J., A. H. Rosenfeld, et al. (1998b). Indoor Environment…Productivity and Health…and $$$. Strategic Planning for Energy and the Environment. **17:** 53-59.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

There is strong evidence that characteristics of buildings and indoor environments significantly influence rates of respiratory disease, allergy and asthma symptoms, sick building symptoms, and worker performance. Theoretical considerations, and limited empirical data, suggest that existing technologies and procedures can improve indoor environments in a manner that significantly increases health and productivity. At present, we can devvelop only crude estimates of the magnitude of productivity gains that may be obtained by providing better indoor environments; however, the projected gains are very large.

Fisk, W. J. (1999). Estimates of Potential Nationwide Productivity and Health benefits from Better Indoor Environments: An Update. Indoor Air Quality Handbook. S. J.D., J. M. Samet and J. F. McCarthy. New York, McGraw Hill. **4:** 4.1-4.36.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The existing literature offers relatively strong evidence that characteristics of buildings and indoor environments significantly influence prevalences of respiratory disease, allergy and asthma symptoms, symptoms of sick building syndrome, and worker performance. Theoretical considerations, and limited empirical data, suggest that existing technologies and procedures can improve indoor environments in a manner that significantly increases health and productivity. At present, we can develop only crude estimates of the magnitude of productivity gains that may be obtained by providing better indoor environments; however, the projected gains are very large. For the United States, we estimate potential annual savings and productivity gains in 1996 dollars of $6 to $14 billion from reduced respiratory disease; $2 to $4 billion from reduced allergies and asthma; $15 to $40 billion from reduced symptoms of sick building syndrome; and $20 to $200 billion from direct improvements in worker performance that are unrelated to health. In two example calculations, the potential financial benefits of improving indoor environments exceed costs by factors of 9 and 14. Further research is recommended to develop more precise and compelling benefit-cost data that are needed to motivate changes in building codes, designs, and operation and maintenance policies.

Fisk, W. J. (2000a). Health and Productivity Gains from Better Indoor Environments and Their Implications for the U.S. Department of Energy. Berkley, California., Indoor Environment Department, Environmental Energy Technologies Division, Lawrence Berkley National Laboratory.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A substantial portion of the U.S. population suffers frequently from communicable respiratory illnesses, allergy and asthma symptoms, and sick building syndrome symptoms. We now have increasingly strong evidence that changes in building design, operation, and maintenance can significantly reduce these illnesses. Decreasing the prevalence or severity of these health effects would lead to lower health care costs, reduced sick leave, and shorter periods of illness-impaired work performance, resulting in annual economic benefits for the U.S. in the tens of billions of dollars. Increasing the awareness of these potential health and economic gains, combined with other factors, could help bring about a shift in the way we design, construct, operate, and occupy buildings. The current goal of providing marginally adequate indoor environments could be replaced by the goal of providing indoor environments that maximize the health, satisfaction, and performance of building occupants. Through research and technology transfer, DOE and its contractors are well positioned to help stimulate this shift in practice and, consequently, improve the health and economic well-being of the U.S. population. Additionally, DOE's energy-efficiency interests would be best served by a program that prepares for the potential shift, specifically by identifying and promoting the most energy efficient methods of improving the indoor environment. The associated research and technology transfer topics of particular relevance to DOE are identified and discussed.

Fisk, W. J. (2000b). Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency. Annual Revue of Energy and the Environment 2000. Berkley, California., Lawrence Berkley National Laboratory. **25:** 537-566.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Theoretical considerations and empirical data suggest that existing technologies and procedures can improve indoor environments in a manner that significantly increases productivity and health. The existing literature contains moderate to strong evidence that characteristics of buildings and indoor environments significantly influence rates of communicable respiratory illness, allergy and asthma symptoms, sick building symptoms, and worker performance. Whereas there is considerable uncertainty in the estimates of the magnitudes of productivity gains that may be obtained by providing better indoor environments, the projected gains are very large. For the United States, the estimated potential annual savings and productivity gains are $6 to $14 billion from reduced respiratory disease, $1 to $4 billion from reduced allergies and asthma, $10 to $30 billion from reduced sick building syndrome symptoms, and $20 to $160 billion from direct improvements in worker performance that are unrelated to health. Productivity gains that are quantified and demonstrated could serve as a strong stimulus for energy efficiency measures that simultaneously improve the indoor environment.

Fisk, W. J. (2002a). How IEQ Affects Health, Productivity. Commercial Building Ventilation & Indoor Environmental Quality. **44:** 56-60.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This article, a summary of Fisk, estimates the nationwide improvements in health and productivity potentially attainable by providing better indoor environmental quality (IEQ) in US buildings. Estimates include the potential reductions in three categories of health effects, the associated economic benefits, and the potential direct improvements in productivity not mediated through health.

Fisk, W. J., G. Brager, et al. (2002b). A Priority Agenda for Energy-Related Indoor Environmental Quality Research. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Fisk, W. J., P. N. Price, et al. (2002c). Worker Productivity and Ventilation Rate in a Call-Centre: Analysis of Time-Series Data for a Group of Call-Centre Workers. Berkley, California, Lawrence Berkley National Laboratory.
Geographical Location: USA
Building Type: Office
Call-Centre
Data Type: quantitative, measurements, on-site
Outcome Focus: occupant, health; occupant productivity

Abstract

In previous studies, increased ventilation rates and reduced indoor carbon dioxide concentrations have been associated with improvements in health at work and increased performance in work-related tasks. Very few studies have assessed whether ventilation rates influence performance of real work. This paper describes part one of a two-part analysis from a productivity study performed in a call center operated by a health maintenance organization. Outside air ventilation rates were manipulated, indoor air temperatures, humidities, and carbon dioxide concentrations were monitored, and worker performance data for advice nurses, with 30-minute resolution, were analyzed via multivariate linear regression to look for an association of performance with building ventilation rate, or with indoor carbon dioxide concentration (which is related to ventilation rate per worker). Results suggest that the effect of ventilation rate on worker performance in this call center was very small (probably less than 1%) or nil, over most of the range of ventilation rate experienced during the study (roughly 12 L s-1 to 48 L s-1 per person). However, there is some evidence suggesting performance improvements of 2% or more when the ventilation rate per person is very high, as indicated by indoor CO2 concentrations exceeding outdoor concentrations by less than 75 ppm.

Fisk, W. J., P. N. Price, et al. (2002d). Worker Performance and Ventilation: Analyses of Time-Series Data for a Group of Call-Center Workers. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: Office
Call-Centre
Data Type: quantitative, measurements, on-site
Outcome Focus: occupant, health; occupant, productivity

Abstract

We investigated the relationship of ventilation rates with the performance of advice nurses working in a call center. Ventilation rates were manipulated; temperatures, humidities, and CO2 concentrations were monitored; and worker performance data, with 30-minute resolution, were collected. Multivariate linear regression was used to investigate the association of worker performance with building ventilation rate, or with indoor CO2 concentration (which is related to ventilation rate per worker). Results suggest that the effect of ventilation rate on worker performance in this call center was very small (probably less than 1%) or nil, over most of the range of ventilation rate (roughly 12 L s-1 to 48 L s-1 per person). However, there is some evidence of worker performance improvements of 2% or more when the ventilation rate per person was very high, as indicated by the indoor CO2 concentration exceeding the outdoor concentration by less than 75 ppm.

Florida, R. (2002). The Rise of the Creative Class and how it is transforming work, leisure, community and everyday life.

Foliente, G. C., P. J. Paevere, et al. (2003). Smart Buildings for Helathy and Sustainable Workplaces: Scoping Study Report. Brisbane, CRC for Construction Innovation.
Geographical Location: Various
Building Type: commercial
Data Type: review
Outcome Focus: occupant, health
operation, energy

Abstract

Fox, J. (1999). EPA: Bad Air in Schools Distracts Students, Staff. Education Daily, Gaithersburg. **32:** 3-4.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Harmful indoor pollutants in many of the nation's schools may be hampering student learning, says an environmental official who urges schools to conduct voluntary inspections of their facilities and equipment.

Freitag, P. K., J. E. Woods, et al. (2002). Health, Energy and Productivity in Schools: Measures of Occupant Performance. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: School
Data Type: Quantitative
Outcome Focus:

Abstract

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

Freitag, P. K., J. E. Woods, et al. (2002). Health, Energy and Productivity in Schools: Measures of Occupant Performance. Indoor Air 2002.
Geographical Location: USA
Building Type: school
Data Type: quantitative, questionnaire, perception assessment, field experiment
Outcome Focus: occupant, productivity

Abstract

In this age of accountability, school districts fail to consider how the poor conditions of

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

Fried, Y. (1990). Workplace characteristics, behavioural interferences, and screening ability as joint predictors of employee reactions: An examination of the intesification approach. Journal of Organizational Behavior. **11:** 267-280.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Fried, Y., L. H. Slowik, et al. (2001). Exploring the relationship between workspace density and employee attitudinal reactions: An integrative model. Journal of Occupational & Organizational Psychology. **74:** 359-372.
Geographical Location:
Building Type: office
university
Data Type: survey
Outcome Focus: occupants, well-being

Abstract

Investigated employee reactions to workspace density by examining the simultaneous moderating effects of job complexity and organizational tenure on the relationship between workspace density and 3 attitudinal outcomes: organizational commitment, job satisfaction, and co-worker satisfaction. 93 employees (average age 40 yrs) of a large university were surveyed. Workplace density was measured by the researchers as the total number of employees who worked within a radius of 15 feet of the target employee. Results show that the strongest negative relations between density and reactions occurred when job complexity and organizational tenure were high, simultaneously. Theoretical and practical implications of the study are discussed. (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Fung, F. and W. G. Hughson (2002). Health Effects of Indoor Fungal Bioaerosol Exposure. Indoor Air 2002. Monterey, California,. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: Office
School
Data Type:
Outcome Focus:

Abstract

Objective: To review current data on the health effects of indoor fungal bioaerosol

exposure based on published studies. Methods: We conducted MEDLINE search and reviewed all English language studies on indoor mould exposure (visible survey or objective sampling) and human health effects published from 1966 to January 2002. Main findings of the studies are analyzed in conjunction with plausible association of health effects and fungal exposure. Results Five case control studies, 16 cross-sectional surveys and 7 case reports met the selection criteria. Current evidence suggests that excessive moisture promotes mould growth and is associated with an increased prevalence of symptoms due to irritation, allergy, and infection. However, specific toxicity due to inhaled fungal toxins has not been scientifically established. Conclusions: Methods for assessing indoor bioaerosol exposure and health effects are not well standardized, making interpretation of existing data difficult. Additional studies are needed to document human exposure-disease and dose-response relationships.

Gann, C. (1998). HVAC: Upgrades as Retention Tools. Journal of Property Management.
Geographical Location: USA
Building Type: office
Data Type: quantitative
Outcome Focus: occupant, productivity

Abstract

Want to make your commercial tenants an offer they can't refuse at renewal time? Tell them you'll increase their worker productivity by 5 to 15 percent. Losses in productivity in the work environment result in billions of dollars of losses each year.

Gawron, V. J. (1984). Noise: Effect and Aftereffect. Ergonomics. **27:** 5-18.
Geographical Location: USA, Colorado
Building Type: university
Data Type: quantitative, qualitative, measurements, on-site survey
Outcome Focus: occupant, productivity (performance)
occupant, response

Abstract

The effects and aftereffects of noise on human performance and addective state were investigated in two experiments. In the first, 48 undergraduate university students completed five paper-and-pencil performance tests in a noisy (85 dBA) and/or quiet (45 dBA) environment. In the second experiment, 24 students completed two mood- and four environment-rating scales under the same conditions as in experiment 1. There were statistically reliable noise effects and aftereffects on the subjects affective ratings but none on their performance.

Gifford, R. (1997). Environmental Psychology: Principles and Practices. United States of America, Allyn and Bacon**:** 503.
Geographical Location: general
Building Type: Schools, office
Data Type: literature review, general
Outcome Focus: Occupant, health
Occupant, productivity
Occupant, well-being
Occupant, response

Abstract

Introduction to Environmental Psychology.

Gilhooley, M. J. (2002). Green Green Grass of Work. Facilities Design & Management**:** 26 - 29.
Geographical Location: USA, Los Angeles
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A little bit of green can go a long way, and were not talking about money. Plants in the workplace have been proven to improve employee productivity and reduce stress.

Glicksman, S. T. (1997). Thermal and behavioral modeling of occupant-controlled heating, ventilating and air conditioning systems. Energy and Buildings. America Massachusetts Cambridge, Elsevier. **25:** 243-249.
Geographical Location: USA
Building Type: office
Data Type: case study, measurements
Outcome Focus: occupant, productivity, operation, energy

Abstract

Occupant-controlled heating, ventilating and air conditioning (HVAC) systems allow inhabitants of open-plan spaces some degree of control over their immediate microclimate. Typically, cooled air is supplied at floor or desktop levels. The amount and direction of air flow is under occupant control. Productivity increases have been attributed to this form of control. This paper proposes a simplified model of the thermal environment created by an occupant-controlled HVAC system and the behaviour of the occupants within it. The thermal environment is characterized by individual nodes representing sub-areas of the conditioned space and a single well-mixed ceiling space above the occupied zone. Random processes are used to simulate the comings and goings of individual occupants and their HVAC control behaviour. The model is used to identify the parameters which have the largest influence on the energy efficiency. Energy use of task HVAC with occupant sensors is found to be less than that of a conventional HVAC system by 13%. Individual HVAC control requires about 10% more energy than uniform temperature conditions.

Goodrich, R. (1982). Seven Office Evaluations. A review. Environment and Behaviour. **14:** 353-378.
Geographical Location: USA, New York
Building Type: Office, High rise
Data Type: Qualitative, Interview, Questionnaire, on site, Observation
Outcome Focus: Occupant, productivity
Occupant, well-being

Abstract

The designed environment of an office, as experienced and used by people, is part of a dynamic system which influences the user's performance and well-being. The case studies reported here -based upon extensive interviews, questionnaires, group interviews, and observations at 14 companies representing a variety of physical environments- document some of the ways in which the designed environment affects behavior and the user's perception of his environment. The designed environment affects, both positively and negatively, morale, communication patterns, perceived privacy, and workers' relationships with others. Similarly, social processes and task variables influence a user's perception of and relation to the environment in

which he works. These findings are reviewed and implications fro design are discussed.

Gratia, E. and A. de Herde (2003). Design of low energy office buildings. Energy and Buildings. **35:** 473-491.
Geographical Location: Belgium
Building Type: office
Data Type: case study; measurements, on-site
Outcome Focus: operation, energy; occupant, health

Abstract

There is an increasing demand for higher quality office buildings. Occupants and developers of office buildings ask for a healthy and stimulating working environment. The advent of computers and other office equipment increased the internal heat gains in most offices. Highly glazed facades, often with poor shading, have become very common. This, together with the extra heat gains from the electric lighting made necessary by deep floor plans, and the wider use of false ceilings, increased the risk of overheating. Decisions taken rapidly in the early stages of design can have a large impact on the performance of the finished building. For example, choices of the overall form of the building, the depth and height of rooms, and the size of windows can together double the eventual energy consumption of the finished building. They can also halve the daylight levels, and increase summer temperatures to levels which affect the occupants' productivity. Later in the design process, radical design changes are rarely made. The paper uses data from practice and meteorological data for Belgium (northern part of Europe) to determine directions which should be used in practice. So, this research represents a help for architects to design energy efficient buildings with a good thermal interior climate.

Graudenz, G. S., J. Kalil, et al. (2002). Upper Respiratory Symptoms Associated with Aging of the Ventilation System in Artificially Ventilated Offices in Sao Paulo, Brazil. Chest. **122:** 729–735.
Geographical Location: Brazil, Sao Paulo
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Background: The increase of work-related respiratory complaints in artificially ventilated buildings has multiple causes, and the role of allergen exposure and symptoms is still controversial. Study objectives: To analyze the risk factors and the association of work-related symptoms with allergen exposure and different conditions of the same air conditioning system in Sao Paulo, Brazil. Design: Workers were classified according to characteristics of the air conditioning system: the first group (group I) with ventilation machinery and ducts with > 20 years of use, the second group (group 2) with ventilation machinery with > 20 years of use and ventilation ducts with < 2 years of use, and the third group (group 3) with ventilation machinery and ducts with < 2 years of use. Logistic regression was performed to check the associations between air conditioning groups, allergen exposure (fungi, mites, animal dander, and cockroach), and symptoms. Results: There was a higher prevalence of building-related worsening of respiratory symptoms (p = 0.004; odds ratio [OR], 8.53) and symptoms of rhinoconjunctivitis (p = 0.01; OR, 8.49) in group 1. There was a lower relative humidity (p = 0.05) and non-significant lower temperature in group 1, when compared to the other groups. The viable mold spores totals were higher outdoors than in the indoor samples (n = 45, p = 0.017). There were higher levels of Der p I in group 2 (p = 0.032). All allergen levels were considered low. Conclusion: There was a strong association of building-related upper-airway symptoms with

places having ventilation systems with > 20 years of use.

Guarneri, M. (2002). How Healthy is your Schools Air? Principal. **81:** 18-21.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

If you're wondering why so many of your students seem to be suffering from asthma these days, you may be breathing the answer.

Guidry, K. (2002). Sick Commercial Buildings: What Appraisers Need to Know. The Appraisal Journal**:** 28-33.
Geographical Location: USA, Louisiana
Building Type: Office
Data Type:
Outcome Focus:

Abstract

An appraiser employed to find the value of a "sick" commercial building (or one suspected to be sick) is obligated to identify the problem as well as make recommendations for remedies. The following article defines sick building syndrome (SBS) and suggests causes, cursory solutions, and preventive measures for SBS.

Gyntelberg, F., P. Suadicani, et al. (1994). Dust and the Sick Building Syndrome. Indoor Air 4**:** 223-238.
Geographical Location: Europe, Denmark, Copenhagen
Building Type: Office
Data Type:
Outcome Focus:

Abstract

In the Danish Town Hall Study it has previously been shown that the sick building syndrome is a widespread phenomenon. This has given rise to speculations as to whether biologically active components in dust or whether absorbed organic gases and vapours in the indoor climate may be partly responsible for the sick building syndrome. Therefore, we wished to study whether qualitative conditions in dust, of a physical, chemical, and biological nature, are related to the prevalence of symptoms of the sick building syndrome. Material and methods. The study included 12 town halls in the Copenhagen area. A total of 870 persons participated, 584 women and 286 men. All the participants filled out a questionnaire regarding health and working conditions, and dust samples were collected with a special vacuum cleaner in the working environment of the participants, after which the contents of inorganic and organic particles as well as of human source fragments (hair, nails, skin) and various fibres were determined. Results. There was a significant correlation (P<O.O5) between the prevalence of gram-negative bacteria in the indoor climate dust, and general symptoms (fatigue, heavy-headedness, headache, dizziness, concentration problems) (corr:coeff.=0.73), as well as symptoms from the muvous membranes of the upper respiratory tract (corr.coeff.:::0.76). Also, there was a significant relation between the prevalence of particles in the dust and the prevalence of symptoms from the mucous membranes (corr.coeff.=0.81). There was a strong and significant correlation between the total amount of volatile organic components (TVOC) and lack of concentration (corr.coeff. =0.85) and feeling heavy-headed (corr.coeff. =0.72). Macromolecular dust (potentially allergenetic material) was significantly correlated to the prevalence of headache and general malaise/dizziness (corr.coeff. =0.66), while

the ability of the dust to liberate histamine was significantly related to the prevalence of general malaise, dizziness (corr.coeff. =0.65) and lack of concentration (corr.coeff. =0.58). Further analyses including a number of potential confounders did not change the results of the above analyses. Conclusion. The results of this study support the hypothesis that qualitative properties of dust are important to the sick building syndrome. The study was based on relatively few buildings, but nevertheless strong correlations were found. In perspective, epidemiological intervention studies should be carried out to investigate whether minimizing the amount of both dust and bacteria in the indoor climate affect the prevalence of sick building syndrome.

Haghighat, F. and G. Donnini (1999). Impact of Psycho-Social Factors on Perception of the Indoor Air Environment Studies in 12 Office Buildings. Building and Environment. **34:** 479-503.

Geographical Location: Canada, Montreal
Building Type: Office, High-Rise
Data Type: qualitative, survey; quantitative, measurements, on-site
Outcome Focus: occupant, well-being; building, operation; building, energy

Abstract

The main function of a mechanically ventilated office building is to provide a healthy and comfortable working environment for occupants, while maintaining minimum energy consumption. Twelve mechanically ventilated buildings were selected. They varied greatly in surface area, number of floors, occupant density, and building use. The indoor air quality, thermal comfort, energy consumption, and perception of occupants were investigated in these buildings. A total of 766 subjects participated in the questionnaire survey during the hot summer months of June, July, and August, and during the cold winter months of January, February, and March. The questions included in the questionnaire dealt with health, environmental sensitivity, work area satisfaction, personal control of the workstation's environment, and job satisfaction. Measured parameters concerning the quality of indoor air included ventilation rate, concentration of TVOC, CO2, CO, RH, and formaldehyde. The thermal comfort parameters included room air, mean radiant, plane radiant asymmetry, and dew point temperatures, as well as air velocity and turbulence intensity. Monthly energy consumption data was also gathered for each building. Ventilation performance, in terms of air flow rate and indoor air quality, was compared with the ASHRAE Standard 62-89R "Ventilation for Acceptable Indoor Air Quality. Atlanta. American Society of Heating, Refrigerating, and Air Conditioning Engineers, Inc. USA." The measured and calculated thermal environmental results were also compared with the ASHRAE Standard 55-92 "Thermal Environmental Conditions for Human Occupancy. Atlanta. American Society of Heating\ Refrigerating\ and Air Conditioning Engineers\ Inc. USA. CO2 and CO levels satisfied the recommended limits. The outdoor airflow rate was half that recommended in only one building. The formaldehyde and TVOC levels were moderately higher than suggested comfort levels. However, more than 56% of the occupants rated dissatisfaction with the indoor air quality. Only 63% of the indoor climatic observations fell within the ASHRAE Standard 55-92 summer comfort zone; 27% in the winter. However, only 69% of those surveyed agreed with the comfort zones. More symptoms were reported by workers who perceived IAQ to be poor. Positive relationships were observed between the job satisfaction and satisfaction with office air quality, ventilation, work area temperature, and ratings of work area environment. However, job dissatisfaction did not correlate with symptom reports. The occupants were more dissatisfied with IAQ when they preferred more air movement. In other words, the higher the perceived air movement, the greater the satisfaction with IAQ.

Hagstrom, K. (2000). Economic Value of high quality indoor air climate. Proceedings of Healthy Buildings. **1**.
Geographical Location: Finland
Building Type: office
Data Type: review, case study
Outcome Focus: operation, cost

Abstract

In the building process it is common that comparison between different systems is made based on the initial costs. Low investment can turn out to be costly from the whole life-cycle viewpoint, if the costs of operation and maintenance are not understood. Today the role of life-cycle costs (LCC) is increasing its importance in the decision-making process. However, also an LCC analysis may lead in the wrong direction, if the difference in indoor environment quality (IEQ) and its impact on the workers productivity is not accounted for.
The information of the indoor environment parameters' influence on the workers productivity is limited. Also the link between LCC and productivity is currently missing. This paper presents a sensitivity analysis methodology for LCC and non-productivity costs comparison. It is also demonstrated that an investment to better HVAC system is profitable already with modest profitability improvements of only a few minutes per day.

Hagstrom, K., R. Hosonen, et al. (2003). Impact of IAQ on Productivity.
Geographical Location: USA
Building Type: various
Data Type: ?
Outcome Focus: occupant, productivity, operation, life

Abstract

Life cycle cost analysis does not consider the impact of IAQ and thermal comfort on productivity

Hansen, W. (1995). The IAQ Challenge to Facility Management: Healthy Buildings Through Affordable Indoor Air Quality Programmes. Facilities. **13:** 12–20.
Geographical Location: USA, California
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Lists proposed regulations for governing indoor air quality (IAQ) in the USA. Outlines various health problems caused by IAQ, making a distinction between building-related illness and sick building syndrome. Discusses factors which affect IAQ.

Hansen, A. C. and H. K. Selte (2000). Air Pollution and Sick-leaves. Environmental and Resource Economics. Netherlands, Kluwer Academic Publishers. **16:** 31-50.
Geographical Location: Oslo, Norway, Europe
Building Type: office building
Data Type: quantitative, field data correlation
Outcome Focus: occupant, health

Abstract

During the last decade an increasing amount of studies have investigated the relationship between air pollution and human health effects. In this study we investigate how these effects in turn induce reduced labour productivity in terms of sick-leaves, which is an important factor in assessment of air pollution costs in urban

areas. For this purpose we employ a logit model along with data on sick-leaves from a large office in Oslo and different air pollutants. Our results indicate that sick-leaves are significantly associated with particulate matter (PM_10), while the associations with SO_2 and NO_2, are more ambiguous. We also try to estimate the induced social costs in terms of lost labour productivity and increased governmental expenditures, although these estimates are more uncertain.

Hansen, A. C. and H. K. Selte (2000). Air Pollution and Sick Leaves. Environmental and resource Economics. **16:** 31-50.
Geographical Location: Europe, Norway
Building Type: Office
Data Type:
Outcome Focus:

Abstract

During the last decade an increasing amount of studies have investigated the relationship between air pollution and human health effects. In this study we investigate how these effects in turn induce reduced labour productivity in terms of sick-leave, which is an important factor in assessment of air pollution costs in urban areas. For this purpose we employ a logit model along with data on sick-leave from a large office in Oslo and different air pollutants. Our results indicate that sick leaves are significantly associated with particulate matter (PMlO), while the associations with SO2 and NO2, are more ambiguous. We also try to estimate the induced social costs in terms of lost labour productivity and increased governmental expenditures, although these estimates are more uncertain.

Hansen, H. L. and S. O. Hanssen (2002). Education, Indoor Environment and HVAC Solutions in School Buildings – Consequences of Differences in Paradigm Shifts. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Norway
Building Type: School
Data Type:
Outcome Focus:

Abstract

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

Hartkopf, V., V. Loftness, et al. (1997). An integrated approach to design and engineering of intelligent buildings--The Intelligent Workplace at Carnegie Mellon University. Automation in Construction. **6:** 401-415.
Geographical Location: USA
Building Type: Office
Data Type: Case Studies; quantititive
Outcome Focus: operation, efficiency

Abstract

In the past few years, there have been significant advances made in the design and engineering of "intelligent" workplaces, buildings that not only accommodate major advances in office technology but provide better physical and environmental settings for the occupants. This paper will briefly present recent approaches to the creation of innovative environments for the advanced workplace. The architectural and engineering advances demonstrated in Japan, Germany, North America, the United Kingdom, and France can be summarized in four major system categories: (1) enclosure innovations including approaches to load balancing, natural ventilation, and daylighting; (2) heating, ventilation and air-conditioning (HVAC) system innovations including approaches to local control and improved environmental contact; (3) data/voice/power "connectivity" innovations; and (4) interior system innovations, including approaches to workstation and workgroup design for improved spatial, thermal, acoustic, visual, and air quality.

In-depth international field studies of over 20 intelligent office buildings have been carried out by a multidisciplinary expert team of the Advanced Building Systems Integration Consortium (ABSIC) based at Carnegie Mellon University. ABSIC is a university-industry-government partnership focused on the definition and development of the advanced workplace. The ABSIC field team evaluated the component and integrated system innovations for their multidimensional performance qualities, through expert analysis, occupancy assessments, and field diagnostics.

Based on the results of the case studies and building on the most recent technological advances, the ABSIC team developed the concepts for the Intelligent Workplace, a 7000 square foot living laboratory of office environments and innovations. This project is now under construction at Carnegie Mellon University and its features are discussed in the second section of this paper.

Hartkopf, V. and V. Loftness (1999). "Global relevance of total building performance." Automation in Construction **8**(4): 377-393.
Geographical Location: USA
Building Type: Office
Data Type: Case Studies; quantititive
Outcome Focus: operation, efficiency

Abstract

Global population and environmental trends demand a radical departure from current building and developmental processes. Applying total building performance thinking can reduce energy consumption, pollution and waste in existing and new construction by a factor of 4 and simultaneously can improve quality of life within buildings—measured through occupant satisfaction, health and productivity. The further development of advanced energy and water systems, and the application of appropriate technology and systems integration concepts will help to enable the elimination of `waste-streams', avoiding obsolescence, as well as managing industrial and agricultural nutrient streams. Instead of treating buildings and their contents as `pre-garbage', worse `pre toxic-waste', all material flows can be considered within life cycles for `cradle to cradle' use. These concepts can make major contributions

towards the creation of more sustainable lifestyles with even greater quality in the industrialized countries and the development and implementation of sustainable urban and building infrastructures in rapidly emerging economies. Rather than the continued export of non-sustainable building solutions, this paper argues for the development and demonstration of such practices in the industrialized countries that would create a progressive `pull' to enable the appropriate implementation of new practices.

Hathaway, W. E. (1994). A study into the effects of types of light on children - a case of daylight robbery.
Geographical Location: Canada
Building Type: school
Data Type: quantitative; case study; measurements, on-site
Outcome Focus: occupant, productivity; occupant, health

Abstract

Based on a review of the literature and a pilot study conducted from 1981 to 1985, a study was carried out that examined physical development and school performance effects of different lighting systems on elementary students. Students' dental health, growth and development, attendance, and academic achievement were examined under four different types of lighting: (a) full spectrum fluorescent lamps, (b) full spectrum fluorescent lamp with ultraviolet light enhancements, (c) cool white fluorescent lamps, and (d) high pressure sodium vapour lamps. Data on 327 students, in grade 4 at the end of the 1986-1987 school year, were collected at the start and the conclusion of the study, which spanned 2 years. The results indicated that over the 2 year period, students under full spectrum fluorescent lamps with ultraviolet supplements developed fewer dental cavities and had better attendance, achievement and growth and development than students under other lights. Students under the high pressure sodium vapour lamps and the slowest rates of growth and development as well as the poorest attendance and achievement. On the basis of the findings of this study it was concluded that lights have important non-visual effects on students who are exposed to them on a regular basis in classrooms.

Haverinen, U., J. Pekkanen, et al. (2002). Evaluating Effects of Moisture Damage Repairs on Students Health Using Questionnaires. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Finland
Building Type: School
Secondary
Data Type:
Outcome Focus:

Abstract

Symptom questionnaire responses were collected from upper secondary and high school students (n=245) before comprehensive repairs of moisture damage in the school unit. The questionnaire study was repeated one year (n=227) and three years (n=256) after the repairs. The data was analyzed both cross-sectionally including all respondents, and longitudinally including paired observations for those individuals who had responded both before and after the repairs. Compared to the situation before the repairs, the situation after the repairs was significantly improved in most of the 20 symptoms studied among the whole population. However, the improvement was not so clear in the paired analysis and regression analysis among the students who had responded to all three questionnaires. The results indicate that the repairs succeeded in terms of that new cases of symptomatic students were no longer expected. However, the situation of the group of exposed individuals may need to be considered separately.

Heath, G. A. and M. J. Mendell (2002). Do Indoor Environments in Schools Influence Student Performance? A Review of the Literature. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA
Building Type: School
Data Type: review
Outcome Focus: occupant, productivity

Abstract

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

Hedge, A. (1984). "Evidence of a relationship between office design and self-reports of ill health among office workers in the United Kingdom." Journal of Architectural and Planning research **1**: 163-174.

Heerwagen, D. R. and G. H. Orians (1986). Adaptation to Windowlessness: A Study of the Use of Visual Decor in Windowed and Windowless Offices. Environment and Behavior. Journal. **18:** 623-639.
Geographical Location: USA, Seattle
Building Type: Office, University
Data Type: qualitative, survey
Outcome Focus: Occupant well-being
occupant response

Abstract

This research examines the use of visual material to decorate windowed and windowless offices. Three hypotheses were tested: (1) Occupants of windowless offices should put up more visual materials than do occupants of windowed offices to compensate for the stimulus deprivation; (2) visual materials in windowless offices should consist of more "surrogate views" (e.g., landscapes and cityscapes) than the visual materials in windowed offices where real views are present : and (3) visual decor in windowless offices should be dominated by materials with a nature content. A detailed content analysis of wall decor used in 75 offices on the University of Washington campus was conducted. Results show that occupants of windowless space used twice as many (195 versus 82) visual materials to decorate their offices. Further, materials in windowless offices were dominated by nature themes as predicted in hypothesis 3. Although windowless occupants did not use significantly more "surrogate views" overall than did occupants of windowed spaces, content of the surrogate views was significantly different for the two windowed conditions. People in windowless offices used more landscapes and fewer cityscapes than did occupants of windowed spaces.

Heerwagen, D. R. (1990). Affective Functioning, "Light Hunger", and Room Brightness Preferences. Environment and Behaviour. **22:** 608-635.
Geographical Location: USA, Seattle
Building Type: office
Data Type: qualitative, questionnaire, on-site, Measurements, laboratory
Outcome Focus: Occupant, health
Occupant, response

Abstract

In this study, room brightness preferences of two groups of subjects were tested across an eight month period in a lighting simulation laboratory. Subjects were selected on the basis of their responses to the Seasonal Pattern Assessment Questionnaire (SPAQ) used by researchers to screen for seasonal affective disorder (SAD). One group of 10 subjects scored high on the SPAQ, indicating seasonal changes in mood and behaviour. A control group matched on age and gender did not experience seasonal changes in any of the symptoms measured by the SPAQ. The study tested two hypotheses: (a) people with SAD are "light hungry" and should prefer a more brightly lighted room; and (b) if "light hunger" is seasonal, then the SAD group should prefer brighter light in the winter than in the spring months. Results indicate that the SAD group preferred a more brightly lighted room than did the control group across all testing sessions, thus supporting the first hypothesis. Because lighting levels did not differ significantly across the testing sessions, light hunger does not appear to be a seasonally expressed need. The SAD group had significantly higher levels of negative affect and depression across the testing sessions than did the control group. However, the SAD-like symptoms did not disappear in June, as expected. These findings suggest that (a) the SAD group did not, in fact, have SAD; or (b) testing did not occur long enough to measure mood and behaviour changes. Results are discussed in terms of vulnerability to affective episodes and lack of light in the environment.

Heerwagen, J. H. (1998a). Design, Productivity and Well Being: What are the Links? The American Institute of Architects Conference on Hightly Effective Facilities. Cincinnati. USA.
Geographical Location: USA
Building Type: office
Data Type: literature review
Outcome Focus: Occupant, health
Occupant, well-being
Occupant, productivity
Operation, Energy
Operation, Environmental

Abstract

There is a growing recognition that to be truly effective, a facility will need to succeed across three interrelated domains: environmental sustainability, organizational effectiveness, and human well being. The sustainable design community that "green" buildings may be a vehicle by which benefits in all three domains can be achieved.

This article draws upon a study founded by the U.S. Department of Energy (Building, Technology, state and Community Programs) to identify and assess the "ancillary benefits" of green buildings, but which are not directly related to its energy efficiency and green features. The project analyzed both individual and organizational level outcomes.

Heerwagen, J. H. (1998b). Of Light, Time and Space: Lighting Quality and Green Building Design. Proceedings of the First CIE Symposium on Lighting Quality. Ottawa, Canada.

Geographical Location: USA, Michigan
Building Type: office
Data Type: qualitative, quantitative, questionnaire, on-site, before and after approach, measurements, on-site
Outcome Focus: occupants, well-being
occupants, health

Abstract

There is increasing interest in the United States and internationally in "healthy buildings" - that is, buildings that positively affect occupants. The interest has focused largely on improving indoor air quality. However, the notion of "healthy' buildings is much broader, and should include an array of benefits. In the United States, there has been increasing attention to energy efficient, "green" building as a vehicle for delivering high quality interior environments.

If occupant benefits of green buildings are as substantial as thought, understanding how workers perceive and experience them is an important step toward designing green facilities that are truly supportive of human performance and well-being. The research described in this paper was funded by the U.S Department of Energy (Office of Building, Technology, state and Community programs), to develop a protocol to identify and assess the "ancillary" benefits of green buildings. ancillary benefits are defined as positive outcomes that occur as a result of the green building but that are not directly related to design goals for energy efficiency and environmental sustainability.

Heerwagen, J., J. Johnson, et al. (1999). Energy Effectiveness and the Ecology of Work: Links to Productivity and Well-Being.

Geographical Location: unknown
Building Type: office
Data Type: theory
Outcome Focus: occupant, well being; occupant, productivity

Abstract

In general, research on the positive outcomes of buildings lags behind research on problems and discomforts. A similar state exists in the field of medicine. We know far more about what makes us sick than what makes us healthy. However, we also know that the mere absence of bad habits does not by itself promote good health. Healthiness derives from a very different set of characteristics - including one's social network, psychological hardiness, general outlook on life, and a perceived sense of control over life situations. Research and theory in environmental psychology suggests that a similar situation exists in buildings. That is, the mere absence of discomforts and problems may not by itself produce high states of well being and performance. Realisation of well-being and performance benefits may depend upon the degree to which a building directly or indirectly affects psychological and cognitive functioning and physical health.

An accumulating body of research in cognitive neuroscience, health psychology, and organisational behaviour suggests that the physical environment can play a role in cultivating high states of well being and performance. While some of these features and attributes are directly related to energy efficient design, others have more indirect, and less obvious linkages.

In this paper, we look at research on factors affecting human performance, with an emphasis on information and knowledge based work. The paper includes a discussion about the effects of building design features on performance, well being, and comfort. We explore the energy linkages, both direct and indirect, in the final section of the paper.

Heerwagen, J. (2000). Green Buildings, Organizational Success and Occupant Productivity. Building Research & Information. **28:** 353-367.
Geographical Location: USA, Europe, General
Building Type: Office
Data Type: Literature Review
Outcome Focus: Occupant, health
Occupant, Productivity
Occupant, well-being
Operation, Energy
Operation, Maintenance
Operation, Environmental

Abstract

Can 'green' buildings positively contribute to business performance and organizational effectiveness? Can 'green' buildings affect high-level organizational outcomes, such as profitability, customer satisfaction and innovation? How do the physical attributes of green buildings affect the physiological, psychological, cognitive and social functioning of building occupants at the individual level? This paper explores the wider context of sustainable design, integrating work form organizational effectiveness and human factors to suggest that 'green' buildings provide economic and organizational benefits for business

Heller, J. F., B. D. Groff, et al. (1977). "Toward an understanding of crowding: The role of physical interaction." Journal of Personality and Social Psychology **35**: 183-190.

Heller, J. F., B. D. Groff, et al. (1977). Toward an understanding of crowding: The role of physical interaction. Journal of Personality and Social Psychology. **35:** 183-190.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Heschong, L. (1999). Daylighting in Schools: An investigation into the Relationship between daylighting and human performance. detailed and summary version, Heschong Mahone Group.
Geographical Location: USA
Building Type: school
Data Type: survey, quantitative
Outcome Focus: occupant, productivity

Abstract

This study looks at the effect of daylighting on human performance. It includes a focus on skylighting as a way to isolate illumination effects from other qualities associated with daylighting from windows, such as view and ventilation. In this project, we established a statistically compelling connection between daylighting and student performance, and between skylighting and retail sales. This report focuses on the school analysis.

Heschong, L. (2002a). Daylighting in Schools: Additional Analysis, Heschong Mahone Group.

Geographical Location: USA
Building Type: school
Data Type: quantitative analysis
Outcome Focus: occupant, productivity

Abstract

This study expands and validates previous research by Heschong Mahone Group that found a statistical correlation between the amount of daylight in elementary school classrooms and the performance of students on standardised math and reading tests. This research was performed under the California Energy Commission's Public Interest Energy Research (PIER) Program and was managed by New Buildings Institute.

The researchers reanalyzed the 1997-1998 school year student performance data from the Capistrano Unified School District (California) and the Seattle Public School District (Washington) to answer questions from the peer review panel. The reanalysis findings are as follows:

- Overall, elementary school students in classrooms with the most daylight showed a 21% improvement in learning rates compared to students in classrooms with the least daylight.
- A teacher survey and teacher bias analysis found no assignment bias that might have skewed the original results; more experienced or more educated teachers (better teachers) were not significantly more likely to be assigned to classrooms with more daylighting.
- A grade level analysis found that the daylighting effect does not vary by grade.
- An absenteeism analysis found that physical classroom characteristics (daylighting, operable windows, air conditioning, portable classrooms) are not associated with variations in and do not have an effect upon student absenteeism. This seems to contradict claims that have been made about the health effects of daylight or other environmental conditions, as reflected in absenteeism rates of building occupants.

Heschong, L., R. L. Wright, et al. (2002b). Daylighting Impact on Human Performance in School. Illuminating Engineering Society.

Geographical Location: USA
Building Type: school
Data Type: quantitative, case study, measurements
Outcome Focus: occupant, productivity

Abstract

The purpose of this study was to see if we could demonstrate a clear relationship between the presence of daylight and human performance in buildings. In this study we used a statistical technique called multivariate regression analysis, which analyzes the importance and impact of many variable simultaneously. The performance data used were gathered from 3 school districts. This analysis allowed us to estimate the effect of a wide number of variables and to determine which variables have no significant effect. Using this method, we established a statistically compelling connection between the presence of daylight and student performance.

The implications of the results of this study extend beyond the educational sector. We believe the conclusions may be transferable to other types of buildings, such as offices and factories, since it is really human performance of children in schools, it is not too large a stretch to suppose that it might also enhance the performance of adults in office buildings.

Heslop, K. (2002). Personal and Environmental Characteristics, Occupational Factors and Psychosocial Correlates of Sick Building Syndrome. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: South Africa, Pretoria
Building Type: Office, High-Rise
Data Type:
Outcome Focus:

Abstract

The relationship between personal and environmental characteristics, occupational factors and psychosocial correlates of sick building syndrome was investigated among 348 employees occupying two buildings in South Africa. One building was characterized as 'sick', whilst the other was not a known sick building. There was a significant relationship between several personal characteristics, environmental characteristics, occupational factors and the total number of symptoms reported. Respondents in the 'sick' building had a propensity to remain absent from work for significantly more days, and experienced greater productivity decrements.

Hodgson, A. T., D. Faulkner, et al. (2002). Effect of Outside Air Ventilation Rate on VOC Concentrations and Emissions in a Call-Center. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA, San Francisco
Building Type: Office, Call-Centre
Data Type:
Outcome Focus:

Abstract

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

Holdsworth, B. and A. Sealey (1992). Healthy buildings : a design primer for a living environment. Harlow England, Longman**:** 148.
Geographical Location: Case studies:
Europe, The Netherlands
Africa, South Africa, Johannesburg
Europe, Denmark, Copenhangen
Europe, England
United States, Oregon
Building Type: office, middle rise,
office, low rise
domestic, low rise
domestic, high rise
domestic, house
school
Data Type: literature review, case studies
ECHOES (Environmentally Controlled Human Operational Enclosed/External space) design matrix
Outcome Focus: occupants, health

Abstract

Hopkinson (1972). Glare from daylighting in buildings. Applied Ergonomics. **3:** 206-215.
Geographical Location: USA
Building Type: office
Data Type: measurements
Outcome Focus: occupant, response

Abstract

Glare can be caused by a direct view of the bright sky from the interior of a building. This glare can be an impediment to vision and even a direct hazard, as on a stairway, or it can cause serious or mild discomfort. Even minor effects may accumulate, as with a low but incessant noise, to lead to fatigue during the working day. Both the disabling and annoying effects of glare have been studied in a number of laboratories, and this article summaries some of the most recent conclusions. Glare is a direct function of both the size of the window and the brightness of the sky seen through it, and an inverse function of the brightness of the room interior. Glare can therefore be reduced by cutting down the size and brightness of the visible patch of sky and by increasing the interior brightness by the judicious use of surface areas of high reflectance. These parameters are related in such a way that an aoverall Glare Index for a room can be computed and values of this Glare Index can be set an codified to ensure that tolerance limits will not be exceeded.

Humphreys, M. A. (1998). Understanding the Adaptive Approach to Thermal Comfort. ASHRAE Transactions:Symposia. **104:** 991-1004.
Geographical Location: UK
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This paper explains the adaptive approach to thermal comfort, and an adaptive model for thermal comfort is presented. The model is an example of a "complex adaptive system" (Casti 1996) whose equilibria are determined by the restrictions acting upon it. People's adaptive actions are generally effective in securing comfort, which occurs at a wide variety of indoor temperatures. These comfort temperatures depend upon the circumstances in which people live, such as the climate and the heating or cooling

regime. The temperatures may be estimated from the mean outdoor temperature and the availability of a heating or cooling plant. The evaluation of the parameters of the adaptive model requires cross-sectional surveys to establish current norms and sequential surveys (with and without intervention) to evaluate the rapidity of people's adaptive actions. Standards for thermal comfort will need revision in the light of the adaptive approach. Implications of the adaptive model for the HVAC industry are noted.

Humphreys, M. A., J. F. Nicol, et al. (2002). An Analysis of Some Subjective Assessments of Indoor Air-Quality in Five European Countries. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, France, Greece, Portugal, Sweden, UK
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The country of origin was found to dominate the perception of air quality. Next most important was the respondents' subjective thermal state. Least important was the thermal environment itself. The concentration of CO2 had a slight negative relation to the perceived air quality. The relative humidity affected the perceptions, air quality being rated most highly at moderate levels of humidity. The air temperature did not affect the perceived air quality if the respondents were in thermal comfort. When respondents felt too warm, high temperature and humidity had an adverse effect on the perceived air-quality. When respondents felt too cool, low temperature and humidity had an adverse effect. These results do not support the view that people prefer the air to be dry and cool, but do support the view that combined high temperature and high humidity have an adverse effect on perceived air quality if people are feeling too warm.

Husman, T., T. Meklin, et al. (2002). Respiratory Infections Among Children in Moisture Damaged Schools. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Finland
Building Type: School
Data Type:
Outcome Focus:

Abstract

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

Hyvarinen, A., T. Husman, et al. (2002). Microbial Exposure and Mould Specific Serum IGG Levels of Symptomatic Schoolchildren. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Finland
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

The association between serum mould-specific IgG levels of 181 primary schoolchildren with asthma or wheezing or cough symptoms and the microbial exposure were determined. The study was conducted in a school with mould damage and in another without such damage. Microbial exposure was characterized with environmental sampling. Serum IgG antibody concentrations to 20 microbial strains were determined with ELISA. There was an association between elevated serum IgG levels to Penicillium notatum and moisture damage in the school. In addition, moisture damage when present both in school and at home was associated with elevated IgG levels to Penicillium notatum and Eurotium amstelodami. These observations were in concordance with microbial findings in the index school. No other positive associations between IgG antibodies and microbial findings of the school buildings were observed; in fact, the microbe-specific IgG levels of children were often higher in the reference school.

Illuminating Engineering Society (1995). Lighting Handbook 8th Edition. USA, Illuminating Engineering Society**:** 359-381.
Geographical Location: not applicable
Building Type: commercial, residential
Data Type: theory, measurement, laboratory
Outcome Focus: occupant, comfort
operation, energy

Abstract

IPMVP Committee (2002). International Performance Measurement & Verification Protocol, Concepts and Practices for Improved Environmental Quality, Volume II. Oak Ridge, Tennesee, Office of Scientific and Technical Information, U.S. Department of Energy.
Geographical Location: Brazil; Europe, Bulgaria; Canada; China; Czech Republic; India; Japan; Korea; Mexico; Poland; Russia ;Sweden ;Ukraine; UK; USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This year 2000 edition of International Performance Measurement and Verification Protocol (IPMVP) has been expanded to address indoor environmental quality (IEQ) issues. It provides information that will help energy efficiency professionals and building owners and managers maintain or improve IEQ and occupant health and comfort during the implementation of building energy conservation measures in retrofits or new construction of commercial and public buildings. Volume II focuses exclusively on indoor environmental quality issues (See Preface of Volume I for overview of IPMVP). This volume starts with a general introduction to IEQ. Best practices for maintaining a high level of IEQ are then reviewed. The potential positive and negative influences of specific energy conservation measures on IEQ are summarized in a tabular format in Section 5. The remainder of the document addresses IEQ measurement and verification procedures that may be used to address the following goals: 1) ensure that the energy conservation measures have

no adverse influence on IEQ, 2) quantify the improvements in IEQ resulting from implementation of energy conservation measures, and 3) verify that selected IEQ parameters satisfy the applicable IEQ guidelines or standards. A multi-step procedure for IEQ measurement and verification is presented, followed by a discussion of general approaches for measurement and verification and then by a table of measurement and verification alternatives linked to specific IEQ parameters. This document has been prepared by an international team of IEQ and building energy efficiency experts and reflects the current state of knowledge. The IPMVP, including the IEQ volume will be updated every two years.

Isaacs, P. Achieving Sustainable Building Results from New Processes and Strategies, Flack + Kurtz Australia.

Geographical Location: Australia
Building Type: office
Data Type: qualitative, case study
Outcome Focus: operation, energy
occupant, comfort

Abstract

Sustainable Design of buildings is not an add-on technology. It is a new way of thinking involving a holistic approach. It requires the early establishment of team responsibilities, environmental goals and evaluation criteria together with agreed processes for value management and life-cycle cost analysis. Key advancing technologies and approaches are in the areas of green house gas abatement and indoor comfort conditions. The concept of energy neutral buildings utilising transitional gas-fuelled energy systems combined with renewable energy systems has emerged as an affordable strategy for greenhouse gas abatement. "New age" building will not only save energy, they will harvest it. The new CSIRO Energy Centre being constructed near Newcastle NSW illustrates a typical means of achieving sustainable building results.

Jackson, Q. and M. Donn (2002). Daylighting in Offices, Does the Availability of Daylight Affect Productivity? ANZASCA 2002. Deakin.

Geographical Location: New Zealand
Building Type: office
Data Type: measurements, on-site
Outcome Focus: occupant, productivity
occupant, response

Abstract

The aim of this study is to determine whether there is a discernable difference in productivity between people working under natural lighting conditions, and people under artificial lighting conditions in an office environment.

The Case Study building was the Schools of Architecture and Design in Wellington, and included six offices on perimeter of the building. Each person was tested eight times two times at night, three times under cloudy skies and three under clear skies.

In order to ascertain people's productivity levels, two tests were employed: a letter-counting task (both on a computer screen and on paper) to determine actual productivity; followed by a Building Evaluation Survey that determined perceived productivity. These tests were accompanied by measurements of illuminance at the working plane and luminance ratios around the computer screen. Analysis revealed that neither technique produced a significant correlation between daylight and productivity. The research team is now working to develop other tools with which to explore the size of the correlation reported in anecdote.

Jitkhajornwanich, K., A. C. Pitts, et al. (1998). Thermal Comfort in Transitional Spaces in the Cool Season of Bangkok. ASHRAE Transactions:Symposia. **104:** 1181-1193.
Geographical Location: Thailand, Bangkok
Building Type: Office
Data Type: survey, on-site
Outcome Focus: occupant, comfort

Abstract

A field survey of 593 subjects occupying both indoor (air-conditioned and naturally ventilated) and outdoor environments was carried out. The focus of the survey dealt with experience of transitional spaces of buildings in the cool season of Bangkok, Thailand. This paper presents the results of the survey. which were compiled and analyzed in the following order: expectation, sensation, preference, and adaptation. The data are also compared with previous research of office environments in Bangkok. The results from the analysis show two important aspects. First, the neutral temperature for the whole sample is 27.1°C (80.8°F) and thermal acceptability is between 25.5°C (77.9°F) and 31.5°C (88.7°F), whereas the expected temperature is 26.7°C (80.1°F). As might be expected, the majority would prefer a "cooler" environment. The results are in good agreement with those of previous research but are beyond the upper limit of International standard ISO 7730. Second, it is shown that the thermal responses of each group are influenced by the acclimatized characteristics of their environmental conditions. The work described here is part of a larger thermal comfort study and program to optimize comfort in buildings in warm climates.

Jones, A. P. (1999). Indoor Air Quality and Health. Atmospheric Environment. **33:** 4535-4564.
Geographical Location: UK
Building Type: Office
Data Type:
Outcome Focus:

Abstract

During the last two decades there has been increasing concern within the scientific community over the effects of indoor air quality on health. Changes in building design devised to improve energy efficiency have meant that modern homes and offices are frequently more airtight than older structures. Furthermore, advances in construction technology have caused a much greater use of synthetic building materials. Whilst these improvements have led to more comfortable buildings with lower running costs, they also provide indoor environments in which contaminants are readily produced and may build up to much higher concentrations than are found outside. This article reviews our current understanding of the relationship between indoor air pollution and health. Indoor pollutants can emanate from a range of sources. The health impacts from indoor exposure to combustion products from heating, cooking, and the smoking of tobacco are examined. Also discussed are the symptoms associated with pollutants emitted from building materials. Of particular importance might be substances known as volatile organic compounds (VOCs), which arise from sources including paints, varnishes, solvents, and preservatives. Furthermore, if the structure of a building begins to deteriorate, exposure to asbestos may be an important risk factor for the chronic respiratory disease mesothelioma. The health effects of inhaled biological particles can be significant, as a large variety of biological materials are present in indoor environments. Their role in inducing illness through immune mechanisms, infectious processes, and direct toxicity is considered. Outdoor sources can be the main contributors to indoor concentrations of some contaminants. Of particular significance is Radon, the radioactive gas that arises from outside, yet only presents a serious health risk when found inside buildings. Radon and its decay

products are now recognised as important indoor pollutants, and their effects are explored. This review also considers the phenomenon that has become known as Sick Building Syndrome (SBS), where the occupants of certain affected buildings repeatedly describe a complex range of vague and often subjective health complaints. These are often attributed to poor air quality. However, many cases of SBS provide a valuable insight into the problems faced by investigators attempting to establish causality. We know much less about the health risks from indoor air pollution than we do about those attributable to the contamination of outdoor air. This imbalance must be redressed by the provision of adequate funding, and the development of a strong commitment to action within both the public and private sectors. It is clear that meeting the challenges and resolving the uncertainties associated with air quality problems in the indoor environment will be a considerable undertaking.

Kaczmarczyk, J., Q. Zeng, et al. (2002). The Effect of a Personalized Ventilation System on Perceived Air Quality and SBS Symptoms. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Perceived air quality, SBS symptoms and performance were studied with 30 human subjects. Experiments were performed in an office set-up with six workplaces, each equipped with a Personalized Ventilation System (PVS). Each PVS allowed the amount of supply air and its direction to be controlled. Subjects participated in four experiments: (1) PVS supplying outdoor air at 20°C; (2) PVS supplying outdoor air at 23°C; (3) PVS supplying recirculated room air; and (4) mixing ventilation. Room temperature was kept constant at 23°C and relative humidity at 30%. Results showed that the best condition in regard to perceived air quality, perception of freshness and intensity of SBS symptoms was when PVS supplied outdoor air at 20°C. Perceived air quality in this case was significantly better ($p<0.01$) than with mixing ventilation. Supplying outdoor air by means of the PVS decreased complaints of headache, and improved the ability to think and to concentrate.

Katchen, M., A. LaPierre, et al. (2001). Evaluating the Potential Health Risks in Relocatable Clasrooms. The Journal of School Health. **71:** 159–161.
Geographical Location: USA, California
Building Type: School
Data Type:
Outcome Focus:

Abstract

Katchen et al discuss the potential exposures associated with portable classroom use. General guidelines for successful health evaluation in relocatable classrooms are featured.

Kato, H., Y. Mizuno, et al. (1996). Environmental Factors Influencing Sensitization and Onset of Japanese Cedar Pollinosis among Junior High School Students. Japanese Journal of Public Health. **43:** 390-397.
Geographical Location: Japan
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

Japanese cedar pollinosis has shown large increases especially in city areas, rather than in the rural, with increases being remarkable especially among people of young age. In order to elucidate factors for sensitization and onset of Japanese cedar pollinosis, a questionnaire survey was conducted and serum IgE antibody levels examined in junior high school students living in three different areas, i.e., city, seaside and mountainous areas in Aichi prefecture. Prevalence rate of Japanese cedar pollinosis, estimated from the number of students having both nasal or ocular allergic symptoms and positive RAST, was the 30.1% in the mountainous area with high Japanese cedar pollen count, being greater than the 15.3% in the city area and the 5.8% in the seaside area, both with low pollen counts. Among the students showing high serum mite (Dermatophagoides farinae) antibody levels, greater positive rates for sensitization to Japanese cedar or orchard grass pollens was observed, compared to mite-unsensitized students. This result suggests that sensitization to seasonal antigens may be corresponding to the capability for sensitization to the mites. Besides this finding, the analysis of replies to the questionnaires showed that students living in concrete or steel-frame buildings had greater serum levels of antibody to Japanese cedar pollen than those living in wood buildings, indicating a possible relationship between the pollen sensitization and indoor environments.

Kats, G., L. Alevantis, et al. (2003). The Costs and Financial Benefits of Green Buildings. Sacramento, California, Californian Sustainable Building Task Force**:** 134.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Integrating “sustainable” or “green” building practices into the construction of state buildings is a solid financial investment. In the most comprehensive analysis of the financial costs and benefits of green building conducted to date, this report finds that a minimal upfront investment of about two percent of construction costs typically yields life cycle savings of over ten times the initial investment. For example, an initial upfront investment of up to $100,000 to incorporate green building features into a $5 million project would result in a savings of at least $1 million over the life of the building, assumed conservatively to be 20 years.1

The financial benefits of green buildings include lower energy, waste disposal, and water costs, lower environmental and emissions costs, lower operations and maintenance costs, and savings from increased productivity and health. These benefits range from being fairly predictable (energy, waste, and water savings) to relatively uncertain (productivity/health benefits). Energy and water savings can be predicted with reasonable precision, measured, and monitored over time. In contrast, productivity and health gains are much less precisely understood and far harder to predict with accuracy.

There is now a very large body of research, reviewed in this report, which demonstrates significant and causal correlation between improvements in building comfort and control measures, and worker health and productivity. However, these

studies vary widely in specific measured correlations. Further, there has been relatively little work completed to evaluate specific, measurable benefits from green building design in California. Clearly, the benefits are significant and not zero, but the data supports a broad range of calculated benefits – in contrast to the more precisely measurable energy, water, and waste savings.

The financial benefits conclusions in this report should therefore be understood in this context. Energy, waste, and water savings as well as emissions reductions can be viewed as fairly precise, reasonably conservative estimates of direct benefits that alone significantly exceed the marginal cost of building green. Health and productivity benefits can be viewed as reasonably conservative estimates within a large range of uncertainty. Further research is necessary to better quantify and capture the precise savings associated with these benefits. Additional studies might include such measures as evaluating green building effects on insured and uninsured health effects, employee turnover, worker well being and, where relevant (e.g. in schools), test scores.

Katzev, R. (1992). The Impact of Energy-efficient Office Lighting Strategies on Employee Satisfaction and Productivity. Environment & Behavior. **24:** 759.
Geographical Location: Canada, Nova Scotia
USA, Seattle
Building Type: Office
Data Type: Quantitative, qualitative, questionnaire, on-site, measurements, laboratory subjects: office employees
laboratory experiment
Outcome Focus: occupants, productivity
occupants, well-being

Abstract

Investigated the productivity, preferences, and affective impact of energy-efficient (ENF) office lighting systems. 24 office personnel were exposed to 4 lighting strategies for a normal workday, spending over 1.5 hrs in each office-lab. The Ss' behaviour was measured on a variety of computer-presented tasks that might occupy them during a normal workday. ENF lighting had a modest impact on performance. With the exception of reading comprehension, there were no differences between the office-labs on the cognitive/intellectual measures of performance. This was true for the error detection task, the spreadsheet entry task, and the brief typing task. Limited support was found for the effect of lighting on mood. However, only a few such states were sampled, and the focus was on negative rather than positive states. (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Kelly, T. (1999). Measuring the ROI of IAQ. Buildings. **93:** 52–54.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Over the last decade, indoor air quality (IAQ) has been a widely debated and publicized topic, drawing the attention of many businesses, industries, and governmental agencies. In that same time span. building occupants have become increasingly concerned and vocal about the overall quality of the air they breathe in the workplace. While many solutions have been developed to address IAQ issues, many building owners and facilities managers have not been quick to take advantage of them. The issue is generally addressed on a reactive basis. Occupant complaints or, even worse, a lawsuit or loss of tenants often serve as the primary drivers behind IAQ initiatives. Seldom is an investment in IAQ considered on the same basis as

other capital investments which is to ask, "what kind of financial return can be expected from the expenditure'?" Yet, surprising to many facilities professionals, there can be a fiscal return on investment (ROI) made to improve IAQ, and it can be calculated in advance. What's even more surprising is that the payback, which entails things like productivity gains made by occupants, can actually eclipse payback on investments made for other types of improvements, such as energy efficiency.

Kemp, P. C., P. Dingle, et al. (1998). Particulate Matter Intervention Study: a Causal Factor of Building-Related Symptoms in an Older Building. Indoor Air. **8:** 153-171.
Geographical Location: Europe, Germany, Berlin
Building Type: Office, High-Rise
Data Type:
Outcome Focus:

Abstract

Five floors of a 20-year old 6-story office building were investigated using an integrated step-by-step investigation strategy. This involved a walkthrough inspection, an occupant questionnaire, and targeted environmental monitoring of indoor air quality and comfort parameters. The initial questionnaire survey revealed a high occurrence of building-related symptoms. The walkthrough inspection and environmental monitoring identified deposits of surface dust (indoor surface pollution - ISP) on carpets and hard surfaces, and elevated levels of carbon dioxide and respirable suspended particulate matter (RSP) throughout the building. An intervention study (blinded to the occupants) was targeted at reducing 15P levels by replacing normal carpet cleaning practices with higher performance vacuum cleaners and improved cleaning practices. The intervention reduced 15P levels and significantly lowered R5P concentrations by approx. 80% from initial values and against control floors. A follow-up 585 questionnaire revealed significant reductions in all but two of the symptoms. The most significant reductions occurred with symptoms of eye irritation, throat irritation, dry unproductive cough, and nose irritation. The study showed that in older buildings with poor ventilation, a buildup of 1SP, and elevated RSP levels, using higher performance carpet cleaning practices can reduce RSP to acceptable levels and can reduce 585 symptoms.

Kinshella, M. R., M. V. Van Dyke, et al. (2001). Perceptions of Indoor Air Quality Associated with Ventilation System Types in Elementary Schools,. Applied Occupational and Environmental Hygiene. **16:** 952-960.
Geographical Location: U.S.A., Colorado, Denver
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

With the increased utilization of school buildings on a year-round basis, school indoor air quality has become a national concern. The purpose of this study was to evaluate possible associations between ventilation system type and occupant perception of indoor air quality. Staff (n =403) from12 schools completed a self-administered questionnaire. Carbon dioxide (CO2) levels, air exchange rates, and particle counts were also measured for each school. Schools with unit ventilator (UV) systems had the lowest mean CO2 level at 637 ppm, followed by the variable air volume (VAV) systems with 664 ppm, and constant volume (CV) systems with a mean of 703 ppm. Schools with UV systems had the lowest mean air exchange rate at 2.67 air changes per hour (ACH), followed by the VAV system type at 2.80 ACH and the CV system type at 4.61 ACH. Indoor versus outdoor particle ratios were calculated for each ventilation system type. Particles with aerodynamic diameters ranging from 0.1-1.0 ¹m had a geometric mean ratio ranging from 0.38 to 0.68; particles with aerodynamic

diameters ranging from 1-3 ¹m had ratios ranging from 1.39 to 5.47, and particles with aerodynamic diameters greater than 3 ¹m had ratios ranging from 3.20 to 14.76. Schools using VAV systems had a significantly lower prevalence of red and watery eyes while schools with UV systems had an elevated prevalence of nasal congestion, sore throat, headache, and dustiness complaints. This increased prevalence of complaints in buildings with UV systems may be due to the increased particulate levels.

Kirchner, S., N. Pasquier, et al. (2002). The French Permanent Survey on Indoor Air Quality Survey in Dwellings and Schools. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, France
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

Decided by the French Government in 1999, the permanent survey on indoor air quality provides data for risk assessment and risk management related to exposure to indoor air pollution. Among the potential investigated indoor spaces including all types of indoor environments (excluding industrial ones), dwellings and schools were identified as priority for the first investigations. The first survey includes 1) measurements on 40 priority indoor parameters: COV, NO2, CO, CO2, bacteria, moulds, allerge ns, MMMF, temperature, humidity, 2) questionnaires on building characteristics, occupants description and time activities diaries. For radon, lead and asbestos existing database will be assessed. For particulate matters, legionella and biocides, specific measurement methods are being developed for later inclusion in the survey. A pilot survey has been conducted in 2001 on 99 sites. A full-scale survey on 800 investigation sites should start from 2002. The selection of buildings will aim at a representative sampling of the French building stock.

Klitzman, S. and J. Stellman (1989). The impact of the physical environment on the psychological well being of office workers. Social Science and Medicine. **29:** 733-742.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Knez, I. (1995). Effects of indoor lighting on mood and cognition. Journal of Environmental Psychology. Journal. **15:** 39-51.
Geographical Location: Europe, Sweden
Building Type: office
Data Type: qualitative, quantitative, questionnaire, on site. Laboratory measurements, Laboratory
Outcome Focus: occupant performance

Abstract

The impact of indoor lighting, gender, and age on mood and cognitive performance was examined in a between-subject experiment. It was hypothesized that indoor lighting is an affective source that may convey emotional meanings differentiated by gender, age, or both. A two-way interaction between type of lamp and age on negative mood showed that younger adults (about 23 years old) best preserved a negative mood in the "warm" (more reddish) white lighting while working with a battery of cognitive tasks for 90 minutes; for the older adults (about 65 years old),

"cool" (more bluish) white lighting accounted for the identical effect. The younger females were shown to preserve the positive mood as well as the negative mood better than the younger males, and a main effect of age in all cognitive tasks revealed the superiority of younger to older adults in cognitive performance.

Knez, I. and I. Enmarker (1998). Effects of office lighting on mood and cognitive performance and a gender effect in work-related judgment. Environment and Behaviour. **30:** 553-567.
Geographical Location: Sweden
Building Type: office
Data Type: questionnaire, measurements, laboratory
Outcome Focus: occupant, response

Abstract

The study presents an investigation of the effects of the recommended office lighting on subjects' mood and cognitive performance in the physical setting of an office. In addition, a gender effect in the performance appraisal task was examined, both as a between- and within-subject factor. The results showed no significant effect of the lighting on the performance of cognitive tasks. However, an interaction between gender and colour temperature on mood showed that 3000K (reddish) and 4000K (bluish) office lighting may communicate different affective loadings or meanings to each gender.

Knez, I. and C. Kers (2000). Effects of indoor lighting, gender, and age on mood and cognitive performance. Environment and Behavior. **32:** 817-831.
Geographical Location: Sweden
Building Type: office
Data Type: measurements, laboratory, interview
Outcome Focus: occupant, response

Abstract

The impact of indoor lighting, gender, and age on mood and cognitive performance was examined in a between-subject experiment. It was hypothesized that indoor lighting is an affective source that may convey emotional meanings differentiated by gender, age, or both. A two-way interaction between type of lamp and age on negative mood showed that younger adults (about 23 years old) best preserved a negative mood in the "warm" (more reddish) white lighting while working with a battery of cognitive tasks for 90 minutes; for the older adults (about 65 years old), "cool" (more bluish) white lighting accounted for the identical effect. The younger females were shown to preserve the positive mood as well as the negative mood better than the younger males, and a main effect of age in all cognitive tasks revealed the superiority of younger to older adults in cognitive performance.

Kowalski, W. J. (2000). Indoor Mould Growth: Health Hazards and Remediation. Heating/Piping/Air Conditioning Engineering : HPAC. **72:** 80.
Geographical Location: USA, Pennsylvania
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The writer discusses the health hazards and remediation of indoor mould growth. The topics covered include the specific health problems associated with mould growth, sick building syndrome, the organisms responsible, the origin of fungal spores, the causes of fungal growth, and the measures that can be taken to prevent it.

Kumar, S. and W. J. Fisk (2002). IEQ and the Impact on Building Occupants. Commercial Building Ventilation & Indoor Environmental Quality. **44:** 50-52.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Research into indoor environmental quality (IEQ) and its effects on health, comfort and performance of occupants is becoming increasingly essential. Facility managers are interested in IEQ's close relationship to energy use. Employers hope to enhance employee comfort and productivity, reduce absenteeism and health-care costs, and reduce risk of litigation. The rising interest in this field has placed additional pressure on the research community for practical guidelines on creating a safe, healthy and comfortable indoor environment.

Kumar, S. and W. J. Fisk (2002). The Role of Emerging Energy-Efficient Technology in Promoting Workplace Productivity and Health: Final Report. Berkley, California, Lawrence Berkley National Laboratory.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Research into indoor environmental quality (IEQ) and its effects on health, comfort, and performance of occupants is becoming an increasing priority as interest in high performance buildings and organizational productivity advances. Facility managers are interested in IEQ's close relationship to energy use in facilities and employers want to enhance employee comfort and productivity, reduce absenteeism and health costs, and reduce or even eliminate litigation by providing excellent indoor environments to employees. The increasing interest in this field as architects, engineers, facility managers, building investors, health officials, jurists, and the public seek simple and general guidelines on creating safe, healthy, and comfortable indoor environment, has put additional pressure on the research community. In the last twenty years, IEQ researchers have advanced our understanding of the influence of IEQ on health and productivity, but many uncertainties remain. Consequently, there is a critical need to expand research in this field, particularly research that is highly multidisciplinary. In addition, there is a strong need to better communicate knowledge currently documented in research publications to building professionals in order to encourage implementation of designs and practices that enhance health and productivity. Against this background, the Indoor Health and Productivity (IHP) project aims to develop a fuller understanding of the relationships between physical attributes of the workplace (e.g. thermal, lighting, ventilation, and air quality) in nonresidential and non-industrial buildings and the health and productivity of occupants. A particular emphasis of the IHP project is to identify and communicate key research findings, with their practical and policy implications, to policymakers, design practitioners, facility managers, construction and energy services companies, and building investors.

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Kumar, S. and W. J. Fisk (2002). IEQ and the Impact on Employee Sick Leave. ASHRAE Journal. **July:** 97-98.
Geographical Location: USA, Massachusetts
Building Type: Office
Data Type:
Outcome Focus:

Abstract

When selecting minimum ventilation rates, employers should balance the well-recognized energy costs of providing higher minimum ventilation rates with the expected, but less well quantified, health benefits from a higher ventilation rate. This is a summary of the paper by Milton, et al. that found low employee sick leave associated with high ventilation rates in a set of buildings located in Massachusetts. A simple cost-benefit analysis also is presented.

Küller, R. and C. Lindsten (1992). Health and Behaviour of children in classrooms with and without windows. Journal of Environmental Psychology, Academic Press Ltd. **12:** 305-317.
Geographical Location: Sweden
Building Type: school
Data Type: measurements, on-site
Outcome Focus: occupant, health

Abstract

The aim of the study were to assess the effects of light on the production of stress hormones, classroom performance, body growth, and sick leave, of school children

Küller, R. and L. Wetterberg (1996). The subterranean work environment: impact on well-being and health. Environment International. **22:** 33-52.
Geographical Location: Sweden
Building Type: office
subterranean
Data Type: measurements, on-site
Outcome Focus: occupant, health
occupant, response

Abstract

The purpose of the present study was to compare subterranean environments with environments above ground. More specifically, the study focused on the impact of reduced diurnal and seasonal variations and reduced sensory stimulation for persons working underground. The spaces below ground were perceived to be more enclosed, the lighting was considered to be less bright and less pleasant, and there were complaints of visual fatigue. Light measurements showed that the illuminances were on the average twice as high in the offices above ground. There was somewhat more noise in the subterranean environments. The level of morning cortisol displayed a substantial annual variation in personnel above ground, whereas the annual variation below ground was much less pronounced. Also, the afternoon level of cortisol was lower for the personnel working in the subterranean environments. The concentration of melatonin was almost three times higher during nighttime than during daytime, and this diurnal variation (amplitude) was much larger in the underground personnel. The personnel working underground slept almost half an hour more every night. Concerning illness, there was no overall difference, but the annual incidence patterns were distinctly different.

Kwiecinski, G. F. (1985). VDT operator problems: is there a real culprit? The Office. **101:** 104-6.
Geographical Location:
Building Type: office
Data Type: literature review
Outcome Focus: occupants, well-being

Abstract

Along with its ability to increase efficiency and productivity in the office, users blame the VDT for many physical ailments-back and neck pains, eyestrain, blurred vision, stomach aches, nausea and changes in colour perception. VDT operators are also experiencing problems of a psychological nature-stress, anxiety and loneliness due to job specialization. A report prepared by a panel of experts brought together by the National Research Council cites poor office and workplace design as the real cause of most of the problems. Research by the Optometric Extension Program Foundation confirms that headaches, sore, tired, red or burning eyes are the result of a workstation that is improperly designed for VDT use. If VDT users constantly complain about vision, first try setting up workstations according to `people-engineered' guidelines. If the problems continue, it's time for individual vision testing

Kwok, A. G. (1998). Thermal Comfort in Tropical Classrooms. ASHRAE Transactions Symposia**:** 1031-1047.
Geographical Location: USA, Hawaii
Building Type: school
Data Type: survey, questionnaires, measurements, interviews, observations
Outcome Focus: occupant, response; occupant, well-being

Abstract

This paper examines the comfort criteria of ANSI/ASHRAE Standard 55-1992 for their applicability in tropical classrooms. A field study conducted in Hawaii used a variety of methods to collect the data: survey questionnaires, physical measurements, interviews, and behavioural observations. A total of 3,544 students and teachers completed questionnaires in 29 naturally ventilated and air-conditioned classrooms in six schools during two seasons. The majority of classrooms failed to meet the physical specifications of the standard 55 comfort zone. Thermal neutrality, preference, and acceptability results are compared with other field studies and the Standard 55 criteria. Acceptability votes by occupants of both naturally ventilated and air conditioned classrooms exceeded the standard's 80% acceptability criteria, regardless of whether physical conditions were in or out of the comfort zone.

Kwok, A. and C. Chun (2003). Thermal comfort in Japanese schools. Solar Energy. **in press**.
Geographical Location: Japan
USA
Building Type: school
Data Type: survey; measurements, on-site
Outcome Focus: occupant, productivity; occupant, well-being

Abstract

Comfort standards (ASHRAE 55, ISO 7730) specify exact physical criteria for producing acceptable thermal environments, which include temperature, air movement, and humidity limits that are often difficult to comply with, particularly in the subtropical climate of Japan. Changing expectations of comfort are important in evaluating comfort since schools in Japan are not typically air-conditioned. With the rapid growth of school buildings in the US and all over the world, provisions for comfort are critical to student performance and occupant well-being. Are these temperate-climate, air-conditioning based standards applicable in these locations?

This paper builds upon previous thermal comfort work that has focused primarily on office environments. For this project we adapt traditional methods of data collection and inquiry for use in the school environment. During the late summer 2000, we conducted surveys in naturally ventilated and air-conditioned schools, polling responses from 74 students, while simultaneously measuring indoor climate variables. Air-conditioned classrooms had conditions within the comfort zone, causing occupants to report `slightly cool' thermal sensations. The naturally ventilated classrooms were 3 °C warmer than the air-conditioned classrooms and occupants voted that conditions were also within the central three categories (surrounding neutral) of the ASHRAE thermal sensation scale—therefore equated with comfort. These `neutral' sensations, however, do not correlate to people's preferred thermal state. Comfort responses are discussed in terms of comparisons to ASHRAE Standard 55-92 Thermal Conditions for Human Occupancy.

Lackney, J. A. (1997). The Relationship between Environmental Quality of School Facilities and Student Performance. Energy Smart Schools: Opportunities to Save Money, Save Energy and Improve Student Performance. A Congressional Briefing to the U.S. House of Representatives Committee on Science,.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

Congressional testimony is presented concerning school buildings and their connection to student health, behaviour, and learning, including a review of selected empirical studies conducted over the past 30 years showing an explicit relationship between physical characteristics of school buildings and educational outcomes. The factors responsible for student achievement are ecological in that they act together as a whole in shaping the context within which learning takes place. The testimony includes brief examinations on student behaviour, health, and academic achievement as influenced by the use of natural lighting, the reduction of noise through proper location and siting of schools. optimal indoor climate, sick buildings and indoor air quality, school and class size, schools placed close to their neighbourhoods, and the overall condition and management of the school building.

Lagoudi, A., M. Loizidou, et al. (1996). Symptoms Experienced, Environmental Factors and Energy Consumption in Office Buildings. Energy and Buildings. **24:** 237–243.
Geographical Location: Europe
Greece
Athens
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A major increase of complaints has been observed by the occupants of buildings. concerning health symptoms and comfort. In this study, the occupants' experience of symptoms as well as the occupants' sensation of the environmental parameters were estimated in six office buildings, where the indoor air quality was investigated. It was found that the percentage of building related symptoms experienced by the occupants of the buildings was high and it was strongly related to human comfort and human sensation concerning the environmental conditions. The human response to the environmental conditions showed that none of the parameters was judged as being unacceptable overall, which indicates that the number of symptoms observed in each building cannot be attributed to one cause but to the contribution of various

environmental parameters. Moreover, it was found that the increase of energy consumption was associated with the increase of health symptoms for these buildings.

Lang, J. T. (1987). Creating architectural theory : the role of the behavioural sciences in environmental design. New York, Van Nostrand Reinhold Co**:** ix, 278.
Geographical Location: USA
Building Type: Office
domestic
general
Data Type: Literature review
Outcome Focus: occupant, well-being
occupant, behaviour
occupant, response

Abstract

Lang, S. S. (2001). The Real Dirt on Carpets. School Planning & Management. **40:** 15.
Geographical Location: USA, New York
Building Type: School
Data Type:
Outcome Focus:

Abstract

Focuses on the indoor air quality research in schools by Cornell University in New York City. Implication of indoor air quality on the increase of respiratory problems among school children; Attribution of dust-mite allergens on asthmatic attacks; Disadvantages of carpeting in schools. INSET: Choose High-Performance Carpeting.

Langkilde, G., K. Alexandersen, et al. (1973). Mental Performance During Slight Cool or Warm Discomfort. Archives des sciences physiologiques (Paris). **27:** 511-518.
Geographical Location: Europe, Paris
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Leaman, A. (1995). Dissatisfaction and office productivity. Facilities. **13:** 13-19.
Geographical Location: England
Building Type: office
Data Type: survey
Outcome Focus: occupant, productivity

Abstract

Examines the question of whether people's productivity in offices is affected by environmental conditions, such as heat, lighting, ventilation and noise. Findings point to individuals' perception that uncomfortable working conditions affect their productivity. However, difficulties in measurement of tasks and study being too small and unrepresentative lead to uncertain conclusions. Outlines features of best possible buildings and suggests they will contain satisfied and productive occupants.

Leaman, A. and B. Bordass (1999). Productivity in buildings: the killer variables. Building Research and Information. **27:** 4-19.
Geographical Location: England
Building Type: office
Data Type: ?
Outcome Focus: occupant, productivity

Abstract

Loses and gains of up to 15% of turnover in a typical office organisation might be attributable to the design, management and use of the indoor environment. There is growing evidence to show that associations between perceived productivity and clusters of factors such as comfort, health and satisfaction of staff. Some of the management, design and use characteristics which contribute towards better energy efficiency also help productivity, thereby helping to close the loop on a potential virtuous circle. Unfortunately, the vast majority of occupied buildings do not have these self reinforcing qualities and many are unmanageably complex. This paper examines which factors within the control of building designers and managers best contribute to human productivity - the killer variables of the title.

Leaman, A., R. Bunn, et al. (2000). PROBE Birchensale School 1. Building Services Journal.
Geographical Location: England
Building Type: school
Data Type: case study
Outcome Focus: operation, design

Abstract

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Leaman, A. and B. Bordass (2001). Assessing building performance in use 4: the Probe occupant surveys and their implications. Building Research and Information. **29:** 129-143.
Geographical Location: England
Building Type: building
Data Type: case study, survey
Outcome Focus: occupant, well-being

Abstract

The main findings form the Probe occupant surveys are assessed. The emphasis is on the consequences for strategic thinking on how best to design and manage buildings to improve conditions for occupants and users, taking examples from the Probe studies. Comfort, health and productivity of occupants are positively associated statistically; and all are easily undermined by chronic, low-level problems. Improvement may not necessarily require raising overall environmental standards - particularly if this requires more energy or reduces perceived control, which occupants think has been falling steadily in recent years. Noise-related problems, are also growing with today's trend to more open, more diverse and often more reverberant environments. For the occupant, 'satisficing' may be better than optimising; and big benefits can come from minimizing the main causes of discomfort, ill health and low productivity - for example by designing and managing to help individuals to choose how to overcome local problems when they occur. Perhaps the greatest enemy of occupant satisfaction is where a building and its systems have become too complicated for its managers - even if this has often occurred initially at their request. Its greatest friends are simplicity, intelligibility, managed feedback, respect for people's comments and rapid response.

Leaman, A. (2003). Post-occupancy evaluation**:** 24.
Geographical Location: England
Building Type: building
Data Type: case study, survey, measurement, on-site
Outcome Focus: operation, energy
occupant, response

Abstract

post occupancy evaluation of buildings tries to answer two broad questions: "How is a building working" and "Is this intended?". POE was coined in the 1970s in the USA to describe the process of assessing buildings in use, initially from the occupants' point of view.

Leather, P., M. Pyrgas, et al. (1998). Windows in the workplace: sunlight, view, and occupational stress. Environment and Behavior. **30:** 739 (24).
Geographical Location: Europe, Southern Region, Mediterranean region
Building Type: office, industry
Data Type: Qualitative, survey, questionnaire, on-site subjects: workers (white and blue collar)
Outcome Focus: occupants, Health
Occupants, productivity

Abstract

This article investigates the direct and indirect effects of windows in the workplace on job satisfaction, intention to quit, and general well-being. The impact of three specific influencing mechanisms are examined: general level of illumination, sunlight penetration, and view. The extent to which these environmental features might moderate the negative consequences of job stress is investigated. The sample consisted of 100 white- and blue-collar workers who were employed in a large wine-producing organization in the Mediterranean region of Southern Europe. The results showed a significant direct effect for sunlight penetration on job satisfaction, intention to quit, and general well-being. A view of natural elements (i.e., trees, vegetation, plants, and foliage) was found to buffer the negative impact of job stress on intention to quit and to have a similar, albeit marginal, effect on general well-being. No effects for general level of illumination were found.

Legislative Assembly of NSW (2001). Sick Building Syndrome, A Report by the Standing Committee on Public Works, State Government of New South Wales, State Government of New South Wales.
Geographical Location: Australia, New South Wales
Building Type: Office
Data Type:
Outcome Focus:

Abstract

In recent years governments have taken direct and decisive action on improving the quality of the ambient air, the Government's 1998 Action for Transport being one example. In today's modern industrial society, however, people spend anywhere from 70 to 90 per cent of their time indoors. So the quality of that indoor air is an issue worthy of consideration. Indoor air quality is defined as the nature of the air that affects the health and well-being of the building's occupants. Factors which impact upon the quality of the indoor air are the external air; the building materials and the heating, ventilation and air conditioning (HVAC) systems (through air temperature, humidity and ventilation rates); and the interior of the building (layout, furnishings, fittings and equipment). Current indications are that poor indoor air quality has adverse implications for health. The consequence of this is a reduction in the quality

of life for occupants, loss of productivity for employers and the potential for costly legal action against those with legal responsibilities for these indoor environments. A number of health problems are associated with indoor air pollution, including Building Related Illness (BRI), Multiple Chemical Sensitivity (MCS) and Sick Building Syndrome (SBS). Sick Building Syndrome is a condition which affects a significant number of building occupants but which abates when the occupants leave the building. The symptoms occur in a higher proportion of the building occupants than in the community generally. SBS is not confined to office buildings.

Leifer (1998). Evaluating user satisfaction: case studies in Australasia. Facilities. **16:** 138-142.
Geographical Location: Australia, Queensland; New Zealand
Building Type: Office
Data Type: Survey
Outcome Focus: occupant, productivity; occupant, response

Abstract

This paper briefly describes problems in the methodology of a 1994 World Health Organisation Study of Building Health in office workers. The advantages of the Works Canada Office User Satisfaction Survey instrument is described. The Works Canada Survey's application to 16 regional Queensland Government offices is described in relation to its ability to target building maintenance and refurbishment related to occupant satisfaction and productivity. The article describes modifications made to the Works Canada instrument to adapt it to Australian conditions, and also to introduce Building Health parameters. The paper describes its application to benchmark the performance of four of the University of Auckland's office accommodation buildings. The benefits that facility managers can make from such as survey methodology are discussed.

Leslie, R. P. (2003). Capturing the daylight dividend in buildings: why and how? Building and Environment, Pergamon. **38:** pp381-385.
Geographical Location: various
Building Type: building
Data Type: review
Outcome Focus: occupant, health
operation, energy

Abstract

This article reviews the literature on daylighting, the design of buildings to use light from the Sun. Daylighting supports human health and activities and reduces energy demand. Current research suggests health, productivity, and economic benefits from daylighting. Good daylighting techniques include configuring buildings properly, elongating buildings along an east–west axis, locating critical visual tasks near the building's perimeter, bringing the light in high, admitting daylight from more than one side of a space, controlling direct sunlight, using light-coloured interior surfaces, and locating workstations and computer screens perpendicular to windows.

Leyten, J. L. and A. C. Boerstra (2002a). Individual Differences in Sensitivity to Indoor Air Complaints: Physical or Psychcological? Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Netherlands
Building Type: Office
Data Type:
Outcome Focus:

Abstract

An overview of three relevant and comparatively methodologically strong studies indicates that individual differences in proneness to experience indoor air complaints are not of a psychological nature. That means that they are not caused by differences in expectations or differences in general proneness to complain. However more research is needed.

Leyten, J. L. and A. C. Boerstra (2002b). Two Distinct Causal Paths From Indoor Air Problems to Sickness Absenteeism. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Netherlands
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

LightLab, I. P. L. The Unified Glare Rating System UGR as a Productivity Tool. Lab Notes. Victoria Australia, LightLab Int. **2**.
Geographical Location: Australia
Building Type: various
Data Type: theory
Outcome Focus: operation, environment; occupant, productivity

Abstract

Loftness, V. E. (2002). Adding value: Productivity and Quality of Life in Futurework Environments. Futurework 2020. Phase two: Presenting the Future of the Workplace. American Society of Interior Designers. Washington, D. C., ASID.
Geographical Location: USA
Building Type: office
Data Type: literature review
Outcome Focus: occupant, productivity
occupant, well-being
occupant, health

Abstract

Lomonaco, C. and D. Miller (1997). Comfort and Control in the Workplace. ASHRAE Journal. **September 1997:** 50-56.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

While the metrics for measuring productivity and environmental comfort are not standardized, there is growing evidence which demonstrates that comfort of one's own individual environment in the workplace has a positive impact on productivity. Just as important as the physical measures of comfort is the perception of control of one's own environment in the workplace.

Lorsch, H. G. and O. A. Abdou (1994). The Impact of the Building Indoor Environment on Occupant Productivity – Part 1 – Recent Studies, Measures and Costs. Part 2 – Effects of Temperature. Part 3 - Effects of Indoor Air Quality. ASHRAE Transactions. **100:** 741-749, 895-913.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The three papers summarize the results of a survey undertaken to collect and systematise information on quantitative relations between the indoor air environment and worker productivity.

Part 2:

There is general agreement that improved working conditions - and the office environment is certainly one of
the more important working conditions - tend to increase productivity. When temperatures climbed to uncomfortable levels, output was reduced. On the other hand, output improved in many industrial operations and in a few offices when high temperatures were modified by cooling or air conditioning. When temperatures were either too high or too low, error rates and accident rates increased. While most people maintain high productivity for a short time under adverse environmental conditions, there is a temperature/time threshold beyond which productivity rapidly decreases.

Part 3:

A number of research studies demonstrated that there is no simple relationship between single environmental elements and complex human behaviour. There is some evidence that air pollution or the perception that it exists can create stress among employees who believe that it poses a threat to their health. The stress may be particularly intense among people who believe they have no control over the pollution. It is further argued that psychosocial factors, such as labor-management relations and satisfaction or dissatisfaction with other factors in the work environment, can have a profound influence on the level of response of the occupants to their environment. Although hard data are difficult to collect, it is likely that productivity in the office environment is sensitive to conditions leading to poor indoor air quality, this being linked to the "sick building syndrome." More than half of all sick building problems are attributed to inadequate or improperly operated or maintained ventilation systems. It has been shown that both ventilation/air movement and humidity can have a profound effect on productivity in the workplace; however, they cannot be singled out by themselves. Studies suggest that there is a synergistic effect of a multitude of factors that affect the performance of workers in their workplace. It is argued that when considering the irritant-level health effects people

are alleging in most cases, it is questionable that they could be occurring only because of the indoor air. But if some stress and ergonomic concerns are added, perhaps that is when the problems start to show up. There are some indications that giving occupants greater local control over their environmental conditions improves their work performance and their work commitment and morale, with other positive implications for improving overall productivity within an organization.

Lundin, L. (1999). Allergic and Non-Allergic Students' Perception of the Same High School Environment. Indoor Air. **9:** 92-102.
Geographical Location: Europe, Sweden
Building Type: School, Secondary
Data Type:
Outcome Focus:

Abstract

The aim of the study was to describe how allergics and non-allergics perceive the same environment. All high school students in a town in southern Sweden were invited to answer a questionnaire concerning allergy, subjective symptoms, annoyance reactions and perception of the environment (response rate: 81%). The results show that only 45% of the students were non-allergic (n=1,715). Since the symptom frequency among non-allergic students was normal, the schools were classified as healthy. However, compared to the non-allergic students, a higher percentage among the allergics suffered from symptoms every week, a lower percentage was satisfied with the air quality and the cleaning, and a higher percentage was bothered every week by temperature, stuffy / stale air, bad odour, passive smoke, bad lighting, noise, dust and dirt (ANOVA, P<O.O5). The findings could indicate that allergics note discomfort earlier than non-allergics by being more critical in general and especially critical to factors that could effect their health. The findings could also indicate that awareness of ones own sensitivity could lead to attention to different risk factors, which in turn could lead to stress/anxiety, which could make symptoms worse. The conclusion is that it is important to take allergy into consideration when the environment is assessed.

Lynch, R. M. and H. Kipen (1998). Building-Related Illness and Employee Lost Time Following Application of Hot Asphalt Roof: A Call for Prevention. Toxicology and Industrial Health. **14:** 857-868.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Industrial hygiene sampling within an office building during and following a roof renovation revealed low-level exposure to high-boiling organic compounds, associated with complaints of eye and upper respiratory tract irritation among building occupants. Health complaints continued substantially beyond the time frame of the renovation completion, despite a lack of objective industrial hygiene findings for volatile organic compounds (VOCs) and microbiological contamination, and a lack of consistent medical findings among employees evaluated by an occupational physician. An analysis of employee attendance records suggests lost attendance and reduced productivity costs. Preventive strategies include proper planning and scheduling of building renovations to prevent employee exposure to asphalt roof emissions.

Macrae, J. H. (1997). A discussion of the Australian National Standard for Occupational Noise. **25:** 109-112.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Madu, S. N. (1990). Effect of noise on memory and recall among Nigerian students. Journal of African Psychology. **1:** 15-23.
Geographical Location: Africa, Nigeria
Building Type: university
Data Type: Quantitative
Measurements, laboratory
Outcome Focus: occupants, productivity

Abstract

Investigated the effect of noise (60, 80 and 100 db) on memory and recall performance of 120 university undergraduates (aged 16-30 yrs) in Nigeria. 45 males and 45 females served as the experimental group (in the noise conditions) and the rest as a control group (in the no-noise condition). Performance was measured by the number of words recalled out of a set of 30 words. A 4 * 2 * 3 ANOVA and the protected t-test were used to test the effect of the 3 independent variables (noise, sex, and age) on performance. Performance increased with increase in noise decibels, there was no difference between the performance of the males and that of the females under the same noise conditions, and the younger Ss performed better than the older ones when put under the same noise conditions. Findings are discussed cross-culturally and in relation to some Nigeria-specific problems. (French abstract) (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Mahnke, F. H. and R. H. Mahnke (1987). Color and light in man-made environments. New York, Van Nostrand Reinhold**:** xi, 140 , 8 of plates.
Geographical Location: Europe
USA
Building Type: Office, School, Industry
Data Type: literature review
Outcome Focus: occupant, well-being
occupant, health

Abstract

Mahnke, F. H. (1996). Colour, environment, and human response : an interdisciplinary understanding of colour and its use as a beneficial element in the design of the architectural environment. New York, John Wiley & Sons**:** xii, 234 + 16 of plates.
Geographical Location:
Building Type:
Data Type: Literature review
Outcome Focus: occupants, well-being
occupants, health

Abstract

Malone, B. and E. P. Cox (2002). What's your IAQ? It Could Mean Your Health. Journal of

School Business Management. **14:** 26-29.
Geographical Location: USA
Building Type: School
Data Type: qualitative, survey
Outcome Focus: occupant, productivity

Abstract

Scientists believe that there is a correlation between indoor air quality (IAQ) and the apparent rise in asthma and allergies among school age children: The increase in the number of children with respiratory problems is alarming. An Executive Order was issued by former President Clinton, "Protection of Children from Environmental Health Risks and Safety Risks" to address the concerns. This prompted the U.S. Environmental Protection Agency to issue new air quality standards for the protection of school children. The "Presidential Fiscal Year 2000 Asthma Initiative" was created to provide a better understanding between indoor environment and asthma especially in schools, homes, and day-care centers. A recent report on the state of schools in the U.S. revealed one school in eight, or 13,200 schools were inadequate for learning. Some of these buildings are old and in desperate need of repair, but the indoor air quality may be more of a concern for parents. One out of every five Americans goes to school every day during the school year; the potential for major health concerns and litigation in the future is not a fabricated problem; it is as real as it gets (Seyffer, 1999). The latest legal actions have now defined acceptable indoor air quality as a "reasonable standard of care" (Hays, June 2000). School administrators must make sure that policies and procedures are clearly identified and consistent with the standard of care criteria. Highly publicized air quality problems in a school can be a nightmare for the leaders of a school system. Understanding the issues involved will serve the administrator well as they pay increasing attention to this issue. Minimizing the health risks of students is a rising agenda item for administrators seeking to meet the physical as well as the intellectual needs of the school community.

Mandel, D. R., R. M. Baron, et al. (1980). Room Utilization and Dimensions of Density: Effects of Height and View. Environment and Behaviour. **12:** 308-319.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Marans, R. W. (1982). Evaluating open and convention office design. Environment and Behaviour. **14:** 333-351.
Geographical Location: USA, Michigan
Building Type: Office
Data Type: development of a model; quantitative; qualitative; questionnaire, ; n-site; observations; measurement, on-site
Outcome Focus: occupants, well-being; occupants, response; occupants, productivity; occupants, performance; occupants, satisfaction

Abstract

In an attempt to overcome limitations characteristics of past evaluations, a conceptual model is presented as a guide to evaluators in collecting and analyzing data on office environments. A number of components of the model are then examined using data from a study of a new federal office building. Findings corroborate those reported by others in showing that conventional offices are viewed more favourably by people occupying them than workers in either open or pooled office arrangements. The

amount of workspace available to the worker is the most important factor associated with work station satisfaction, even after taking into account the type of work station and the workers' ratings of specific work station attributes. It is also demonstrated that people's feelings about the ambience of the agency within which they work and the architecture of the building influence their reactions to immediate workspace. It is suggested that space planners and designers who want their work appreciated by the user need concern themselves with the details of the workspace as well as the larger scale environment.

Mathisen, H. M., J. A. Jenssen, et al. (2002). Effects on Health Related Symptoms of Carpet Removal and Ventilation Improvement in Eleven Schools - A Controlled Intervention Study. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Norway, Trondheim
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

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

McCallum, R., C. E. Rusbalt, et al. (1979). "Effects of resource availability and importance of behaviour on the experience of crowding." Journal of Personality and Social Psychology **37**: 1304-1313.

McCartney, K. J. and M. A. Humphreys (2002). Thermal Comfort and Productivity. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Meininghaus, R., A. Kouniali, et al. (2003). Risk Assessment of Sensory Irritants in Indoor Air-a Case Study in a French School. Environment International. **28:** 553-557.
Geographical Location: Europe, France
Building Type: School
Data Type:
Outcome Focus:

Abstract

Exposure to airborne pollutants can result in adverse health effects. Acute symptoms can for instance comprise of irritation of the eyes or of the respiratory tract (called sensory irritation). In a recent case, health problems were reported in a French school and supposedly attributed to the presence of airborne irritant pollutants. Based on measured concentrations, the risk of developing the described health effects was assessed. Numerous airborne sensory irritants (aldehydes, organic acids, volatile organic compounds (VOCs), SO2, NH) were identified and quantified in the indoor air by using active and passive sampling and online monitoring techniques. Reference values based on toxicological properties of compounds (sensory irritants) were taken from the literature. If not available, tentative values were specially developed for this purpose. Concentrations of all sensory irritants remain below their corresponding guideline values and are comparable to literature data. It was concluded that the risk of developing sensory irritation due to the presence of the studied compounds is negligible. This holds both for individual compounds and for the mixture of studied compounds. Limitations of the employed sampling strategy, and of existing sampling and analytical techniques, which do not allow for analysing more reactive compounds-which are strong sensory irritants-may play a role. New sampling techniques need to be developed. Psychosocial factors (group behaviour, increased attention to sensory irritation) should also be taken into account when dealing with health complaints on sensory irritation.

Meklin, T., T. Husman, et al. (2002). Effects of Moisture Damage Repair on Microbial Exposure and Health Effects in Schools. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Finland
Building Type: School, Primary
Data Type:
Outcome Focus:

Abstract

This intervention study was designed to show the effects of the renovation of moisture and mould damaged school building on the schoolchildren's health and exposure. Microbial sampling from indoor air of the school and a health questionnaire study were performed before and after renovation. The results were compared to those from non-damaged reference school. The effect of a thorough renovation in the damaged school was seen as decreased concentrations of airborne fungi and decreased diversity of mycoflora. There was a significant decrease in the prevalence of the respiratory symptoms among schoolchildren after the renovation. The results show that the symptoms are associated with the moisture damage and that the increased symptom levels can be normalized with proper repair measures.

Meklin, T., T. Husman, et al. (2002). Indoor Air Microbes and Respiratory Symptoms of Children in Moisture Damaged and Reference Schools. Indoor Air. **12:** 175-183.
Geographical Location: Europe, Finland
Building Type: School, Primary, Secondary
Data Type:
Outcome Focus:

Abstract

Microbial indoor air quality and respiratory symptoms of children were studied in 24 schools with visible moisture and mould problems, and in eight non-damaged schools. School buildings of concrete/brick and wooden construction were included. The indoor environment investigations included technical building inspections for visible moisture signs and microbial sampling using six-stage impactor for viable airborne microbes. Children's health information was collected by questionnaires. The effect of moisture damage on concentrations of fungi was clearly seen in buildings of concrete/brick construction, but not in wooden school buildings. Occurrence of Cladosporium, Aspergillus versicolor, Stachybotrys, and actinobacteria showed some indicator value for moisture damage. Presence of moisture damage in school buildings was a significant risk factor for respiratory symptoms in schoolchildren. Association between moisture damage and respiratory symptoms of children was significant for buildings of concrete/brick construction but not for wooden school buildings. The highest symptom prevalence was found during spring seasons, after a long exposure period in damaged schools. The results emphasize the importance of the building frame as a determinant of exposure and symptoms.

Mendell, M. J., W. J. Fisk, et al. (1993). Elevated Symptom Prevalence Associated with Mechanical Ventilation in Office Buildings: Findings from the California Healthy Building Study, Phase 1. Berkley, California, Lawrence Berkley National Laboratory.
Geographical Location: USA, California
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Background. European epidemiologic studies have found health symptoms in office workers to be consistently increased in air-conditioned buildings relative to naturally ventilated buildings. Because this had not been studied in the U.S., the California Healthy Building Study assessed the relationship of ventilation system type to office worker symptoms in a set of U .S. buildings selected without regard to worker complaints. Methods. Questionnaire data, building information, and environmental measures were collected from spaces within 12 public office buildings having one of three ventilation types: natural ventilation (NV) , mechanical ventilation without air-conditioning (MV), and mechanical ventilation with air-conditioning (AC). Multiple logistic regression was used to assess relations between ventilation type and work-related symptoms, adjusting for potential confounding by building, job, and personal factors. Results. 880 completed questionnaires (response rate 85%) were received. Overall prevalences of four work-related symptoms were greater than 20% . Higher adjusted prevalences of several work-related symptoms were associated with both MY and AC, relative to NV .The highest adjusted prevalence odds ratios were found for dry or itchy skin [MV , 5.8 (95% confidence interval = 1.5-22) ; AC, 5.6 (1.6-20)] and tight chest or difficulty breathing [MY, 3.6 (0.9-15); AC, 4.3 (1.1-16)]. Available evidence suggests that reporting bias is unlikely to explain these findings. Symptom prevalence was not associated with specific environmental measurements made. Conclusions. This study provides further evidence that work-related symptoms among office workers are common, even in buildings not considered to be "problem" buildings, and are increased in association with unidentified factors in some

mechanically ventilated or air-conditioned buildings. Research to identify these factors should include assessment of contaminants emitted by ventilation systems.

Mendell, M. J., W. J. Fisk, et al. (1996). Elevated Symptom Prevalence Associated with Ventilation Type in Office Buildings. Epidemiology. **7:** 583-589.
Geographical Location: USA, California
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The California Healthy Building Study was designed to assess relations between ventilation system type and office worker symptoms in a set of U.S. buildings selected without regard to worker complaints. Twelve public office buildings in northern California meeting specific eligibility criteria were studied in the summer of 1990: three naturally ventilated, three mechanically ventilated (without air conditioning), and six air-conditioned buildings. Questionnaire data were collected from 880 workers in selected spaces within the study buildings. We adjusted effect estimates for various ventilation types for personal, job, and work place factors using logistic regression, and alternatively, using a mixed effects model (SAS/GLIMM1X) to adjust for correlated responses within study spaces. Higher adjusted prevalences of most symptom outcomes were associated with both mechanical and air-conditioned ventilation, relative to natural. With a conservative adjustment for problem building status, the highest adjusted prevalence odds ratios from logistic regression models were for dry or itchy skin [mechanical: odds ratio (OR) = 6.0, 95% confidence interval (CI) = 1.6-22; air-conditioned: OR = 6.0, 95% CI = 1.7-21) and lower respiratory symptoms (mechanical: OR = 2.9, 95% CI = 0.7-11; air conditioned: OR = 4.0, 95% CI = 1.1-15). GLIMMIX estimates were similar, with slightly wider confidence intervals. Reporting bias was small. These findings of symptom increases within mechanically ventilated and air-conditioned U.S. buildings support previous findings available only from European buildings.

Mendell, M. J., W. J. Fisk, et al. (2002). Improving the Health of Workers in Indoor Environments: Priority Research Needs for a National Occupational Research Agenda. American Journal of Public Health.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Indoor non-industrial work environments were designated a priority research area through the nationwide stakeholder process that created the National Occupational Research Agenda. A multidisciplinary research team used member consensus and quantitative estimates, with extensive external review, to develop a specific research agenda. The team outlined the following priority research topics: building-influenced communicable respiratory infections, building-related asthma/allergic diseases, and non-specific building-related symptoms; indoor environmental science; and methods for increasing implementation of healthful building practices. Available data suggest that improving building environments may result in health benefits for more than 15 million of the 89 million US indoor workers, with estimated economic benefits of $5 to $75 billion annually. Research on these topics, requiring new collaborations and resources, offers enormous Potential health and economic returns.

Mendell, M. J., W. J. Fisk, et al. (2002). Indoor Particles and Symptoms Among Office Workers: Results from a Double-Blind Cross-Over Study. Epidemiology 2002. **13:** 296-304. .
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Background: We studied the effects of removing small airborne particles in an office building without unusual contaminant sources or occupant complaints. Methods: We conducted a double-blind crossover study of enhanced particle filtration in an office building in the Midwest U.S. in 1993. We replaced standard particle filters, in separate ventilation systems on two floors, with highly efficient filters, on alternate floors weekly over four weeks. Repeated-measures models were used to analyze data from weekly worker questionnaires and multiple environmental measurements. Results: Bioaerosol concentrations were low. Enhanced filtration reduced concentrations of the smallest airborne particles by 94%. This reduction was not associated with reduced symptoms among the 396 respondents, but three performance-related mental states improved; for example, the confusion scale decreased (-3.7%; 95% confidence limits (CL) = -6.5, -0.9). Most environmental dissatisfaction variables also improved; eg, “stuffy” air, -5.3% (95% CL = -10.3, -0.4). Cooler temperatures within the recommended comfort range were associated with remarkably large improvement in most outcomes; for example, per 1ºC decrease, chest tightness decreased -23.4% (95% CL = -38.1, -8.7). Conclusions: Benefits of enhanced filtration require assessment in buildings with higher particulate contaminant levels, in studies controlling for temperature effects. Benefits from lower indoor temperatures need confirmation.

Menzies, D., R. Tamblyn, et al. (1996). Exposure to Varying Levels of Contaminants and Symptoms among Office Workers in Two Office Buildings. American Journal of Public Health. **86**.
Geographical Location: Canada, Quebec, Montreal
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Objectives. We hypothesized that exposure to contaminants would be associated with symptoms reported by office workers. Methods. In two mechanically ventilated office buildings in Montreal, the outdoor air supply was manipulated for 6 weeks, while symptoms were reported and environmental parameters were measured at multiple sites. Results. Contaminant concentrations varied considerably, in part related to experimental changes in outdoor air supply. Eye symptoms were reported with higher dust and with higher concentrations of nitrogen dioxide. Mucosal symptoms were increased with higher TVOCs, higher nitrogen dioxide, and higher total contaminant load. Systemic symptoms were associated with higher dust levels. Conclusions. Symptoms reported by the workers were associated with increased concentrations of several contaminants and a summary measure of all contaminants.

Menzies, D., J. Pasztor, et al. (1997). Effect of a New Ventilation System on Health and Well-Being of Office Workers. Archives of Environmental Health. **52:** 360–367.
Geographical Location: Canada, Quebec, Montreal
Building Type: Office
Data Type:
Outcome Focus: occupant, health; occupant, productivity

Abstract

Sick building syndrome is the term given to a heterogeneous constellation of symptoms that affects workers in modern mechanically ventilated office buildings. Although the cause is unknown there is evidence that the local environment of the workstation is an important determinant of symptoms. In this study, investigators examined the effect of a new, individually controlled ventifi1tion system on workers' symptoms. Investigators studied two groups of workers in one mechanically ventilated office building: (I) a control group at whose worksite no intervention was made and (2) an intervention group. The intervention consisted of installation of a device that allowed each worker control over the ventilation supplied to his or her worksite. Just before, and 4 and 16mo after installation of this device, workers completed self-administered questionnaires regarding occurrence of symptoms. The new ventilation system resulted in higher air velocities, more variable temperatures, and higher concentrations of airborne dust and fungal spores. Four months after installation, workers with the new ventilation system reported fewer symptoms that were (a) work-related {p < .05} and that were work-related and frequent (p < .05}; in addition, they reported fewer symptoms that reduced their capacity to work{p< .01). Sixteen months after installation, workers with the new device reported fewer symptoms than at baseline, (although not as significantly), and they indicated that the indoor air quality improved their productivity by 11%, compared with a 4% reduction of productivity among the control group of workers (p< .001). Investigators concluded that the new ventilation system, which provided the workers with individual control over ventilation, was associated with important and sustained reduction in symptoms.

Menzies, D., J. Pasztor, et al. (1998). Germicidal Ultraviolet Irradiation in Air Conditioning Systems: Effect on Office Worker Health and Wellbeing: A Pilot Study. Occupational Environmental Medicine. **56:** 397-402.
Geographical Location: Canada, Quebec, Montreal
Building Type: Office
Data Type: measurements, on-site
Outcome Focus: occupant, health

Abstract

Objectives - The indoor environment of modern office buildings represents a new ecosystem that has been created totally by humans. Bacteria and fungi may contaminate this indoor environment, including the ventilation systems themselves, which in turn may result in adverse health effects. The objectives of this study were to test whether installation and operation of germicidal ultraviolet (GUV) lights in central ventilation systems would be feasible, without adverse effects, undetected by building occupants, and effective in eliminating microbial contamination. Methods - GUV lights were installed in the ventilation systems serving three floors of an office building, and were turned on and off during a total of four alternating 3 week blocks. Workers reported their environmental satisfaction, symptoms, as well as sickness absence, without knowledge of whether GUV lights were on or off. The indoor environment was measured in detail including airborne and surface bacteria and fungi. Results - Airborne bacteria and fungi were not significantly different whether GUV lights were on or off, but were virtu- ally eliminated from the surfaces of the ventilation system after 3 weeks of operation of GUV light. Of the other environ-mental variables measured, only total airborne particulates were significantly different

under the two experimental conditions-higher with GUV lights on than off. Of 113 eligible workers, 104 (87%) participated; their environmental satisfaction ratings were not different whether GUV lights were on or off. Headache, difficulty concentrating, and eye irritation occurred less often with GUV lights on whereas skin rash or irritation was more common. Overall, the average number of work related symptoms reported was 1.1 with GUV lights off compared with 0.9 with GUV lights on. Conclusion - Installation and operation of GUV lights in central heating, ventilation and air conditioning systems of office buildings is feasible, cannot be detected by workers, and does not seem to result in any adverse effects.

Metzger, E. A. (2000). Real relief. Occupational Health & Safety. **69:** 221.
Geographical Location: USA
Building Type: office
Data Type: design guidelines
Outcome Focus: occupant, productivity
occupant, health

Abstract

According to the Bureau of Labour and Statistics, musculoskeletal disorders now account for one-third of all occupational illnesses and injuries. With an increase in musculoskeletal disorders, lost work days, and compensation costs, the working world is in need of some form of relief. One of the answers is ergonomic seating. One of the most important features of ergonomic seating is the ability to adapt and support posture changes quickly and easily for the same person at different times throughout the day, for different workers in large hotel offices, or for different workers on different shifts. In addition to increased worker productivity and comfort, ergonomic seating also can have an impact on cumulative trauma and/or soft tissue problems.

Meyer, H. W., H. Wurtz, et al. (2002). Moulds and Health – An Epidemiological Study. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Denmark
Building Type: School
Data Type:
Outcome Focus:

Abstract

The objective was to test the hypothesis that building related symptoms (BRS) in adolescent school children were associated with mould growth in school buildings. In the questionnaire study including eight “wet” and seven “dry” schools sufficient responses were returned from 1053 adolescent pupils of 8th and 9th grade. At the end of a working day dust was sampled from floors of the class rooms of these pupils, and analysed for culturable fungi. When dividing the buildings into “dry”, “intermediate” and “wet” a surprising tendency towards higher prevalences of BRS in “dry” buildings was seen, though a significant trend was only found for eye irritation. Significantly higher prevalences of eye irritation, throat irritation, headache, concentration problems, and dizziness were seen with increasing levels of viable total moulds in collected floor dust.

Milton, D. K., P. M. Glencross, et al. (2000). Risk of Sick Leave Associated with Outdoor Ventilation Level, Humidification, and Building Related Complaints. Indoor Air. **10:** 212-221.
Geographical Location: USA, Massachusetts
Building Type: Office
Data Type:
Outcome Focus:

Abstract

We analyzed 1994 sick leave for 3,720 hourly employees of a large Massachusetts manufacturer, in 40 buildings with 115 independently ventilated work areas. Corporate records identified building characteristics and IEQ complaints. We rated ventilation as moderate (·25 cfm/person, 12 lsª1) or high (·50 cfm/person, 24 lsª1) outdoor air supply based on knowledge of ventilation systems and CO2 measurements on a subset of work areas, and used Poisson regression to analyze sick leave controlled for age, gender, seniority, hours of non-illness absence, shift, ethnicity, crowding, and type of job (office, technical, or manufacturing worker). We found consistent associations of increased sick leave with lower levels of outdoor air supply and IEQ complaints. Among office workers, the relative risk for short-term sick leave was 1.53 (95% confidence 1.22-1.92) with lower ventilation, and 1.52 (1.18-1.97) in areas with IEQ complaints. The effect of ventilation was independent of IEQ complaints and among those exposed to lower outdoor air supply rates the attributable risk of short-term sick leave was 35%. The cost of sick leave attributable to ventilation at current recommended rates was estimated as $480 per employee per year at Polaroid. These findings suggest that net savings of $400 per employee per year may be obtained with increased ventilation. Thus, currently recommended levels of outdoor air supply may be associated with significant morbidity, and lost productivity on a national scale could be as much as $22.8 billion per year. Additional studies of IEQ impacts on productivity and sick leave, and the mechanisms underlying the apparent association are needed.

Mitchell, W. (1999). Etopia, Urban Jim but not as we know it, MIT Press.

Molhave, L. (2000). Indoor Air Quality and Health. Healthy Buildings 2000. O. Seppanen and J. Seateri. Espoo, Finland. **1:** 3-14.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

A World Health Organization working group is aiming at establishment of a WHO document with statements on occupants rights to indoor air quality. It follows from the statements that an internationally acceptable set of guidelines and recommendations is required based on uniform requirements to the indoor air quality. This paper summarizes the known effects of IAQ and suggests a set of priority causalities for which guidelines or recommendations can be set and a group of secondary causalities for which interim recommendations could be set. In addition a group of potential or hypothetical causalities are identified for which no rational guideline or recommendation can be made because of lack of information.

Molhave, L. and M. Krzyzanowski (2000). The Right to Healthy Indoor Air. Indoor Air. **10:** 211 pp.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The control of indoor air quality often is inadequate in spite of its significant role in determining health. Tensions emerge and conflicts may occur between persons suffering from indoor air pollution and those whose actions influence indoor air quality negatively. Most exposure to indoor air occurs in private homes, and intervention by public regulation is often considered a violation of personal freedom. Furthermore, commercial interests often have delayed the implementation of indoor air pollution controls in spite of the scientific evidence of harmful heath impacts. To a large extent, the reason for the inadequate quality of indoor air is due to poor articulation, appreciation and understanding of basic principles underlying the policies and actions related to indoor air quality. In a consequence, general public is not familiar with those principles, and with the rights associated with them. A World Health Organisation (WHO) Working Group was convened to agree on a set of statements on "The right to healthy indoor air", derived from fundamental principles in the fields of human rights, biomedical ethics, and ecological sustainability. These statements inform the individuals and groups responsible for healthy indoor air about their rights and obligations, and empower the general public by making them familiar with those rights. Nine statements and comments were established at a WHO Working Group meeting held at Bilthoven, Netherlands, May 15-17, 2000. Twenty-three members of 18 countries attended this meeting. The Working Group has recommended that the principles be brought to the attention of governments with the goal of placing healthy indoor air on their agenda for future action.

Molhave, L., S. K. Kjaergaard, et al. (2002). Effects in the Eyes Caused by Exposure to Office Dust. Indoor Air. **12:** 165-174.
Geographical Location: Europe, Denmark
Building Type: Office
Data Type:
Outcome Focus:

Abstract

This Danish Office Dust Experiment compares the responses of 24 normal non-sensitive adult subjects to exposure to normal office dust in the air at 136 and 390 lg/m3 (median) and to their responses in clean air. The exposure duration was 5 1/4 h in a climate chamber under controlled conditions. The dust had no major identifiable specific reactive compounds. The overall conclusion is that healthy subjects without any hypersensitive reactions seem to respond to exposure to the house dust. The effects observed were all found in interaction with response modifying factors. The effects were a decrease in inflammatory cells in tear fluids, increased epithelium defects, and a decrease in break-up time. No effect was seen on eye reddening, or eye sensitivity to CO2. As no specific hypotheses could be specified before the study for the observed interactions, no definitive conclusions can be made. Furthermore, it seemed that there was no consistency in the interacting factors after the exposure and the next morning. A tentative analysis of the effects of the importance of personal characteristics showed that only a minority within the subject group may respond to the exposure. However, no common set of sensitivity measures could be defined for these responders.

Molhave, L., M. Krzyzanowski, et al. (2002). The Right to Healthy Indoor Status by 2002. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Muhic, S. and V. Butala (2002). Impact of CO2 Concentration, Temperature and Relative Humidity of Air on the Health and Sense of Wellbeing of Employees in Air-Conditioned and Naturally Ventilated Offices. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Slovenia
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The current sense of wellbeing and health of employees engaged in similar types of activities in both air-conditioned (AC) and naturally ventilated (NV) buildings were analysed using an IAQ assessment, measurement of thermal comfort parameters, and a survey of employees. A questionnaire concerning the current sense of wellbeing was given while concurrently measuring CO2 concentration, air temperature and relative humidity in the given building. Suitable statistical methods and models were used. The employees in both analysed buildings connect most of their health problems and current unpleasant feelings to the indoor environment, although more so in the AC than in the NV building. Statistically significant connections between CO2 concentration and current sense of wellbeing parameters were found.

Mullins, R. (1998). Daylighting: Does it improve office productivity? America, Milwaukee, The Business Journal of Milwaukee.
Geographical Location: USA
Building Type: Office
Data Type: Interview – opinion; Case Study
Outcome Focus: occupant, productivity

Abstract

For employees who would rather be outside playing than inside working, daylighting may be the compromise that makes them happy but keeps them productive.

Mulvihill, K. (2000). Is Your Office Making You Sick? Working Mother. **May:** p20, 2p.
Geographical Location: USA
Building Type: office
Data Type: literature review
Outcome Focus: occupants, health

Abstract

Offers advice to employees in the United States on how to protect themselves from occupational hazards of the modern work environment. Class action lawsuit by employees who developed sickness as a result of years of exposure to carbonless copy paper.

Myatt, T. A., J. Staudenmayer, et al. (2002a). A Study of Indoor Carbon Dioxide Levels and Sick Leave Among Office Workers. Environmental Health: A Global Science Source. **1:** 1-10.
Geographical Location: USA, Massachusetts, Boston
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Background

A previous observational study detected a strong positive relationship between sick leave absences and carbon dioxide (CO2) concentrations in office buildings in the Boston area. The authors speculated that the observed association was due to a causal effect associated with low dilution ventilation, perhaps increased airborne transmission of respiratory infections. This study was undertaken to explore this association.

Methods: We conducted an intervention study of indoor CO2 levels and sick leave among hourly office workers employed by a large corporation. Outdoor air supply rates were adjusted periodically to increase the range of CO2 concentrations. We recorded indoor CO2 concentrations every 10 minutes and calculated a CO2 concentration differential as a measure of outdoor air supply per person by subtracting the 1-3 a.m. average CO2 concentration from the same-day 9 a.m. - 5 a.m. average concentration. The metric of CO2 differential was used as a surrogate for the concentration of exhaled breath and for potential exposure to human source airborne respiratory pathogens. Results: The weekly mean, workday, CO2 concentration differential ranged from 37 to 250 ppm with a peak CO2 concentration above background of 312 ppm as compared with the American Society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) recommended maximum differential of 700 ppm. We determined the frequency of sick leave among 294 hourly workers scheduled to work approximately 49,804.2 days in the study areas using company records. We found no association between sick leave and CO2 differential. Conclusions: The CO2 differential was in the range of very low values, as compared with the ASHRAE recommended maximum differential of 700 ppm. Although no effect was found, this study was unable to test whether higher CO2 differentials may be associated with increased sick leave.

Myatt, T. A., J. Staudenmayer, et al. (2002b). An Intervention Study of Outdoor Air Supply Rates and Sick Leave Among Office Workers. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: USA, Massachusetts, Boston
Building Type: Office
Data Type:
Outcome Focus:

Abstract

We conducted an intervention study of outdoor air supply rates and sick leave among hourly office workers employed by Polaroid Corporation. High and moderately high outdoor air supply rates were specified in a random block design in two office buildings. Indoor CO2 concentrations were measured every ten minutes. We calculated a CO2 concentration differential by subtracting the daily average CO2 concentration in the study area during 1-3 AM, when the building was not occupied, from the same-day average concentration between 9-5 PM. The mean weekly, workday, CO2 concentration differential ranged from 37 to 250 ppm as compared with the ASHRAE recommended maximum differential of 700 ppm. We determined the frequency of sick leave among 294 hourly workers scheduled to work 49804.2 days in the study areas using company records. Generalized additive mixed models showed no association of CO2 differential at the relatively low values studied and sick leave in the studied buildings.

Myhrvold, A. N., E. Olsen, et al. (1996). Indoor Environment in School Pupils' Health and Performance in Regard to CO2 Concentrations. Indoor Air '96. Y. S., K. K., I. K., T. S. and T. Iwata. Nagoya, Japan. **The 7th International Conference on Indoor Air Quality and Climate:** 369-374.
Geographical Location: Europe, Norway
Building Type: School
Data Type:
Outcome Focus:

Abstract

The results in this paper represent a small part of a 3 year ongoing research project, "Indoor Environment in Schools". The project has been an effect study of rehabilitation in schools with poor indoor air quality. This project is a co-operation between the counties of Oppland and Vest Agder, the municipality of Ha in Rogaland and RF-Rogaland Research. The aim of the project has been to investigate the indoor environment in regard to the pupils' health, social environment and level of performance. The project has included field investigations of indoor air quality, pupils' health and social climate in addition to a reaction time test, called SPES. The results show both correlations between pupils' health and the CO2 concentrations in the class rooms, and between the pupils' performance and the CO2 concentrations.

Myhrvold, A. N. and E. Olsen (1997). Pupils' Health and Performance due to Renovation of Schools. Healthy Buildings/IAQ (Indoor Air Quality) '97: Global Issues and Regional Solutions. J. E. Woods, D. T. Grimsrud and N. Boschi. Washington DC**:** 81-86.
Geographical Location: Europe, Norway
Building Type: School
Data Type:
Outcome Focus:

Abstract

Nakano, J., S. Tanabe, et al. (2002). Differences in Perception of Indoor Environment Between Japanese and non-Japanese Workers. Energy and Buildings. **34:** 615-621.
Geographical Location: Japan, Tokyo
Building Type: Ofice
Data Type:
Outcome Focus:

Abstract

Field surveys were conducted at an office with multinational workers in Japan to investigate the differences in the way groups of occupants perceive the environment under real working conditions. Returned questionnaires, 406 in total, were classified into three groups according to their nationality and sex. Only 26% of workers reported their working environment to be comfortable. A significant neutral temperature difference of 3.1 8C was observed between the Japanese female group and the non-Japanese male group under their usual working conditions. Japanese females reported a higher frequency of sick building syndrome related symptoms compared to other groups. Occupant comfort and reported frequency of SBS symptoms were closely related to deviation of the thermal sensation vote from neutral. The thermal environment was found to be a major factor affecting occupant comfort in the concerned office. Differences in the perception of the indoor environment were negatively affecting the ratings of their working environment.

National Science and Technology Council Indoor Health and Productivity Bibliography. Brodt, Fisk, Hillet al, Lawerence Berkley Laboratories.
Geographical Location: USA
Building Type: various
Data Type: review
Outcome Focus: occupant, productivity
occupant, health

Abstract

Welcome to the IHP Bibliography section. The bibliography is updated and new records are added periodically. Currently, it contains more than 900 papers from more than 100 journals and conference proceedings. The IHP bibliography is available for public use.

Anyone can browse and search the on-line bibliography by clicking on the navigation buttons on the top right. Almost 90% of the papers (journal papers and papers published in conference proceedings) in the bibliography have abstracts that can also be viewed on-line.

Nelson, N. A., J. D. Kaufman, et al. (1995). Health Symptoms and the Work Environment in Four Nonproblem United States Office Buildings. Scand Work Environ Health. **21:** 51-59.
Geographical Location: USA, Washington
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Objectives: The objective of this study was to quantify health symptom reports in four "non-problem" buildings and to assess the relationship between symptoms and air quality measures, workstation characteristics, and psychosocial aspects of the workplace. Methods: Environmental sampling was conducted in four office buildings occupied by employees working for the state of Washington in March of 1992. A questionnaire was concurrently administered to building occupants. Results: While measured contaminant levels were low. symptoms were frequent. Fifty-five percent of

the 646 respondents reported recent symptoms which affected the eyes, nose, or throat and improved when away from work. Symptoms were not associated with measured contaminant levels, but, rather, with perceptions about air movement, dryness, odours, and noise. Psychosocial factors were less strongly associated with symptoms. Conclusions: Even in non-problem buildings, symptom reports can be frequent and may represent overall satisfaction with the work environment. In response to symptoms ascribed to air quality problems, it may be appropriate to address employee perceptions regarding the work environment in addition to evaluating environmental characteristics relating to chemicals, biological contamination, air movement, temperature, and humidity.

Newsham, G. R. and D. K. Tiller (1997). A Field Study of Office Thermal Comfort Using Questionaire Software. ASHRAE Transactions: Research. **103:** 3-17.
Geographical Location: Canada, Ontario, Ottawa
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Custom software to automatically administer questionnaires on computer screens was installed on computers in four open-plan offices. Five questions related to thermal comfort were presented twice per day for three months. Results indicate that this new method of subjective data collection was successful and efficient: the participants had few complaints about the method of questionnaire delivery, and a substantial literature review demonstrates that our results are comparable with results from other field studies of thermal comfort conducted using different methods. Participants responded to the questionnaire 29% of the occasions on which it could have been presented and took an average of 45 seconds to answer the five questions. Overall, the number of thermal sensation votes indicating thermal acceptabilit) were as predicted by the ANSJ/ASHRAE Standard and by the comfort theory on which this standard was based. However, our results indicate a greater sensitivity to temperatures away from the neutral temperature than theory predicts. Only 11% of the variance in thermal sensation vote was explained by indoor air temperature. Approximately 15% of the people modified their clothing in the hour prior to the appearance of the questionnaire, suggesting that clothing modification may be an important mechanism for achieving thermal comfort.

Newsham (1998). Cost effective open plan environments. COPE Seminar.
Geographical Location: Canada
Building Type: office
Data Type: theory; case study
Outcome Focus: operation, cost; occupant, productivity

Abstract

Dramatic changes in office design and furnishings are occurring all over North America. These changes have captured the attention of mainstream media, and many organisations are considering following the trend. Whether labelled "space optimisation", "hotelling", or "hot desking", the changes have a basic theme in common: A desire to reduce occupied floor space and its associated costs; and, A belief that a physical change can effect an organisational change that will increase productivity.

Nicklas, M. a. B., G. (1996). "Analysis of performance of students in daylit schools." Sunworld **20**(3).

Nicol, F. (2003). The dialectics of thermal comfort. United Kingdom**:** 16.
Geographical Location: various
Building Type: office
Data Type: survey, theory
Outcome Focus: occupant, well-being

Abstract

Covers the relationship between people and buildings: how buildings affect people and how people affect buildings. Also the role of climate (in/out), culture and economics. The study is multi-disciplinary involving physiology, physics, psychophysics, building science, social science and meteorology.

Niemela, R., J. Railio, et al. (2000). Assessing the Effects of Indoor Environment on Productivity. CLIMA 2000. Naples, Italy. **Proceedings of the Seventh World Congress**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Niemela, R., M. Hannula, et al. (2002). The effect of air temperature on labour productivity in call centres - a case study. Energy and Buildings. **34:** 759-764.
Geographical Location: Finland
Building Type: office
Data Type: case study, measurement, on-site
Outcome Focus: occupant, productivity

Abstract

The aim of this paper was to investigate the effect of air temperature on labour productivity in telecommunication offices. The study was conducted as a case study in two call centres because the work in the call centres can be considered to represent typical activities in the telecommunication industry. The study design consisted of an observational approach and an intervention approach. In Call Centre I, the productivity between two zones with temperature difference was compared. In Call Centre II, the intervention was conducted by installing cooling units to lower high temperature in the summer. Productivity was monitored both before and after the intervention, and it was measured as labour productivity by monitoring the number of telephone calls divided by the active work time. The indoor climate of both call centres was determined by measuring thermal climate and concentrations of relevant air pollutants as well as the acoustical environment and lighting levels. The study shows that productivity may fall by 5–7% at the elevated indoor temperatures.

Nilsen, S. K., P. Blom, et al. (2002). An Intervention Study of Relationships between Indoor Air-Related Health Problems, Productivity and Cleanliness in an Office Setting. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Europe, Norway
Building Type: Office
Data Type:
Outcome Focus:

Abstract

An intervention study was conducted in an office building to examine the effect of improved cleaning quality on perceived indoor air quality, health and productivity. Effects of a controlled increase in cleaning quality were studied by questionnaires,

registration of sickness absence, psychological tests, measurements of air quality, and visual and instrumental measurements of cleaning quality as described in the internordic standard INSTA 800. The intervention (blind) included introduction of a quality based cleaning programme including all interior surfaces on 2 floors. The intervention led to reduced dust load on furniture and fixtures. INSTA 800 proved to be a good tool to assess cleaning quality. No correlations were found between the two methods used for measuring cleaning quality. Instrumental measurements should be chosen if low dust loads on surfaces are desired. The results indicated that improved cleaning quality may reduce SBS symptoms, improve productivity and reduce short time sickness absence.

Nishihara, N., Y. Yamamoto, et al. (2002). Effect of Thermal Environment on Productivity Evaluated by Task Performances, Fatigue Feelings and Cerebral Blood Oxygenation Changes. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Japan, Tokyo
Building Type: Office
Data Type:
Outcome Focus:

Abstract

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

Niven, R. M., A. M. Fletcher, et al. (2000). Building sickness syndrome in healthy and unhealthy buildings: an epidemiological and environmental assessment with cluster analysis. Occupational and Environmental Medicine. **57:** 627.
Geographical Location: UK
Building Type: Office
Data Type:
Outcome Focus:

Abstract

OBJECTIVES: Building sickness syndrome remains poorly understood. Aetiological factors range from temperature, humidity, and air movement to internal pollutants, dust, lighting, and noise factors. The reported study was designed to investigate whether relations between symptoms of sick building syndrome and measured environmental factors existed within state of the art air conditioned buildings with satisfactory maintenance programmes expected to provide a healthy indoor environment.

METHODS: Five buildings were studied, three of which were state of the art air conditioned buildings. One was a naturally ventilated control building and one a previously studied and known sick building. A questionnaire was administered to the study population to measure the presence of building related symptoms. This was followed by a detailed environmental survey in identified high and low symptom areas within each building. These areas were compared for their environmental

performance.
RESULTS: Two of the air conditioned buildings performed well with a low prevalence of building related symptoms. Both of these buildings out performed the naturally ventilated building for the low number of symptoms and in many of the environmental measures. One building (C), expected to perform well from a design viewpoint had a high prevalence of symptoms and behaved in a similar manner to the known sick building. Environmental indices associated with symptoms varied from building to building. Consistent associations between environmental variables were found for particulates (itchy eyes, dry throat, headache, and lethargy) across all buildings. There were persisting relations between particulates and symptoms (headache, lethargy, and dry skin) even in the building with the lowest level of symptoms and of measured airborne particulates (building B). There were also consistent findings for noise variables with low frequency noise being directly associated with symptoms (stuffy nose, itchy eyes, and dry skin) and higher frequency noise being relatively protective across all buildings.
CONCLUSIONS: This is the first epidemiological study of expected state of the art, air conditioned buildings. These buildings can produce an internal environment better than that of naturally ventilated buildings for both reported symptoms and environmental variables. The factors associated with symptoms varied widely across the different buildings studied although consistent associations for symptoms were found with increased exposure to particulates and low frequency noise.

Norbäck, D., Y.-H. Mi, et al. (2002). Current Asthma, Respiratory Infections and Hypersensitivity to Moulds in Pupils in Shanghai, China, In Relation to Microbial Components in the Classrooms. Indoor Air 2002. Monterey, California.
Geographical Location: China; Shanghai
Building Type: School
Data Type: quantitative, measurement, on-site
Outcome Focus: occupant, health

Abstract

Thirty classrooms in 10 schools in Shanghai (China) were investigated. Dust was collected by vacuum cleaning, analysed for ergosterol, muramic acid, and 3-hydroxy fatty acids (LPS; endotoxin) by tandem mass spectrometry (GC-MSMS). Airborne microorganisms were measured by CAMNEA. The pupils received a questionnaire, 1414 participated (99%). The mean age was 13 y, 45% reported respiratory infections, 5.4% mould allergy, and 3.1% current asthma. Respiratory infections were positively associated with viable moulds in air (p=0.04), viable bacteria (p=0.02), 3-methylfuran (p=0.04), and negatively associated with LPS (p=0.01). Current asthma was positively associated with 1-octen-3-ol (p=0.047), and negatively associated with LPS (p=0.05). Mould allergy/intolerance was positively associated with total moulds (p=0.002) and muramic acid (p<0.001). Respiratory health and intolerance was associated with microbial components in the schools. LPS in settled dust seems to be protective, while muramic acid, viable bacteria, viable and total moulds, and MVOC were associated with adverse health

NSW Legislative Assembly (2001). Report on Sick Building Syndrome. S. C. o. P. Works.
Geographical Location: Australia, Sydney; USA
Building Type: office
Data Type: Review; Expert witness
Outcome Focus: occupant, health

Abstract

no abstract (only forward and executive summary)

Nunes, F., R. Menzies, et al. (1993). The Effect of Varying Level of Outside Air Supply on Neurobehavioral Performance Function during a Study of Sick Building Syndrome. Indoor Air '93. J. J. K. Jaakkola, R. Ilmarinen and Seppanen. Helsinki, Finland. **The 6th International Conference on Indoor Air Quality and Climate:** 53-58.
Geographical Location: Canada, Montreal
Building Type: Office
Data Type:
Outcome Focus:

Abstract

It is generally believed that there exists a relationship between the quality of the indoor office environment, reporting of symptoms of sick building syndrome (SBS) and worker productivity. However, there is no standardized instrument for objective measures, and productivity of most office workers is difficult to measure. 47 workers in one mechanically ventilated office building completed computer-based neurobehavioral performance tests as part of a study of SBS in which the outdoor air supply was experimentally varied. For three weeks workers completed questionnaires regarding symptoms suffered that day, and completed, without supervision, two tests of neurobehavioural function -the continuous performance test (CPT) and the symbol-digit substitution test (SST), while the indoor environment was characterized in detail. Response times, variability, and fatigue for CPT and SST were very similar over all 3 weeks. Personal characteristics such as younger age and clerical work were associated with better performance in CPT. Workers who reported any symptom had significantly higher CPT response times ($P < .001$), and higher SST error rates ($p = .07$). There were modest correlations between higher temperature, lower humidity, and lower air velocity, and slower CPT response times. We conclude that computer-based neurobehavioral tests appear to be a promising tool for determining the impact of symptoms as well as environmental conditions on office workers performance.

O'Reilly, J. T. (1998). Keeping buildings healthy : how to monitor and prevent indoor environmental problems. New York, J. Wiley**:** xvii, 361.
Geographical Location:
Building Type:
Data Type:
Outcome Focus: occupants, health

Abstract

Odemis, K. (1997). Effects of lighting on human performance in offices. Bilkent University, Turkey**:** 6.
Geographical Location: various
Building Type: office
Data Type: qualitative, review
Outcome Focus: occupant performance

Abstract

Lighting is an essential ingredient of work environments. Not only does it influence an individual's perception of work-related tasks, but it also effects their general emotional/motivational state and health. It is clear that many other factors, such as skill, education and previous experience affect productivity, but lighting is one of the least expensive and most important factors that influence human performance in the work environment (Katzev 1992).

Oldham, G. R. and N. L. Rotchford (1983). Relationships between office characteristics and employee reactions: A study of the physical environment. Administrative Science Quarterly. **28:** 545-556.
Geographical Location: USA. Midwest
Building Type: Office
Data Type: qualitative, survey, questionnaire, on-site subjects: office employee
Outcome Focus: occupants, well-being

Abstract

Examined the relationships between objective office characteristics (openness, office density, workspace density, accessibility, and office darkness) and several measures of employee reactions (satisfaction, behaviour during discretionary periods, and spatial markers) in 19 offices of a large university. Data were collected from 114 full-time employees, 93% of whom were women. The extent to which 3 sets of intervening variables explained these relationships was examined. The intervening variables were interpersonal experiences (conflict, friendship opportunities, agent feedback), job experiences (task significance, autonomy, task identity), and environmental experiences (crowding, concentration, privacy). Results indicate that each of the office characteristics related significantly to one or more of the employee reaction measures. Moreover, office characteristics affected several employee reactions through their impact on the intervening variables. (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Oldham, G. R. and Y. Fried (1987). Employee Reactions to Workspace Characteristics. Journal of Applied Psychology. **72:** p75, 6p.
Geographical Location: USA
Building Type: office
Data Type: qualitative
quantitative
questionnaires on-site
measurements, on-site
Outcome Focus: occupants, productivity
occupants, well-being

Abstract

Investigates the independent and joint effects of workspace characteristics on employee reactions. Variance in employee turnover and work satisfaction; Withdrawal from the office during discretionary period; Dissatisfaction of employees on social density, room darkness, number of enclosures and interpersonal distance.

Oldham, G. R. (1988). Effects of Changes in Workspace Partitions and Spatial Density on Employee Reations: A Quasy-experiment. Journal of Applied Psychology. **73:** 253-258.
Geographical Location: USA
Building Type: office
Data Type: qualitative, quantitative, case study
Outcome Focus: occupant, response
occupant, well-being

Abstract

This study examined the effects of moving from an open-plan office to one of two alternative office designs: (a) an office with partitions surrounding employee work areas or (b) a low-density open-plan office with more usable space per employee. A total of 65 claims adjusters from three offices of a large insurance organization provided data at two points in time: 3 months before the office changes and 3 months after the changes. Hierarchical regression analyses and paired t tests showed that, relative to employees in a control office, employees who moved from an open-plan

office to either a low-density open-plan office or to a partitioned office experienced significant improvements ($p < .01$) in task privacy, communication privacy, crowding, and office satisfaction. Moreover, two individual difference measures influenced significantly ($p < .05$) the effects of the office changes on the crowding responses. Employees who had low levels of stimulus screening or high privacy needs reported the largest decreases in perceived crowding after the office changes. The implications of these findings for future research on office design are discussed.

Oldham, G. R., C. T. Kulik, et al. (1991). Physical environments and employee reactions: Effects of stimulus-screening skills and job complexity. Academy of Management Journal. **34:** 929-938.

Geographical Location: USA. South
Building Type: office
Data Type: Qualitative
quantitative
survey
questionnaire, on-site
organiztion records of employee performance
Measurements, on-site
Outcome Focus: occupants, productivity

Abstract

Examined the moderating effects of stimulus-screening skills and job complexity on relations between environmental characteristics and employee reactions. Data of 3 types were obtained from 298 full-time government employees: physical measurements of environments, organization records concerning employee performance, and questionnaires completed by Ss at their desks. Ss exhibited the lowest performance and satisfaction when their jobs were low in complexity, their screening skills were weak, and they worked in dense areas with few enclosures or close to other employees. (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Oliver and Shackelton (1998). The Indoor Air We Breathe. Public Health Reports. **113:** 398–409.

Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Increasingly recognised as a potential public health problem since the outbreak of Legionnaire's disease in Philadelphia in 1976, polluted indoor air has been associated with health problems that include asthma, sick building syndrome, multiple chemical sensitivity, and hypersensitivity pneumonitis. Symptoms are often non-specific and include headache, eye and throat irritation, chest tightness and shortness of breath and fatigue. Airborne contaminants include commonly used chemicals, vehicular exhaust, microbial organisms, fibrous glass particles, and dust. Identified causes include defective building design and construction, aging of buildings and their ventilation systems, poor climate control, inattention to building maintenance. A major contributory factor is the explosion in the use of chemicals in building construction and furnishing materials over the past four decades. Organizational issues and psychological variables often contribute to the problem and hinder its resolution. This article describes the health problems related to poor indoor air quality and offers solutions.

Ooi, P. L., K. T. Goh, et al. (1997). Epidemiology of Sick Building Syndrome and its Associated Risk Factors in Singapore. Occupational Environmental Medicine. **55:** 188-193.
Geographical Location: Singapore
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Objectives- To investigate the occurrence of sick building syndrome in a tropical city, and its relation to indoor air quality and other factors. Methods-2856 office workers in 56 randomly selected public and private sector buildings were surveyed. The study consisted of a self administered questionnaire assessing symptoms and perception of the physical and psychosocial environment, inspection of the building plans and premises, and measurement of temperature, relative humidity, respirable particles, chemicals, bioaerosols, and other variables. Results-Symptoms typical of the sick building syndrome were reported in 19.6% of the respondents. Multivariate modelling substantiated contributions associated with low thermal comfort, high work related stress, too much noise, a history of allergy or other medical conditions, poor lighting, young employees, and female sex. Measurements of indoor air quality or ventilation were not found to be reliable predictors of the symptoms. Conclusion-The survey confirmed the presence of sick building syndrome and its risk factors in the tropics. A biopsychosocial approach to the problem involving symptomatic treatment, environmental control, good ergonomic design, and stress management is recommended.

Oseland, N. A. (1998). Acceptable Temperature Ranges in Naturally Ventilated and Air-Conditioned Offices. ASHRAE Transactions:Symposia. **104:** 1018-1030.
Geographical Location: UK, England
Building Type: Office
Data Type:
Outcome Focus:

Abstract

The thermal environment in eight naturally ventilated and eight air-conditioned offices, located throughout England, was continuously monitored for one week in winter and one week in the following summer. The occupants assessed their thermal sensation (TS) every half-day on the ASHRAE seven-point scale. In total, 1,692 occupants made II ,450 votes in winter and 1,363 people made 9,505 votes in summer. Weighted regression analysis was used to compute the neutral temperature and acceptable temperature range relating to 3.5 <= TS <= 4.5. The overall comfort range in naturally ventilated offices in winter and summer, 4.9°C and 3.9°C (8.8°F and 7.0°F), respectively, was wider than that found in air-conditioned offices, 2.6°C and 2.4°C (4.7°F and 4.3°F), respectively. The neutral temperature in naturally ventilated offices was 0.7°C (1.3°F) lower in winter and 2.1°C (3.8°F) lower in summer than in air-conditioned offices. However, there was only a marginal difference in clothing insulation and activity levels between the two types of offices. The lower neutral temperature in naturally ventilated offices in summer may partly be due to an overestimation of warmth due to conditions typically being warmer than the previous day. Discrepancies of up to 3.0°C (5.4°F) were found between the observed neutral temperatures and those predicted by ISO 7730 for naturally ventilated offices in summer. In contrast, for the air-conditioned offices in winter and summer and naturally ventilated offices in winter, the predicted neutral temperatures were much closer to those reported. with a maximum difference of only 0.6°C (I.IOF). In winter, the percentage of occupants satisfied with the temperature in the naturally ventilated buildings (76%) was higher than in the air-conditioned offices (70%), whereas in summer, there was less satisfaction in the naturally ventilated offices.(69%) than in

the air-conditioned offices (73%). The occupants were less dissatisfied in the naturally ventilated buildings in winter than in summer, whereas there was only a marginal difference in dissatisfaction between seasons in the air-conditioned offices.

P, D. (1999). "Beyond the Information Revolution." The Atlantic Monthly **284**.

Pacific Gas and Electric (2003). Daylighting Initiative, WWW.
Geographical Location: U.S.A.
Building Type: Office; Schools
Data Type: Case Study; Measurements, on-site; tests
Outcome Focus: occupant, productivity; building, energy

Abstract

http://www.pge.com/003_save_energy/003c_edu_train/pec/daylight/daylight.shtml

Pahwa, D. (1996). New Ventilation Standards for Indoor Air Quality (IAQ) vs Energy Conservation: Enthalpy wheels meet the Challenge. FRIGAIR 1996. South Africa.
Geographical Location: various
Building Type: unknown
Data Type: ?
Outcome Focus: operation, energy

Abstract

Palmer, M. A. M. (2001). Green Buildings and Worker Productivity A Review of the Literature. San Francisco.
Geographical Location: USA
Building Type: office
Data Type: review, case studies
Outcome Focus: occupant, well being
operation, energy

Abstract

Americans make up less than 5% of the world's population, yet consume 25% of the earth's resources and create 25% of the world's greenhouse gases. We are told that the construction and operation of buildings are major contributors to this problem, and being building industry professionals we have a major responsibility to improve the performance of our buildings and environments.

The most compelling argument for improving building efficiency and performance may be found in the relationship between occupant comfort and worker productivity. Worker salaries constitute the major cost of operating a commercial building, generally estimated at over 90% of the total operating costs, so that even a small increase in employee productivity can substantially increase a company's financial return.

Palmer, M. and A. Mariscal (2002). Green Buildings and Worker Productivity - A Review of the Literature. SF Environment.
Geographical Location: USA
Building Type: Office
Data Type:
Outcome Focus:

Abstract

Palomaki, E., M. Seuri, et al. (2002). Damaged Flooring Material and Absenteeism in an Office. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Flooring materials may break down if mounted on a damp concrete surface. There are some reports relating to upper respiratory and asthma symptoms caused by degradation by-products of polyvinyl chloride building materials. Here, we report increased number of upper respiratory, conjunctival and dermal symptoms among employees exposed to the degradation by-products of linoleum floor coverings. The number of sick leaves caused by respiratory symptoms and diseases rose simultaneously. The damaged flooring materials were removed and replaced by epoxy coating, which is not affected by moisture. After the repairs, the number of sick leaves due to respiratory symptoms and diseases decreased by 14%. It was calculated that the repair costs were paid back in two years in terms of decreased expenditures on the care of respiratory diseases and symptoms.

Pan, Z., L. Molhave, et al. (2000). Effects on Eyes and Nose in Humans after Experimental Exposure to Airborne Office Dust. Indoor Air. **10:** 237-245.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

To test sensory irritation symptoms and physiological effects on humans caused by airborne office dust, ten subjects were exposed to both clean air and airborne non-industrial office dust for 3 h in a climate chamber. The average dust concentration in exposure sessions was 394 mg/m3 total suspended dust (TSD). Tear film break-up time, foam formation in the eye canthus, conjunctival epithelial damage, nasal volume, and nasal minimal cross-sectional area were assessed. Tear film break-up time decreased significantly after dust exposure and nasal volume showed a tendency to decrease. In a questionnaire investigation, significant effects were found from the questions: "facial skin humidity", "throat irritation", "feeling needs of coughing", "dry nose", "concentration difficulty", and "headache". Additionally, the intensity of the questions "facial skin humidity", "dry nose", "body skin temperature", "sluggishness", and "sleepiness" worsened over time. A correlation analysis showed that perceived "air quality" was significantly correlated with "dry eyes", "eye irritation", "facial skin irritation", "nose irritation", and "feeling stressed by chamber occupancy" for subacute responses, and with "odour intensity" for acute responses. This supports that the perceived air quality may be a function of odour and irritation symptoms. A number of localized symptoms of irritation (e.g. dry nose, throat irritation, coughing) and of general symptoms (e.g. sluggishness, sleepiness, headache, ability to concentration) were mutually correlated acutely and subacutely. These results indicate that non-industrial office dust may cause physiological changes and sensory symptoms in eyes and nose and that these effects have different time courses.

Pasanen, T., T. Keskikuru, et al. (2002). Indoor Air Quality and the Adequacy of Cleaning in 25 Finnish Schools. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Indoor air quality and the adequacy of cleaning were studied in 25 schools in a Finnish city. Methods included a questionnaire for teachers (Örebro MM-40-FIN) and measurements of ventilation rate, CO2, temperature, particulate matter (PM) and surface dust in 56 classrooms. In most classrooms, ventilation rates did not fulfil the rate required by the Finnish building code. CO2-concentrations were lowest in classrooms with mechanical ventilation and highest in classrooms with natural ventilation. Ventilation rates correlated with PM in all particle size groups except the smallest one. Total PM-levels exceeded the recommended values, and almost all classrooms were too warm. No correlation was found between PM and surface dust. According to the questionnaire (n=424 teachers), main problems in the working environment were dust, stuffy or dry air and noise. There was a statistically significant correlation between perceived indoor air quality and symptoms. The prevalence of symptoms did not explain dissatisfaction with work.

Pejtersen, J., H. Brohus, et al. (2001). Effect of Renovating an Office Building on Occupants' Comfort and Health. Indoor Air. **11:** 10-25.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

An intervention study was performed in a mechanically ventilated office building in which there were severe indoor climate complaints among the occupants. In one part of the building a new heating and ventilation strategy was implemented by renovating the HVAC system, and a carpet was replaced with a low-emitting vinyl floor material; the other part of the building was kept unchanged, serving as a control. A comprehensive indoor climate investigation was performed before and after the intervention. Over a 2-week period, the occupants completed a daily questionnaire regarding their comfort and health. Physiological examinations of eyes, nose and lungs were performed on each occupant. Physical, chemical and sensory measurements were performed before and after the intervention. The renewal of the flooring material was performed after a sensory test of alternative solutions in the laboratory. Before the floor material was installed in the office building, a full-scale exposure experiment was performed in the laboratory. The new ventilation strategy and renovation of the HVAC system were selected on the basis of laboratory experiments on a full-scale mock-up of a cellular office. The severity of occupants' environmental perceptions and symptoms was significantly reduced by the intervention.

Plympton, P., S. Conway, et al. (2000). Daylighting in Schools: Improving Student Performance and Health at a price schools can afford. NREL conference paper.
Geographical Location: USA
Building Type: school
Data Type: case study
Outcome Focus: occupant, productivity
occupant, health

Abstract

Over the next 7 years, at least 5000 new schools will be designed and constructed to meet the needs of American students in kindergarten through grade 12 schools. National efforts are underway to encourage the use of daylighting, energy efficiency, and renewable energy technologies in school designs, which can significantly enhance the learning environment. Recent rigorous statistical studies, involving 21000 students in three states, reveal the students perform better in daylit classrooms and indicate the health benefits of daylighting. This paper discusses the evidence regarding daylighting and student performance and development, and presents four case studies of schools that have cost effectively implemented daylighting into their buildings.

PROBE (1999). PROBE3. Building Services Journal.
Geographical Location: England
Building Type: building
Data Type: case study, survey
Outcome Focus: occupant, response
operation, energy

Abstract

Over the last 5 years the PROBE research team has uncovered the stark truths of how buildings really perform. Successes and failures have been reported in equal measure, providing clients designers and end users with valuable, real-world information.

PROBE (2002). PROBE The Centre for Mathematical Sciences. Building Services Journal.
Geographical Location: England
Building Type: building
Data Type: case study, survey
Outcome Focus: occupant, response
operation, energy

Abstract

Projects with recurring design elements can provide a rare opportunity for architects and engineers to apply the lessons learned from early buildings to those constructed later.

QUT (2003). Work Effectiveness Research Program. Brisbane, QUT.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Raiford, R. (2001). New Courses: Unlock the Mysteries of Productivity, Air Quality, and the Indoor Environment in Schools. Buildings. **95:** 40-42.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Discusses the relationship between indoor air quality and productivity and a three-year research project to measure productivity within an educational setting. Also discusses research showing the impact of good indoor air quality on increasing productivity. Ten ways to manage asthma in a school environment are highlighted. (GR)

Raizenne, M., R. Dales, et al. (1998). Air Pollution Exposures and Children's Health. Canadian Journal of Public Health. **89:** S43-S48, S47-S53.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The evidence from a large number of studies indicates that exposures to current outdoor air pollution increase respiratory morbidity in children. Children with asthma, and those with asthma-like symptoms but without a diagnosis of asthma, are considered to be at highest risk of experiencing short term and/or longer-term adverse health effects. Many outdoor air pollutants readily penetrate indoors. Indoor air quality can deteriorate quickly when persistent and uncontrolled emissions occur and the ventilation/air exchange rate is reduced. It has been estimated that children spend 90% of their time indoors, including in school buildings, vehicles and public indoor environments. Environmental tobacco smoke is a well-recognized persistent indoor air contaminant with adverse health effects in children of al1 ages. Uncontrolled moisture in the indoor environment is increasingly recognised to significantly Increase the risk of respiratory morbidity in children. The evidence that air pollutants singly and in combination with other environmental factors elicit adverse health responses in asthmatic and non-asthmatic children and adolescents, appears irrefutable.

Ramakrishnan, K. and K. Cena (1995). Air-Conditioning: Air Pollution and Sick Building Syndrome. Specifier. **4:** 80-83.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The occurrence of sick building syndrome (SBS) in occupied spaces due to indoor air pollution is becoming common. It is difficult to assess the degradation of indoor air quality (IAQ) due to the cocktail effect of various pollutants. Ventilation has been implicated in many problem buildings. This article aims to establish the relationship between ventilation and sensory perception of air quality and gives details of test results of the experimental evaluation of some occupied spaces. It also details the IAQ evaluation methodology used and the interpretation of results obtained. The evaluation includes the measurement of indoor and outdoor carbon dioxide levels, sensory panel assessment of IAQ and occupant survey by means of a survey instrument (panel assessment).

Reinikainen, L. M., L. Aunela-Tapola, et al. (1997). Humidification and perceived indoor air quality in the office environment. Occupational and Environmental Medicine [NLM - MEDLINE]. **54:** 322.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

OBJECTIVE: To evaluate the effect of humidification on the odour, acceptability, and stuffiness of indoor air. METHODS: In a six period cross over trial at the Pasila Office Center, Helsinki, the air of two wings of the building in turn were ventilated with air of 30%-40% humidity. A third wing served as a non-humidified control area. The quality of indoor air was assessed weekly by a panel containing 18 to 23 members. The intraindividual differences in the ratings for odour, stuffiness, and acceptability between humidified and non-humidified wings were used to assess the effect of humidification. The roles of sex, current smoking, and age as potential effect modifiers were assessed by comparing the mean intraindividual differences in ratings between the groups. RESULTS: Humidified air was found to be more odorous and stuffy (paired t test P = 0.0001) and less acceptable than the non-humidified air (McNemar's test P 0.001). The differences in odour and stuffiness between humidified and non-humidified air were greater for women and for non-smokers, and greatest differences were in the youngest age group, and least in the oldest age group. The differences were not significant. CONCLUSIONS: An untrained panel of 20 members is able to differentiate a slight malodour and stuffiness in indoor air. The results suggest that steam air humidification decreases the perceived air quality. This effect is strongest in women and young subjects.

Reinikainen, L. M. and J. J. K. Jaakkola (2001). Effects of Temperature and Humidification in the Office Environment. Archives of Environmental Health. **56:** 365–368.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

In this investigation, the authors evaluated the relationship between temperature and (a) Sick Building Syndrome symptoms and (b) workers' perceptions of air dryness in environments with and without humidification. The authors studied the average intensity of symptoms and perceptions of dry air relative to room temperature in humidified and non-humidified conditions. During the 6 wk of the experiment, 2 wings of the building were humidified one-by-one for 1 wk, followed by a week without humidification. A total of 230 daily questionnaires were completed during the non-humidified period, and 233 were completed during the humidified period. The results were analyzed with linear regression analysis, and the average intensity of dryness symptoms and sensations of dryness increased with each unit increase in temperature above 22 °C, both in the humidified and non-humidified conditions. Sick Building Syndrome symptoms increased relative only to temperature during the period of no humidification. In conclusion, temperatures above 22 °C caused increased dryness symptoms and a sensation of dryness, independent of humidification. The overall intensity of Sick Building Syndrome symptoms increased only when indoor air was not humidified.

Reynolds, S. J., D. W. Black, et al. (2001). Indoor Environmental Quality in Six Commercial Office Buildings in the Midwest United States. Applied Occupational and Environmental Hygiene. **16:** 1065–1077.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The aims of this study were to characterize physical, mechanical, and environmental factors influencing indoor environmental quality (IEQ) in commercial office buildings; document occupant perceptions and psychosocial attributes; and evaluate relationships among these parameters. Six large office buildings in metropolitan areas were selected in Iowa, Minnesota, and Nebraska. Comprehensive sampling was conducted over one week in each building, during all four seasons. This paper presents the study methods and selected results from the first round of sampling (November 1996 to April 1997). Air flow and recirculation rates were quite variable, with the proportion of outdoor air provided to occupants ranging from 10 to 79 CFM/person. Carbon dioxide, carbon monoxide, and temperature were within ranges anticipated for non-problem buildings. Relative humidity was low, ranging from 11.7 to 24.0 percent. Indoor geometric mean concentrations of total volatile organic compounds (TVOCs) ranged from 73 to 235 ¹g/m3. The most prevalent compounds included xylene, toluene, 2-propanol, limonene, and heptane. Geometric mean formaldehyde concentrations ranged from 1.7 to 13.3 ¹g/m3, and mean acetaldehyde levels ranged from <3.0 to 7.5 ¹g/m3. Airborne concentrations of culturable bacteria and fungi were low, with no samples exceeding 150 CFU/m3. Total (direct count) bioaerosols were more variable, ranging from5010 to 10,700 organisms/m3. Geometric mean endotoxin concentrations ranged from 0.5 to 3.0 EU/m3. Respirable particulates (PM10) were low (14 to 36 ¹g/m3). Noise levels ranged from 48 to 56 dBA, with mean light values ranging from 200 to 420 lux. Environmental parameters were significantly correlated with each other. The prevalence of upper respiratory symptoms (dry eyes, runny nose), central nervous system symptoms (headache, irritability), and musculoskeletal symptoms (pain/stiffness in shoulders/neck) were elevated compared to other studies using similar questionnaires. Importantly, psychosocial factors were significantly related to increased symptoms in females, while environmental factors were more closely correlated with symptoms in males. Endotoxin concentrations were associated with symptoms in both males and females. These data will help to identify and quantify the relative role of factors that contribute to sick building syndrome. The data collected in this study may also be used to evaluate the effectiveness of current building operation practices, and can be used to prioritize allocations of resources for reduction of risk associated with IEQ complaints.

Robbins, C. L. (1986). Daylighting: Design and analysis. New York, Van Nostrand Reinhold.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Romm, J. J. and W. D. Browning (1998). Greening the Building and the Bottom Line: Increasing Productivity throught energy efficient design, Rocky Mountain Institute.
Geographical Location: USA
Building Type: commercial
Data Type: case study
Outcome Focus: occupant, productivity operation, energy

Abstract

Rosen, L. N., S. D. Targum, et al. (1999). "Revalence of Seasonal Affective Disorder at four latitudes." Psychiatry Research **31**: 131-144.

Rosenblum, S. and B. Spark (2002). A Guide to Lowering Test Scores. Leadership. **32:** 30-31.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Unhealthy environmental conditions in classrooms can make it difficult for students and teachers to concentrate and affect productivity, health and the bottom line.

Ross, Z. A. and B. Walker (1999). Reading, Writing and Risk: Air Pollution Inside California's Portable Classrooms. Sacramento, California, Environmental Working Group, The Tides Center.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

An exhaustive review of the scientific literature finds clear evidence that some portables can expose children to toxic chemicals at levels that pose an unacceptable risk of cancer or other serious illness.

Roulet, C.-A. (2001). Indoor environment quality in buildings and its impact on outdoor environment. Energy and Buildings. **33:** 183-191.
Geographical Location: Switzerland
Building Type: office
Data Type: review
Outcome Focus: occupant, comfort, operation, energy

Abstract

The main purpose of buildings is to provide a comfortable living environment for their occupants. This includes, among others, thermal, visual and acoustic comfort as well as indoor air quality. Except during the 1950's and 1960's, it has always been considered important that an excess use of energy shoud be avoided in the construction and the management of a building, sometimes even at the cost of user comfort. Energy savings is, however, not the main purpose of the building. Indeed, if it were really so, the largest energy savings would be obtained by not erecting the building in the first place.
Since the Rio conference, there have been more and more incentives to save energy and lower the impact of buildings on the environment. Therefore, there is no excuse

for the buildings sector not to adopt a sustainable development policy.
Some energy is required to control the indoor climate and indoor air quality. Therefore, it is often suspected that energy savings result in poorer indoor environment quality, or, on the contrary, that a high comfort level is the result of high technology and high energy consumption. this is not true. It is now generally admitted among building scientists that high quality energy services do not necessarily incur a high energy use, and that good environment quality can be obtained with a reasonable amount of energy and power, and with a low environmental impact.
The presentation brings some evidence from past and current research to support this assertion.

Rowe, D. M., S. G. Lambert, et al. (1995). Pale Green, Simple and User Friendly: Occupant Perceptions of Thermal Comfort in Office Buildings. Standards for Thermal Comfort. J. F. Nicol, M. A. Humphreys, O. Sykes and S. Roaf. London, E and F.N. Spon**:** 59-69.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper consist of two parts. The first reviews perceptions of thermal comfort in ten Australian office buildings. The second describes some experiences with a suite of offices that are ventilated through windows and doors but are provided with equipment that permits user controlled on-demand cooling and heating. Observations of use of available thermal control options in this building are interpreted to suggest reasons for high levels of dissatisfaction as recorded from the eight air conditioned office buildings described in the first part.

Rowe, D. (1996). Does HVAC Work? Architectural Science Review. **39:** 127-133.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The problems of unsatisfactory air quality are explored, using the results of a recent survey carried out in twelve Australian buildings, and from international literature. The reasons for dissatisfaction are described, and a strategy for improving conditions proposed.

Ruck, N. (1989). Building Design and Human Performance. USA, Van Nostrand Reinhold.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Rudblad, S., K. Andersson, et al. (2001). Nasal Hyperreactivity among Teachers in a School with a Long History of Moisture Problems. American Journal of Rhinology. **15:** 135-141.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Upper airway symptoms have frequently been reported in people working or residing in damp buildings. However, little information has been available on objective pathophysiologic findings in relation to these environments. Twenty-eight teachers, who had worked for at least five years in a recently renovated school that had had severe moisture problems for years, were randomly selected for this study. Eighteen teachers, who had worked in another school that had no moisture problems, were randomly selected to serve as the control group. Although remedial measures had been taken, an increase in the prevalence of mucous membrane irritations was still reported by the teachers in the target school. We used a nasal challenge test with three concentrations of histamine (1,2 and 4 mg/ml). Recordings of swelling of the nasal mucosa were made with rhinostereometry, a very accurate optical non-invasive method. The growth curves of mucosal swelling induced by the three concentrations of histamine differed significantly between the two groups ($p < 0.01$). The frequencies of atopy, evaluated with the skin-prick test, were almost identical in both groups. The study indicates that long-term exposure to indoor environments with moisture problems may contribute to mucosal hyperreactivity of the upper airways. Such hyperreactivity also seems to persist for at least one year after remedial measures have been taken.

Rudblad, S., K. Andersson, et al. (2002). Slowly Decreasing Mucosal Hyperreactivity Years After Working in a School with Moisture Problems. Indoor Air. **12:** 138-144.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Abstract In our .rst study in 1995, teachers, who had worked in a water damaged school for more than 5 years, were tested for nasal histamine reactivity by rhinostereometry. They were found to have significantly increased reactivity compared with teachers in a school without these indoor-climate problems. This finding could not be explained by differences in atopy or other personal characteristics. In this 2-year follow-up study (1995/7), 26 of 28 teachers in the target school and all 18 teachers in the control school, who participated in the initial study, accepted to take part. They were tested with the same histamine provocation procedure and answered the same questionnaire as 2 years earlier. Technical measurements of temperature, relative humidity, dust, carbon dioxide, formaldehyde and total volatile organic compounds (TVOC) were carried out in both schools during the time period between the two test occasions. In this provocation test, the teachers from the repaired water-damaged school still demonstrated an increased reactivity to histamine compared with the teachers in the control school, but the difference between the growth curves of the provocation tests was less than in 1995. Teachers in the target school still complained about the indoor air quality more than their colleagues, although the complaints were less common. No major differences were observed in the technical investigation between the two schools and the measurements were all within values usually seen in schools in northern countries. Our conclusion is that the observed nasal mucosal hyperreactivity among the teachers in the renovated water-damaged school seems to persist over years and

only slowly decrease even after successful remedial measures have been taken.

Runeson, R., D. Norbäck, et al. (2003). Symptoms and Sense of Coherence - a follow-up study of personnel from workplace buildings with indoor air problems. International archives of occupational and environmental health. **76:** 29-38.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

OBJECTIVES. The aim was to study prevalence and change of symptoms in buildings with suspected indoor air problems in relation to sense of coherence (SOC), a psychological measure of a life attitude.

METHODS. A cohort of 194 subjects initially working in 19 Swedish buildings with indoor environmental problems was followed from 1988 to 1998. Information on 16 symptoms compatible with sick building syndrome (SBS) was gathered by an initial questionnaire mailed between 1988 and 1992. The same symptom questionnaire, as well as Antonovsky's SOC, was administered in a postal follow-up study in 1998. The prevalence of symptoms and the change (incidence) plus reminiscence of symptoms were calculated for individual symptoms and a total symptom score (SC). Bivariate analyses, as well as multiple linear and logistic regression analyses, were applied and adjusted for age, gender, history of atopy and tobacco smoking.

RESULTS. SBS was more common in women, younger subjects and those with a history of atopy. A low SOC was related to a higher prevalence of ocular, nasal, and throat symptoms, tiredness, and headache. In addition, subjects with a low SOC developed more symptoms during the follow-up period. Women had a lower SOC value, but there was no relation between SOC and age, smoking, doctor's diagnosed asthma or a history of atopy. Subjects leaving the problem buildings during the follow-up period had a decrease in symptoms and were more often non-smokers, but had the same mean SOC score as those remaining in the same workplace. CONCLUSIONS. The study indicates that SOC can detect personal vulnerability in relation to suspected environmental stress. Symptoms reported in the buildings with suspected indoor air problems are partly reversible, as indicated by the reduction of symptoms among those leaving these buildings. A multi-disciplinary approach including personality aspects, allergic disorders and indoor exposures should be applied in investigations of buildings with suspected indoor air problems.

Ruyssevelt, P. and R. Bunn (2001). PROBE study Birchensale School 2. Building Services Journal.
Geographical Location: England
Building Type: school
Data Type: case study
Outcome Focus: operation, design

Abstract

In the second of three articles, the PROBE Team report on the detailed design of Birchensale Middle School, and how the design team has incorporated PROBE lessons into the specification.

Saegert, S. (1976). Crowding in real environments. Sage contemporary social science issues ; 25. Beverly Hills, Calif., Sage Publications**:** 126.
Geographical Location: USA
Building Type: Domestic, office, general
Data Type: Qualitative, questionnaire
Outcome Focus: Occupant, well-being
Occupant, respond
Occupant, satisfaction

Abstract

Sahlberg, B., G. Smedje, et al. (2002). Sick Building Syndrome (SBS) Among School Employees in the County of Uppsala, Sweden. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Sick building syndrome (SBS) in school employees was investigated in 38 randomly selected schools in mid-Sweden. A questionnaire was mailed in 1993, with follow-up questionnaires in 1995 and 1997. Exposure was measured in 98 classrooms in 1993, and 101 in 1995. In 1993, 1410 employees participated (85%). The prevalence of weekly ocular, dermal, upper respiratory, and general symptoms in 1993 was 8%, 13%, 26%, 28%, respectively. General symptoms were more prevalent at higher temperature. Eye symptoms and tiredness were more common at lower lightning effect. Tiredness was more common at lower illuminance. Headache was more common at less daylight. Eye symptoms were related to total air concentration of bacteria. A relationship between observed building dampness and SBS symptoms was found, but only in schools with an air exchange rate below the median value (<1.8 ach). The study indicates that bacteria, building dampness, temperature and illumination in schools, are associated with SBS.

Salazar, E., M. Merritt, et al. (2002). Evaluation of energy and environmental performance of three primary schools in the Thames Valley.
Geographical Location: England
Building Type: school
Data Type: measurements, case study
Outcome Focus: operation, energy
operation, environment

Abstract

Three similar primary schools in the Thames Valley were examined to evaluate their energy and environmental performance. All three schools had been occupied for 15-26 months at the start of the project. Utility data were used to calculate kWh/m2/annum performance indicators. These were compared to benchmarks for similar building. Data loggers measured room temperature, relative humidity (RH), metabolic carbon dioxide (CO2), and light levels. These results were also compared

Sanders, M. S. and E. J. McCormick (1992). Human Factors in Engineering and Design. Singapore, McGraw-Hill, Inc.
Geographical Location:
Building Type: office
Data Type: theory, literature review
Outcome Focus:

Abstract

Santilli, J. (2002). Health Effects of Mould Exposure in Public Schools. Current Allergy and Asthma Reports. **2:** 460-467.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper profiles the impact of mould exposure on the health of students, teachers, and staff in two public elementary schools in Connecticut, and explains how the air quality in each school was tested, and how the health of teachers and students was assessed. It also proposes standards for testing indoor air quality and evaluating the health impact of indoor mould exposure on students, teachers, and staff members.

Santilli, J. and W. Rockwell (2003). Fungal Contamination of Elementary Schools: a New Environmental Hazard. Annals of Allergy, Asthma and Immunology. **90:** 203.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

BACKGROUND: Sensitivity to fungi is a significant cause of allergic diseases, and prolonged indoor exposure to fungi is a growing health concern.
OBJECTIVE: This study evaluates the health effects of mould-contaminated schools on students and teachers. A discussion of the effectiveness of current methods for evaluating these schools, with a focus on the importance of using total mould spore counts, is also provided.
METHODS: Two Connecticut public schools were tested using multiple air quality testing methods, with the standard for a healthy indoor environment being total mould spore counts lower than 1,000 spores/m3. The health impact of the mould exposure at each school was evaluated using the validated Rhinitis Outcomes Questionnaire.
RESULTS: The testing of the first school found indoor mould counts ranging from 6,000 to 50,000 spores/m3. Eighty-five of the students and teachers reported significant allergic symptoms to the school nurse. This school is currently being demolished. More than 2 years after the exposure ended, a number of occupants of the school continue to have elevated symptoms compared with before their exposure to the school. The testing of the second school revealed total mould spore counts ranging between 2,000 and 9,000 spores/m3, qualifying it an unhealthy environment in need of immediate remediation. Students reported significant allergic symptoms from exposure to certain rooms that are currently being remediated.
CONCLUSIONS: Because of the negative impact on health that indoor mould exposure has, particularly in atopic patients, schools should be routinely tested for fungal contamination. Total mould spore counts should be performed using volumetric air sampling such as the Allergenco MK-3 (Allergenco, San Antonio, TX) because testing air quality via semiquantitative culture sampling alone does not give a true reflection of the extent of fungal contamination. Finally, the standard for a

healthy indoor environment should be defined as having <1,000 spores/m3.

Sattler, B., B. M. Afzal, et al. (2001a). Safe Workplaces and Healthy Learning Places: Environmentally Healthy Schools, American Nurses Association.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Sattler, B., M. Brenda, et al. (2001b). Childrens Health and the Environment: Safe Workplaces and Healthy Learning Places: Environmentally Healthy Schools.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Every school day, parents send their children to school with the hopes that they will be healthy and safe and will receive education. A variety of environmental risks may be posed in some schools that can make them potentially unsafe and unhealthy, and hinder children's ability to learn. This independent study module (ISM) provides the reader with a brief overview of some of the key environmental health risks associated with schools. Information is presented about the environmental exposures, signs and symptoms of toxicity, and the nurses role as an agent of change to help encourage and produce healthy and safe schools. Children's special vulnerabilities are described, as well as child-specific information regarding the toxicity associated with exposures. Pesticides, mercury, asbestos, formaldehyde radon and carbon monoxide poisoning are discussed. Because indoor air quality can be an important variable affecting the learning process, a general section on this issue is presented. Suggestions are provided addressing environmental health and safety problems, including the use of Health and Safety Committees, as well as advocacy education approaches. A resource section provides a brief listing of resources, many of them are websites, which, in turn will link the reader to additional resources.

Savilahti, R., J. Uitti, et al. (2000). Respiratory Morbidity among Children Following Renovation of a Water-Damaged School. Archives of Environmental Health. **55:** 405-410.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The authors sought to determine whether exposure to moulds, resulting from moisture damage in a school, was associated with increased respiratory symptoms and morbidity among schoolchildren and whether the renovation of this building resulted in a decrease in prevalence of respiratory symptoms and morbidity. The study was a follow-up (1-y interval) of children between the ages of 7 and 12 y from two elementary schools in a Finnish suburb. In addition to a questionnaire completed by the parents, the authors assessed the respiratory health of children by examining the health records of a local health center. In the cross-sectional study, the prevalence of symptoms and infections were higher in the exposed group, as were visits to a physician and use of antibiotics. The school was renovated, after which all prevalence decreased and no significant differences remained, except for visits to a physician (according to questionnaire responses). Therefore, moisture damage and

exposure to moulds increased the indoor air problems of schools and affected the respiratory health of children.

Savilahti, R., J. Uitti, et al. (2001). Increased Prevalence of Atopy among Children Exposed to Mold in a School Building. Allergy (Copenhagen). **56:** 175-179.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Background: The purpose of this study was to assess the occurrence of immunoglobulin E sensitization to common environmental allergens (atopy) and new allergic diseases among schoolchildren after starting school in a water-damaged school building. The staff and pupils of a Finnish elementary school with visible water damage and mould complained of respiratory and skin symptoms. The school building was examined and widespread moisture damage was found. A control school with no visible water damage was also examined. No indication of exceptional microbial growth was found in the samples taken from this school. Methods: History of allergic diseases and the year of diagnosis were established by a questionnaire. IgE antibodies to the common environmental allergens were determined from randomly selected groups from both schools. Results: Elevated IgE vallles were significantly more common among the exposed children, as was the occurrence of new allergic diseases after the children started at the school. Conclusions: The odds ratios for the IgE values of the study groups indicated a possible relationship between exposure to microorganisms and IgE sensitization. Exposure to spores, toxins, and other metabolites of moulds may have complex results with unknown immunogenic effects that may act as a non-specific trigger for allergic sensitization leading to the development of atopy.

Savilahti, R., L. Uitti, et al. (2002). Immunoglobulin G Antibodies of Children Exposed to Microrganisms in a Water Damaged School. Pediatric Allergy and Immunology. **13:** 438-442.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The aim of this study was to determine whether exposure to fungi (moulds and yeasts) among children attending a water-damaged school was reflected by the children's immunoglobulin G (IgG) response to microorganisms typical of water damage and whether the presence of these IgG antibodies was associated with respiratory symptoms and morbidity. The relationships between positive IgG antibodies and atopy, described as elevated allergen-specific immunoglobulin E (IgE) antibodies, were also examined. The study population consisted of a randomly selected group of exposed children attending a water-damaged school and a group of unexposed children of the same age. Serum samples for analyses of IgG and IgE antibodies were drawn from the children. The respiratory morbidity, the number of positive IgG antibodies to nine microorganisms indicating water damage, and IgE sensitization to common environmental allergens (phadiatop@) were studied. The mean number of positive IgG findings was significantly higher among the exposed children. The number of positive IgG antibodies did not correlate with respiratory illnesses or symptoms at the individual level even though the exposed children who had positive IgG antibodies to four or more microorganisms in the total group comparison tended to have higher respiratory morbidity. In the exposed group, a negative correlation was found between the number of positive IgG antibodies and

the total value of allergen-specific IgE antibodies. As among adults exposed to microorganisms at work, IgG antibodies in children seem to be a relevant indicator of exposure to microorganisms in a water-damaged school on the group level.

Savinar, J. (1975). The effect of ceiling height on personal space. Man-Environment systems. **5:** 321-324.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Scarse, J. I. (2001). Curbing the growth in UK commercial energy consumption. Building Research and Information. **29:** 51-61.
Geographical Location: England
Building Type: office
Data Type: case study
Outcome Focus: operation, energy

Abstract

The rate of growth in UK commercial energy consumption since the early 1970s has been approximately three times greater than in the domestic sector. Consumption is projected to continue growing faster than in all other sectors except transport. Increasing floor space has been accompanied by rising energy intensity in many commercial buildings. In the office sector, demand for air conditioning has grown rapidly, and this is associated with a dramatic increase in CO2 emissions. Significant cost-effective CO2 savings have been identified in the sector, using readily available technologies. The Climate Change Levy, and questions of comfort, health and productivity among workers, are pushing energy issues up the agenda for many businesses. However positive action is impeded by barriers in the commercial property sector, such as conflicts of interest between landlords and tenants, poor information and professional conservatism. These barriers act to limit energy efficiency investment, to the detriment of building occupants and wider society for generations to come. These problems will limit the efficacy of existing initiatives that aim to curb commercial sector energy use. The Association for the Conservation of Energy considers that new legislation is needed. This would require freeholders to improve the energy efficiency of their new and existing buildings, in consultation with occupiers and/or unions. Further research is needed on options for sharing the costs and benefits with occupiers and/or energy service companies.

Schakel, E. G. Quite comfort - HVAC systems and acoustics.
Geographical Location: USA
Building Type: office, commercial
Data Type: survey
Outcome Focus: occupant, productivity

Abstract

In today's competitive economy, worker productivity is critical to success. A great deal of new technology is devoted to improving productivity, but one of the simplest and most obvious factors is often overlooked - noise. According to the American Society of Interior Designers (ASID), Washington, D.C., an industry-sponsored study showed that more than 80 percent of the workers surveyed believed they would be more productive if their workspaces were quieter. Their belief was confirmed: When noise was reduced, productivity measurably improved.

Schiller, G., E. Arens, et al. (1988). A Field Study of Thermal Environments and comfort in Office Buildings. ASHRAE Transactions
RP-462. **2:** 280-293.
Geographical Location: USA
Building Type: office
Data Type: measurement, questionnaire
Outcome Focus: occupant response

Abstract

This paper presents the initial findings of ASHRAE research projects RP-462, a field study of environmental conditions and occupant comfort in ten office buildings in the San Francisco Bay region. We made a total of 2342 visits to 304 participants during 2 seasons, collecting a full set of physical measurements and subjective responses at each visit. This paper we describe the building environments and their conformity to the requirements of the thermal standards, the distribution of thermal sensation responses, neutral and preferred temperatures, conditions of thermal acceptability, and gender and seasonal effects on comfort responses. A few of the results are as follows: 78.2% (winter) and 52.8% (summer) of the workstation measurements fell within the ASHRAE standard 55-81 comfort zones; the higher summer comfort zone was judged as too warm based on several rating scales; neutral temperatures were 22.0 dC (winter) and 22.6 dC (summer), and preferred temperatures were 0.2-0.6 dC cooler.

Schneider, M. (2002). Do School Facilities Affect Academic Outcomes? National Clearing House for Educational Facilities**:** 1-24.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

On any given school day, about twenty percent of Americans spend time in a school building. The average age of our schools is close to fifty years, and studies by the U.S. General Accounting Office have documented widespread physical deficiencies in many of them. Faced with an aging building stock and growing, shifting student enrollments, states and communities are working hard to build and modernize K-12 facilities. Those involved in school planning and design see this as an opportunity to enhance academic outcomes by creating better learning environments. Their logic is compelling - how can we expect students to perform at high levels in school buildings that are substandard? We all know that clean, quiet, safe, comfortable, and healthy environments are an important component of successful teaching and learning. But which facility attributes affect academic outcomes the most and in what manner and degree? A growing body of research addresses these questions. Some of it is good, some less so; much of it is inconclusive. The research is examined here in six categories: indoor air quality, ventilation, and thermal comfort; lighting; acoustics; building age and quality; school size; and class size.

Schwela, D. (2001). Progress on the Indoor Environment and Reduction of Health Impacts. ASIA Pacific conference on the environment. Progress on energy efficiency and indoor air quality. Y. W. Wong. Singapore, ASHRAE Singapore, Malaysian Chapter. **2:** 411-433.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Seep, Glosemeyer, et al. (2000). Classroom Acoustics. Noise Pollution Clearinghouse.
Geographical Location: USA
Building Type: school
Data Type: qualitative
theory
case study
Outcome Focus: occupant, productivity

Abstract

The United States is currently in the midst of the largest campaign of school construction and renovation in history. With the increased emphasis on education, we must seize the opportunity to end a long-standing American practice: the building of classrooms with inferior acoustics. This invisible problem has far-reaching implications for learning, but is easily solved.

Sensharma, N. P., J. E. Woods, et al. (1996). Relationship bewteen the Indoor Environment and Productivity: A Literature Review. ASHRAE. **RP-700:** 686-700.
Geographical Location: various
Building Type: office
Data Type: literature review
Outcome Focus: occupant, productivity

Abstract

Results of studies assessing the relationship between indoor environmental quality and productivity are often divergent. Additionally, these results provide little direction to design and construction professionals for achieving environmental quality that supports occupant performance and productivity. The objective of this literature review was to identify commonly used measures of productivity and their links with factors in the indoor environment related to HVAC system performance. This literature search identified 262 references, 53 of which were found to be relevant in addressing these issues. As a means to analyzing the results reported in the literature, measures of productivity were classified in terms of traditional and non-traditional figures of merit (FOMs). It was found that office environments are the primary focus of current research and that most studies do not address the wide range of factors that may influence productivity. Additionally, contradicting results were found regarding the relationship between human responses, occupant performance, and productivity. It is concluded from these results that FOMs can be standardized for specific building functional categories (BFCs) but that site-specific modifications may be needed. To identify FOMs that are measurable and controllable, it is important to identify links between occupant performance and productivity and a set of factors including systems, exposures, and human responses. It is recommended that future research focus on defining reliable and valid FOMs, standardizing FOMs for each BFC, and clarifying the links in human responses, occupant performance, and productivity.

Seppanen, O. A., W. J. Fisk, et al. (1999). Association of Ventilation Rates and CO2 Concentrations with Health and Other Responses in Commercial and Institutional Buildings. Indoor Air. **9:** 226-252.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper reviews current literature on the associations of ventilation rates and

carbon dioxide concentrations in non-residential and non-industrial buildings (primarily offices) with health and other human outcomes. Twenty studies, with close to 30,000 subjects, investigated the association of ventilation rates with human responses, and 21 studies, with over 30,000 subjects, investigated the association of carbon dioxide concentration with these responses. Almost all studies found that ventilation rates below 10 Ls-1 per person in all building types were associated with statistically significant worsening in one or more health or perceived air quality outcomes. Some studies determined that increases in ventilation rates above 10 Ls-1 per person, up to approximately 20 Ls-1 per person, were associated with further significant decreases in the prevalence of SBS symptoms or with further significant improvements in perceived air quality. The carbon dioxide studies support these findings. About half of the carbon dioxide studies suggest that the risk of sick building syndrome symptoms continued to decrease significantly with decreasing carbon dioxide concentrations below 800 ppm. The ventilation studies reported relative risks of 1.5 - 2 for respiratory illnesses and 1.1 - 6 for sick building syndrome symptoms for low compared to high ventilation rates.

Seppanen, O. and W. J. Fisk (2002a). Relationship of SBS-Symptoms and Ventilation System Type in Office Buildings. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper provides a summary of current knowledge about the associations of ventilation types in office buildings with sick building syndrome symptoms. Most studies completed to date indicate that relative to natural ventilation, air conditioning, with or without humidification, was consistently associated with a statistically significant increase in the prevalence of one or more SBS symptoms, by approximately 30% to 200%. In two of three analyses from a single study, symptom prevalences were also significantly higher in air conditioned buildings than in buildings with simple mechanical ventilation and no humidification. The available data also suggest, with less consistency, an increase in risk of symptoms with simple mechanical ventilation relative to natural ventilation. The statistically significant associations of mechanical ventilation and air conditioning with SBS symptoms are much more frequent than expected from chance and also not likely to be a consequence of confounding by several potential personal, job, or building-related confounders.

Seppanen, O. and W. J. Fisk (2002b). Association of Ventilation System Type with SBS Symptoms in Office Workers. Indoor Air. **12:** 98-112.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper provides a review and synthesis of current knowledge about the associations of ventilation system types in office buildings with sick building syndrome symptoms and discusses potential explanations for the associations. Relative to natural ventilation, air conditioning, with or without humidification, was consistently associated with a statistically significant increase in the prevalence of one or more SBS symptoms. Prevalences were typically higher by approximately 30% to 200% in the air conditioned buildings. In two of three assessments from a single study,

symptom prevalences were also significantly higher in air conditioned buildings than in buildings with simple mechanical ventilation and no humidification. In approximately half of assessments, SBS symptom prevalences were significantly higher in buildings with simple mechanical ventilation than in buildings with natural ventilation. Insufficient information was available for conclusions about the potential increased risk of SBS symptoms with humidification. The statistically significant associations of mechanical ventilation and air conditioning with SBS symptoms are much more frequent than expected from chance and also not likely to be a consequence of confounding by several potential personal, job, or building related confounders. The reasons for the increases in symptom prevalences with mechanical ventilation and particularly with air conditioning remain unclear. Multiple deficiencies in HVAC system design, construction, operation, or maintenance, including some which cause pollutant emissions from HVAC systems, may contribute to the increases in symptom prevalences.

Seppanen, O. A., W. J. Fisk, et al. (2002b). Ventilation Rates and Health. Commercial Building Ventilation & Indoor Environmental Quality. **44:** 56-58.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

While ventilation rates do not directly affect occupant health or perception outcomes, they affect indoor environmental conditions including air pollutant concentrations that may modify the occupants' health or perceptions. This article summarizes the review by Seppanen, et al. of current literature on the relationship of ventilation rates and carbon dioxide concentrations in non-residential and non-industrial buildings (primarily offices) with the health of the building's occupants and with the occupants' perceptions of indoor air quality (IAQ). The review aims to provide a better scientific basis for setting health-related ventilation standards. This summary focuses primarily on the ventilation rate studies.

Seppanen, O., W. J. Fisk, et al. (2002c). Ventilation Rates and Health. ASHRAE Journal [H.W. Wilson - AST]. **44:** 56.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

A review of current literature on the relationship of ventilation rates and carbon dioxide concentrations in non-residential and non-industrial buildings to the health of the building's occupants and the occupants' perceptions of indoor air quality. The goals are to provide a better scientific basis for setting health-related ventilation standards. The focus is primarily on ventilation rate studies.

Shiver, H. K. (2000). Energy Use in Buildings, with an emphasis on energy expended through Lighting. Washington and Lee University.
Geographical Location: USA
Building Type: university
Data Type: case study, survey, literature review
Outcome Focus: operation, energy

Abstract

The design of any building derives from considered responses to climate, technology,

culture, and site. Considerations of global sustainability and energy conservation bear directly on these four issues and therefore go right to the heart of architectural design.

Shum, M. (2002). An Overview of the Health Effects Due to Mold Exposure. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

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

Sieber, W. K., L. T. Stayner, et al. (1996). The National Institute for Occupational Safety and Health Indoor Environmental Evaluation Experience, Part Three: Associations between Environmental Factors and Self-Reported Health Conditions. Applied Occupational and Environmental Hygiene. **11:** 1387-1392.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Associations between environmental factors and work-related health conditions were assessed using regression techniques with environmental and health data for 2435 respondents in 80 office buildings included in the National Institute for Occupational Safety and Health Hazard Evaluation program. The health conditions analyzed included two symptom groupings - multiple lower respiratory symptoms and multiple atopic symptoms - and the presence of asthma diagnosed after beginning work in the building. Four categories of environmental variables were included: heating, ventilation, and air conditioning (HV AC) system design; HV AC maintenance; building design; and building maintenance. Female gender and age over 40 years showed increased relative risks (RRs) for each health condition. In regression models adjusted for age and gender, RRs of multiple lower respiratory symptoms were increased for variables in the HV AC design and maintenance categories, with the highest RR for presence of debris inside the air intake [RR = 3.1, confidence interval (CI) = 1.8, 5.2] and for poor or no drainage from drain pans (RR = 3.0, CI = 1.7, 5.2). Elevated RRs of multiple atopic symptoms were found for variables in three of the four environmental categories, with the highest for presence of suspended ceiling panels (RR = 2.3, CI = 1.0, 5.5). The RR of asthma was highest if recent renovation with new drywall had been performed (RR = 2.5, CI = 1.4, 4.5). These data are from office spaces about which there was some level of occupant concern, and thus it may not be appropriate to use them to estimate the magnitude and

distribution of symptoms found in all office spaces within U.S. buildings. Furthermore, the high degree of correlation among environmental variables makes it difficult to disentangle which are the most important predictors of work-related health conditions. The analysis is useful, however, for determining factors that may be associated with development of health conditions in the office environment and which might be considered in any building plan to reduce indoor air-related symptoms.

Sigsgaard, T., K. Plesner, et al. (2002). Moulds in the Dust Collector and Health – Children Aged 7 – 10. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This study tested if respiratory symptoms in 7-9 year old school children were associated with mould growth in schools. Eight "wet" and seven "dry" schools including 330 children were studied by means of an interview, spirometry, skin prick test and a "free running test". At each classroom a dust collector was placed for collection of dust for 140 days at app. 1.5 meters height. When dividing the classrooms into quartiles of dust concentration a positive trend was found with increasing quartiles of dust for "sensitisation to moulds" and "nasal symptoms" (Kendal's Tau b [KT]; $p < .05$). For mould exposure we found a positive association between increasing number of moulds and "headache at least once a week" (KT; $p < .05$). These results indicate that the dust collector method for collection of dust is probably a reasonable tool for exposure measurements that are related to health outcomes.

Sinclair, L. (1996). Sick-Building Syndrome: Air on the Side of Safety and Health. Safety + Health. **154:** 40-45.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Poor indoor-air quality can seriously affect workers' health and productivity. Does your building need a checkup?

Sinha, S. P. and S. P. Sinha (1991). Personal space and density as factors in task performance and feeling of crowding. Journal of Social Psychology. **131:** 831-837.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Skulberg, K. R. (1999). Dust, allergy and health in offices: An intervention study on the effect of cleaning. Indoor Air 1. **Proceedings of Indoor Air 1:** 92-93.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The aim of the present study was to examine the hypothesis that decreasing the airborne dust concentration by cleaning in the office will reduce mucous membrane symptoms and nasal airways congestion. This paper focuses on the health effects among allergic and non-allergic office employees. The design was an controlled experimenta1 intervention study with pre- and post-treatment measurements. In the analysis changes in symptoms between the two groups were compared. Intensive cleaning of the offices in the intervention group reduced the airborne dust level compared with the superficial cleaning of the offices in the control group. After the cleaning the participants in the intervention group showed a reduction of mucosal membrane complaints compared to the control group. This reduction was more pronounced among allergic participants, but was also present among non-allergic participants. Multivariate regression analysis indicated that allergy was an independent variable. There was no interaction between the grouping variable and allergy status.

Skyberg, K., K. Skulberg, et al. (2002). Individual and Environmental Variables in Relation to Indoor Air Symptoms Among Office Employees. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

We report a screening questionnaire study in 11 companies without previously recognised indoor air problems. 4556 personal questionnaires were returned from office employees. Individual factors, workload, perceived physical work environment, allergy and symptoms were asked for. Engineers filled in a technical questionnaire on building characteristics, floor surface materials, ventilation, cleaning procedures, heating and cooling, covering 3562 employees. Frequent symptoms were feeling fatigue or heavy-headed, eye irritation and dry facial skin. Women reported symptoms more frequently than men. Employees with allergy had a 1.7 – 2.5 times risk of general symptoms, skin symptoms and mucosal symptoms. The risk of a high symptoms score increased with daily VDU work time. Passive smoking and psychosocial load were also relatively strong predictors of symptoms. Weekly cleaning as compared to a frequency of cleaning 2-4 times a week increased the risk of symptoms. A high ventilation flow and long daily ventilation time was not associated with few symptoms.

Smedge, G., D. Norback, et al. (1996). Asthma Among School Employees in Relation to the School Environment. Indoor Air '96. S. Yoshizawa, K. Kimura and K. Ikeda. Nagoya. **Proceeding of Indoor Air '96, Nagoya 7th International Conference on Indoor Air Quality and Climate:** 611-616.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The relation between the indoor environment and the occurrence of asthma among the employees was investigated as a part of a Swedish school environment project. Data on health effects were gathered by a self-administered questionnaire answered by 1410 subjects (85 %). Data on exposure were collected by measuring a wide range of factors in 96 classrooms. Asthma was more common among subjects working in schools with higher concentrations of total moulds and indoor concentration of microbially produced volatile organic compounds (MVOC). The results stress the importance of minimizing the exposure to microbial growth in the indoor environment.

Smedje, G., D. Norback, et al. (1997). Asthma among Secondary Schoolchildren in Relation to the School Environment. Clinical and Experimental Allergy: Journal of the British Society for Allergy and Clinical Immunology. **27:** 1270-1278.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Background: Poor indoor air quality has been suggested to be related to the increase in the prevalence of asthma that has occurred in the western world, especially among children and young persons. Apart from the home, school is the most important indoor environment for children. Objectives: The aims were to study the prevalence of current asthma among secondary pupils and its relationship to the school environment, but also to personal factors and domestic exposures. Methods: Data on asthmatic symptoms, other health aspects, and domestic exposures were gathered using a questionnaire which was sent to 762 pupils in the seventh form (13-14 years old) in 11 randomly chosen schools in the county of Uppsala in Sweden. Pupils answering 'yes' to having had asthma diagnosed by a physician, and having had recent asthma attacks, or who used asthma medication were defined as having current asthma. Data on exposures at school were gathered by measurements in 28 classrooms. The relationship between asthma and exposures was analysed by multiple logistic regression. Results: The questionnaire was completed by 627 (82%). Current asthma was found among 40 pupils (6.4%). Current asthma was more common in those who had an atopic disposition, or food allergy, or who had attended a day care centre for several years. Controlling for these factors, current asthma was related to several factors in the school environment. There were more pupils with current asthma in schools that were larger, had more open shelves, lower room temperature, higher relative air humidity, higher concentrations of formaldehyde or other volatile organic compounds, viable moulds or bacteria or more cat allergen in the settled dust. Conclusions: Although the pupils attended school for a minor part of their time, our study indicates that the quality of the school environment is of importance and may affect asthmatic symptoms.

Smedje, G. and D. Norback (2000). New Ventilation Systems at Select Schools in Sweden – Effects on Asthma and Exposure. Archives of Environmental Health. **55:** 18 – 25.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The air-exchange rate is often low in schools. The authors studied the possible impact of improving school ventilation on health and exposure of pupils. Questionnaire data on allergies, asthma, and asthmatic symptoms were obtained in 1993 and 1995 for 1,476 primary- and secondary-school pupils in 39 randomly selected schools. Various exposure factors were measured in 1993 and 1995 in approximately 100 classrooms. In 12% of the classrooms, new ventilation systems were installed between 1993 and 1995; the subsequent air-exchange rate increased and the relative humidity and concentration of several airborne pollutants were reduced compared with classrooms in non-improved buildings. The reporting of at least one asthmatic symptom and the reporting of more asthmatic symptoms in 1995 than in 1993 were less common among the 143 pupils who attended schools with new ventilation systems.

Smedje, G. and D. Norbäck (2001). Incidence of Asthma Diagnosis and Self-Reported Allergy in Relation to the School Environment - A Four-Year Follow-Up Study in Schoolchildren. International Journal of Tuberculosis and Lung Disease. **5:** 1059-1066.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

SETTING: In schools, the indoor air quality is often poor and there is growing concern about its impact on the pupils' health.
OBJECTIVE: To study the incidence of asthma diagnosis and self-reported allergy in schoolchildren in relation to the school environment.
DESIGN: Data on asthma and allergies were collected through a postal questionnaire answered in 1993 and 1997 by 1347 (78%) pupils (initially aged 7-13 years) in 39 randomly chosen schools. Indoor pollutants were measured in about 100 classrooms in 1993 and 1995. Relationships between indoor pollutants and incidence of asthma diagnosis and self-reported allergy were studied by multiple logistic regression, adjusting for age, sex, atopy and smoking.
RESULTS: The incidence of asthma diagnosis was higher in pupils attending schools with more settled dust and more cat allergen (Fel d 1) in this dust. Incidence of self-reported furry pet allergy was higher in schools with more respirable particles. Among children without a history of atopy, a new asthma diagnosis was more common at higher concentrations of formaldehyde and total moulds in the classroom air.
CONCLUSION: A school environment with more dust, cat allergen, formaldehyde and moulds may affect the incidence of asthma and sensitivity to furry pets in schoolchildren.

Smedje, G., D. Norback, et al. (2002). Effects of Contaminated Supply Air Filters on Symptoms from the Eyes and the Nose – A Double-Blind Experimental Study. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

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

Smith, K., S. Mehta, et al. (2002). The Global Burden of Disease from Indoor Air Pollution: Results from Comparitive Risk Assessment. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Recent estimates (organized and coordinated by WHO) of the global burden of disease for some two dozen risk factors by age, sex, and region include, inter alia, malnutrition, hypertension, tobacco use, obesity, unsafe sex, and several environmental risk factors, including lead, climate change, and indoor and outdoor air pollution. Only two categories of indoor pollution were deemed sufficiently well characterized regarding both exposure and risk to attempt to make global estimates: environmental tobacco smoke and combustion products from household use of solid fuels (biomass and coal). We summarize here the approaches used to estimate the health impacts from solid fuel use, including exposure modeling and meta-analyses for major disease endpoints. Although all the risk factor studies are not yet completed, the results seem to place indoor air pollution as a major risk factor worldwide, perhaps fifth after malnutrition, tobacco, HIV, and poor water/hygiene/sanitation in attributable burden.

Smolkin, R. (2003). Breathing Easier. School Administrator. **60:** 6.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Explores the efforts to deal with the issue of indoor air quality in school premises in the U.S. Relationship between school environment and student health; Environmental problems facing schools in the country; Prevalence of asthma in school children; Initiatives of education associations to educate superintendents about indoor air quality.

Solberg, D. P. W. (1999). IAQ Risk Management. Energy & Engineered Systems.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Verification of outside ventilation codes is cheap IAQ insurance and a smart investment

Sommer, R. (1969). Personal Space: The behavioral basis of design. Englewood Cliff, Prentice-Hall.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Soon, A. and E. Indermitte (2002). What are "Office Workers" in Estonia and What Do They Complain? Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: Estonia
Building Type: office
Data Type: qualitative, questionnaire, self-administered, inspection
Outcome Focus: occupant, productivity

Abstract

Several alternative approaches were used in order to get a sample of offices and office workers that are not influenced by investigator's interests. Data were gathered by selfadministered questionnaire with concurrent survey on technical characteristics of buildings that were obtained from building managers and data from visual inspection of buildings. Also, package of environmental measurements was done. Buildings surveyed were at different age and with various maintenance facilities. "Office workers" as presumed doing certain work tasks in rooms equipped with "classical" office tools were rather various group of workers performing a list of different tasks and spending in office rooms 3 to 13 hours a day. Most frequent complaints were those related to poor thermal environment. Few associations between complaints and measured indoor environment can be demonstrated. Results of current study suggest that thermal environment is an important factor for office workers' comfort.

Spagnolo, J. and R. de Dear (2003). A field study of thermal comfort in outdoor and semi-outdoor environments in subtropical Sydney Australia. Building and Environment. **38:** 721-738.
Geographical Location: Australia
Building Type: outdoor
Data Type: survey; instrument
Outcome Focus: occupant, response

Abstract

In the absense of empirical outdoor thermal comfort studies it has been widely assumed that indoor comfort theory generalises to outdoor settings without modification. Many indoor models were developed to describe thermal discomfort, not stress, therefore their relevance to conditions that vary greatly from neutraliity, as

many outdoor climatic conditions do, has not been critically validated in the field to date.

Spicer, C. (1997). IAQ's Economic and Productivity Issues. Engineered Systems. **14**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

When providing an acceptable indoor environment, customer and employee productivity should indirectly improve.

Stefano (2000). Energy efficiency and the environment: the potential for energy efficient lighting to save energy and reduce carbon dioxide emissions at Melbourne University, Australia. Energy. **25:** 823-839.
Geographical Location: Australia, Melbourne
Building Type: office; hall; room; toilet; library
Data Type: Survey (inventory and personal)
Outcome Focus: operation, energy

Abstract

In this study, the potential to improve the energy efficiency of lighting systems at Melbourne University was assessed. The cost effectiveness of different lighting technology alternatives was also calculated. Electricity used by existing 1.2 metre fluorescent lighting fixtures and four energy efficient lighting technology alternatives was compared. Relative to the existing system, installation of the four lighting technology alternatives would result in energy savings of 13.9%, 20.5%, 24.4% and 64.9%, respectively. If the technology alternative that saved the most electricity was installed, carbon dioxide emissions associated with the University's electricity use would be reduced by about 10%. Economic analysis shows that overall, none of the four technology alternatives are cost effective, although fine scale analysis shows that one technology alternative is cost effective in two out of the five room categories that were examined. Three barriers to the cost effective installation of energy efficient lighting technologies at Melbourne University are identified: (a) low lighting system operating hours, (b) the low cost of electricity and (c) the high cost of energy efficient lighting components.

Stenberg, B., N. Eriksson, et al. (1994). The Sick Building Syndrome (SBS) in Office Workers: A Case-Referent Study of Personal, Psychosocial and Building-Related Risk Indicators. International Journal of Epidemiology. **24:** 1190-1197.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Background. The Office Illness Project in Northern Sweden, comprising both a screening questionnaire study of 4943 office workers and a case-referent study of Sick Building Syndrome (SBS) in 464 subjects was recently completed. Previously published results from the survey showed that female gender, asthma/rhinitis, high psychosocial work load, paper and visual display terminal (VDT) work were related to an increased prevalence of SBS symptoms.
Methods. The case-referent study presented in this paper used data from the questionnaire supplemented with information from a clinical examination, a survey of psychosocial factors at work and building data from inspection and measurements

taken at the work sites.
Results. Personal factors such as atopy and photosensitive skin, psychosocial conditions and physical exposure factors influencing indoor air quality (IAQ), such as outdoor air flow rates and the presence of photocopiers were related to an increased prevalence of the reported SBS symptoms. The results were established using multivariate analysis.
Conclusions. The rate response relationship between actually measured ventilation rates and the prevalence of perceived SBS symptoms presents strong evidence for the association between IAQ factors and health.

Stenberg, B. and S. Wall (1995). Why do Women Report 'Sick Building Symptoms' More Often Than Men? Social Science Medicine. **40:** 491 – 502.
Geographical Location: not specified
Building Type: office
Data Type: questionnaire
Outcome Focus: occupant, health

Abstract

The prevalence of general, mucosal and skin symptoms compatible with the 'Sick Building Syndrome' (SBS) was studied in Swedish office workers. The marked excess in symptom prevalence among females, 12% SBS cases as compared to 4% among males, was analysed with respect to differences in biological or acquired risks and different illness and reporting (interview) behaviour among males and females. The distribution of risk indicators for symptoms was recorded in a questionnaire to 4943 employees. The skin symptom questions were validated in a clinical examination. Most risk indicators, such as paper work and psychosocial work load, had an unfavourable distribution for females. In the multivariate analysis however, female sex remained the most prominent risk indicator almost unaffected by the addition of other factors. Neither did effect modification contribute to the excess prevalence among females. The results from the clinical examination indicate that the excess symptom prevalence among females is real and not a reporting artefact. As the factors studied did not explain the excess symptom prevalence among females, the sex differential observed can be a reflection of a general excess of psychosomatic symptoms among women. Although inequalities in social conditions did not substantially explain the sex differential in symptom reporting, the importance of life situation and social roles should be further explored. As the studied variables are surrogates for actual measurements, another important issue is whether sex differences in working conditions, entailing different hierarchical positions in the office, have consequences for indoor air quality factors that are important for the symptoms. The study strongly underlines the importance of taking the sex distribution into account when surveying risk indicators for SBS symptoms.

Sterling, P. and N. Paquette (1998). Toxic Chemical Exposure in Schools: Our Children at Risk. D. Rapaport and M. Floegel. **Vermont Public Interest Research Group:** 1-26.
Geographical Location: USA, Vermont
Building Type: School
Data Type:
Outcome Focus:

Abstract

Toxic chemicals can be found throughout school grounds in pesticides, building materials, school supplies, cleaning products, office equipment and personal care products. This report details the prevalence of toxic chemicals within schools and recommends methods for reducing exposure.

Stevenson, J., J. Willson, et al. (1985). Environment Feature. Modern Office. **24:** 25.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The office working environment can help or hamper worker productivity. One factor to consider in developing a good working environment is the aesthetic appearance. Colours in the room can determine the moods of employees and visitors. Accessories, such as wall hangings, paintings, pictures, plants, and desk ornaments, add a personal touch to the workplace. Proper lighting and glass wall coverings can psychologically enlarge an area to create a roomy feeling. Health factors also are very important in planning a work environment. Office equipment manufacturers are using ergonomics to design chairs, tables, and desks that will reduce worker strains. Other important environmental health considerations include the safety of wheelchair employees during emergencies, smokers in the workplace, and stress factors for pregnant women working with computers.

Stone, N. J. and J. M. Irvine (1993). Performance, Mood, Satisfaction, and Task Type in Various Work Environments: A Preliminary Study. Journal of General Psychology. **120:** 489-497.
Geographical Location: USA, Nebraska
Building Type: university
note: although the study was done in a university, university students played the role of clerical work
Data Type: Qualitative
quantitative
measurement, laboratory
questionnaire, on-site
Outcome Focus: occupant, productivity (performance)
occupant, response

Abstract

We investigated the influence of windows on performance, mood, and satisfaction for different task types. Forty students worked computational or managerial tasks in offices with or without windows. Contrary to expectation, windowed offices did not effect higher performance, positive mood, or satisfaction. Actually, students felt slightly more confident ($p < .10$) and more in control ($p < .01$) in the windowless condition, suggesting a need for privacy to reduce evaluation apprehension. How windows affect performance, mood, and satisfaction remains unclear.

Stone, N. J. and J. M. Irvine (1994). Direct or Indirect Window Access, Task Type and Performance. Journal of Environmental Psychology. **14:** 57-63.
Geographical Location: USA, Nebraska
Building Type: University
note: university students were used for the testing, but doing filing, computational and creative work, suggesting that the studies are more for office work type.
Data Type: Qualitative; questionnnaire, on-site; measurement, laboratory
Outcome Focus: occupant, productivity (performance); occupant, response

Abstract

Window access, task type, and the room (windowed or windowless) were manipulated to investigate their effects on performance and individuals' perceptions of the task and room, and had either a direct or indirect interaction with the window.

Contrary to expectation, performance and perceptions were not affected by the interaction of window access, task type, and the room. Also, performance was not higher for those working in a room with a window. A marginal interaction effect ($p < 0.10$) indicated that the creative task is affected by the type of access. Also, the effects on perceptions of the task and room tend to indicate that windowed rooms do contribute a dynamic environment. Specifically, the windowed room apperred to effect task oddurred in the windowless room; however, boredom tended to be reduced when one faced the window. Implication of these results and suggestions for future research are discussed.

Stone, N. J. (1998). Windows and environmental cues on performance and mood. Environment and Behaviour. **30:** 306 (16).
Geographical Location: USA. Midwest
Building Type: Office
Data Type: Qualitative; Quantitative; Survey.; Questionnaire, on-site Interview; Measurements, laboratory; variables: windowed environment, windowless environment, task difficulty
Outcome Focus: windowed environment; windowless environment; work performance; mood; posters

Abstract

Task type and the presence of windows and posters were manipulated to examine their effects on individuals' performance, mood, and perceptions. Male and female undergraduates worked either a filing, computational, or creative task in a windowed or windowless room, with or without a poster (i.e., task-relevant cues). As predicted, the presence of windows did not affect performance. Window presence increased perceptions that the room was motivating and the likelihood that one looked about the room for help with the computational task. Unexpectedly, the number of errors on the computational task was reduced when the task-relevant poster was present. Poster presence also increased positive mood and decreased fatigue perceptions for individuals performing the creative task. Overall, poster presence increased confidence. Because perceptions of task demand were related to several outcome variables, the stimulation from windows and posters appears to interact with the task demand.

Sundell, J. (1994). On the association between building ventilation characteristics, some indoor environmental exposures, some allergic manifestations, and subjective symptom reports. Indoor Air Suppl. **2**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

The prevalence of some allergic and other hypersensitivity disorders has increased during recent decades, especially in industrialized countries. In Sweden, allergy towards house dust mites has increased and is linked to the home environment. In many countries, subjectively reported indoor-related symptoms such as those contained in the sick-building syndrome (SBS) have become a problem of concern. Typically, SBS involves general symptoms (e.g. headache and fatigue), mucous membrane symptoms (e.g. irritation of upper airways and the eye) and skin symptoms. SBS is attributed to a specific indoor environment, typically the place of work or the home. Great changes in building hygiene have taken place within recent decades due to e.g. the use of many new building materials, new technologies and energy-saving measures that have reduced ventilation. The aims of the present

thesis are I) to assess the associations between ventilation characteristics of homes, house dust mite infestation and allergy among children; 2) to assess the association between ventilation characteristics and occurrence of reported SBS-related symptoms among office workers; 3) to analyze associations between reported SBS-related symptoms and the reported sensation of dryness and associations between the reported sensation of dryness and physical air humidity, room characteristics and chemical factors; and 4) to study changes in total volatile organic compounds (TVOC) or formaldehyde concentration from outdoor air to room air and to study the associations between SBS-related symptom reports and concentrations of TVOC and formaldehyde in room air. The results from 3 different building and occupant studies are included. The first was a study in 2 steps on the association between allergic diseases among children (n = 160), house dust mite infestation, indoor exposure to air humidity, VOC and formaldehyde and the characteristics of the ventilation of homes (step I: case-control study; step 2: comparative study of homes with high or low house dust mite infestation). The second was an office illness study in 3 steps on associations between building, room and ventilation characteristics, TVOC and formaldehyde and occurrence of reported SBS-related symptoms among office workers (n = 5986) (step I: screening questionnaire; step 2: case-control studies; step 3: comparative study of buildings in which occupants exhibit a high or low prevalence of symptoms). The third study was a technical and chemical field study on the possible re-entrainment of indoor air pollutants (formaldehyde) via rotary heat exchangers. The methods used in the three studies comprised questionnaires, clinical investigations, site inspections and environmental measurements. In a region with cold winters, house dust mite infestation and thus house dust mite allergy was found to be associated with a low total outdoor air flow rate of the home and of the bedroom as well. A low outdoor air flow rate in offices was associated with an elevated prevalence of SBS symptoms. Ventilation operating hours less than 10 h per day, the presence of photocopiers, video display terminal work, a low rating of psychosocial conditions at work, female sex and reported asthma, eczema and skin sensitivity to sunlight were associated with an elevated risk of SBS symptoms. The type of ventilation system, recirculation of air and presence of rotary heat exchangers were not demonstrated to be associated with an elevated risk of SBS symptoms. TVOC may not be a valid construct of indoor air pollution from a health perspective in the low concentration exposure range. Indoor air chemistry, involving, for example, the possible transformation products of VOC may be important. The perception of "dry air" was associated with SBS symptoms. This perception was not demonstrated to be associated with physical air humidity.

Sundstrom, E., R. E. Burt, et al. (1980). Privacy at Work: Architectural Correlates of Job Satisfaction and Job Performance. Academy of Management Journal. **J. 12:** 101-117.

Geographical Location: USA, Tennessee
Building Type: Office
Data Type: Qualitative
Survey
Questionnaire, on-site
Outcome Focus: Occupant, well-being
Occupant, response

Abstract

Research on the role of the physical setting in interpersonal behaviour in organizations has been particularly uncommon, although social and environmental psychologists have developed theories that could apply. Social and environmental psychology can be applied to work settings. The role of privacy in job satisfaction and job performance is one area where such psychology can be utilized. Privacy can be defined in 2 ways: 1. as a psychological state, and 2. as a physical feature of the environment. In other words, privacy is architectural or psychological questionnaires

were sent out to about 150 administrative employees of the State of Tennessee, with 85 participating in the study. In a second study, a small group of clerical workers were assessed, and a third examination included both clerical employees and people in complex jobs in a wide range or workspaces. It was illustrated that architectural privacy was consistently linked with psychological privacy. People who rated their workspaces as private tended to report less noise, distraction, and crowding problems than those in less private environments. However, practically no relationship was discovered between architectural accessibility and social interaction among co-workers. In conclusion, architectural and psychological privacy are associated, and both types of privacy are related to satisfaction with workspaces and job satisfaction.

Sundstrom, E., K. Herbert, et al. (1982). Privacy and Communication in an Open-Plan Office. A case study. Environment and Behaviour. **14:** 379-392.
Geographical Location: USA
Building Type: Office, high rise
Data Type: Qualitative
quantitative
survey
questionnaire, on site. Before and after relocation
measurements on site
Outcome Focus: Occupant, well-being
Occupant, response

Abstract

Seventy employees at four job levels in a large corporation completed a questionnaire on their office environments six months before and six weeks after moving form a conventional office to an "open-plan" office. Neither satisfaction with communications nor perceptions of noise changed after relocation, but satisfaction with privacy declined among former occupants of walled offices. The decrease in privacy reflected a decrease in confidentiality of conversation, as shown by the questionnaire and acoustical measurements. Implication for office design are discussed.

Sundstrom, E. (1986). Work places: the psychology of the physical environment in offices and factories. M. Sundstrom. Cambridge, Cambridge University Press**:** 461.
Geographical Location: unknown
Building Type: office, commercial, industrial
Data Type: case study
Outcome Focus: occupant, well-being; occupant, response

Abstract

Sutton, R. I. and A. Rafaeli (1987). Characteristics of work stations as potential occupational stressors. Academy of Management Journal. **30:** 260-276.
Geographical Location: USA, Michigan
Building Type: Office, (University Building)
Data Type: qualitative
quantitative
interview
observation
survey
questionnaire, on-site
Outcome Focus: occupant, well-being

Abstract

Investigated 2 categories of possible occupational physical stressors--intrusions from

atmospheric conditions and intrusions from other employees--using 109 clerical workers. Results show that contrary to predictions, such intrusions were not consistently related to negative reactions. Evidence suggests that intrusions were more strongly associated with reactions to Ss' work stations than with general reactions to their work. Results also indicate that Ss reporting high role overload had relatively fewer negative reactions to hotness and density. Findings provide modest support for the detachment hypothesis, which predicts that overworked employees concentrate harder on their work than other employees and ignore intrusions stemming from their physical environment. (PsycINFO Database Record (c) 2002 APA, all rights reserved)

Thomas, G. B. (1995). Floor based air-conditioning offers major long term benefits. Facilities. **13:** 20-21.
Geographical Location: England
Building Type: office
Data Type: case study
Outcome Focus: operation, maintenance
occupant, well-being

Abstract

Reviews forms of air conditioning in buildings. Argues that ceiling-based systems have their disadvantages and that the best way to provide a comfortable and healthy working environment, that is also flexible, is the underfloor route. Points to a recent study, which reveals savings in direct costs as a result of using underfloor air conditioning.

Todde, V. (2000). Perception and Sensitivity to Horizontal Turbulent Air Flows at the Head Region. Indoor Air. **10:** 297-305.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Abstract This work deals with experimental investigations on human reaction to local air movements of people in global thermal comfort, performing light activity. An analysis on draught risk was developed comparing the results with previous research findings on human response to draught. The intensity of air velocity, in terms of mean value and relative turbulence, was referred to the level at which normally clothed people could perceive and feel air movements behind the neck, in global neutral thermal condition. This work provides evidence of how the exposure duration to air movements plays a fundamental role on air flow sensitivity. The human reaction to an air flow was observed to vary with exposure duration: the feeling changes in intensity while the air flow persists blowing constantly. Moreover, different reactions have been observed between female and male test persons. Although these results were observed in the typical situation of horizontal air jet flows blowing from behind, they could apply in climatically controlled environments, where air flow is supplied horizontally at low speed, and the occupants are sitting far from the inlet section.

Toffler, A. (1985). The Adaptive Corporation. London, Pan Press.

Toftum, J. and O. P. Fanger (1999). Air Humidity Requirements for Human Comfort. ASHRAE Transactions. **105**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Upper humidity limits for the comfort zone determined from two recently presented models for predicting discomfort due to skin humidity and insufficient respiratory cooling are proposed. The proposed limits are compared with the maximum permissible humidity level prescribed in existing standards for the thermal indoor environment. The skin humidity model predicts discomfort as a function of the relative humidity of the skin, which is determined by existing models for human heat and moisture transfer based on environmental parameters, clothing characteristics, and activity level. The respiratory model predicts discomfort as a function of the driving forces for heat loss from the respiratory tract, namely, the temperature and humidity of the surrounding air. An upper humidity limit based on a relative skin humidity of 0.54, corresponding to 20% dissatisfied, results in a maximum permissible humidity level near 100% RH. The requirements for respiratory comfort are much more stringent and result in lower permissible indoor air humidities. Compared with the upper humidity limit specified in existing thermal comfort standards, e.g., ASHRAE Addendum 55a, the humidity limit based on skin humidity was less restrictive and the humidity limit based on respiratory comfort was far more restrictive.

Toftum, J. (2002a). Human Response to Combined Indoor Environment Exposures. Energy and Buildings. **34:** 601 – 606.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Most thermal comfort standards and guidelines presume sedentary, light activity and a neutral overall thermal sensation when predicting local thermal discomfort. In addition, current standards specify criteria for separate aspects of the indoor environment, e.g. thermal climate, air quality or noise, with only little consideration of possible interactions between the different types of exposure. The studies summarized in this article found a clear impact of activity and overall thermal sensation on human sensitivity to air movement, whereas no interaction effects of exposure to several local thermal discomfort factors were observed. Limited evidence was found of significant interactions between different aspects of the indoor environment. Only for the effect of air temperature and air humidity on sensory air quality were well-established relationships available.

Toftum, J., G. Reimann, et al. (2002b). Perceived Air Quality, Thermal Comfort and SBS Symptoms at Low Air Temperature and Increased Radiant Temperature. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This study investigated if low air temperature, which is known to improve the

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

Torres, V. M. (2000). Indoor Air Quality in Schools. Texas Institute for the Indoor Environment. The University of Texas at Austin**:** 1-14.
Geographical Location: USA, Texas
Building Type: School
Data Type:
Outcome Focus:

Abstract

Urban residents spend approximately 90% of their time indoors (US EPA 1996b). During their kindergarten, elementary and secondary education years, children will spend a minimum of 23% of their time inside of a school building. By comparison, they spend 5–10% of their time outdoors. Given that it is unhealthy, particularly for children and the elderly, when outdoor pollutant levels exceed the National Ambient Air Quality Standards (US EPA 1997), we become even more concerned when children and the elderly are exposed to environments where concentrations of air pollutants are 2 to 5 times higher than the maximum acceptable outdoor levels (US EPA 1995).

Children are at even greater risk in these environments because they breathe a greater volume of air— and hence a greater weight of pollutants— relative to their body weights than do adults. Furthermore, when one considers that if our children spend 2 to 4 times as much time in these environments as outdoors, their exposure (equal to dose x time)to these pollutants can become quite high.

Torrey, J. (2002). Increased productivity= good business. Occupational Health & Safety. **71:** 172-175.
Geographical Location: United States
Building Type: office
Data Type: pilot study
measurements on site
Outcome Focus: occupant, health
occupant, productivity

Abstract

Toumainen, M., J. Smolander, et al. (2002). Modelling the Cost Effects of the Indoor Environment. Indoor Air 2002. Monterey, California,. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

A deteriorated indoor environment causes various symptoms, sicknesses, sick leaves, reduced comfort and losses in productivity. When all these items are

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

Trout, D., J. Bernstein, et al. (2001). Bioaerosol Lung Damage in a Worker with Repeated Exposure to Fungi in a Water-Damaged Building. Environmental Health Perspectives. **109:** 641 – 644.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

There has been increased concern over health effects related to potential exposure of building occupants to bio-aerosols. We report the case of a worker with respiratory illness related to bio-aerosol exposure in a water-damaged building with extensive fungal contamination. We performed environmental tests to evaluate potential exposure to fungi, and we used mycotoxin-soecific IgG antibody in serologic studies in the attempt to evaluate exposure to mycotoxins. Extensive fungal contamination was documented in many areas of building. Penicillium, Aspergillus and Stachybotrys species were among the most predominant fungi found in air sampling. Our serologic test was not useful in differentiating workers who were probably occupationally exposed to mycotoxins from those were not; however, it did yield evidence that individuals may make specific IgG antibodies to macrocyclic tricothecene mycotoxins. Further research is needed concerning health effects related to bio-aerosol exposures, particularly regarding markers of exposure is specific fungi that may produce mycotoxins. In the absence of clinical tools specific for evaluation of mycotoxin-related illness, a systematic clinical approach for evaluating persons with suspected building-related respiratory illness is warranted.

U.S. Environmental Protection Authority (1991). Building Air Quality, Guide to Owners and Managers, US Government Printing Office.
Geographical Location: USA
Building Type: commercial
Data Type: qualitative, theory
Outcome Focus: operation, maintenance

Abstract

US Government (1999). To Establish the High Performance Schools Program in the Department of Education and for Other Purposes.
Geographical Location: USA
Building Type: School
Data Type:
Outcome Focus:

Abstract

A Bill to establish the High Performance Schools Program in the Department of Education and for other purposes.

Veitch, J. A. and S. L. McColl (1994). Full-Spectrum Fluorescent lighting effect on people: A critical review. IRC Internal Report No.659.
Geographical Location: various
Building Type: various
Data Type: literature review
Outcome Focus: occupant, health

Abstract

Full-spectrum fluorescent lighting has been credited with causing dramatic improvements in wide variety of behaviours, mental health outcomes, and physical health effects. These effects include reduction in dental caries, improved classroom behaviour in schoolchildren, enhanced academic achievements, more efficient visual performance, more attractive appearance of both people and spaces, and improved mood in cases of seasonal depression. Popular media reports have tended to emphasize studies that have demonstrated differences in outcomes as a function of light source spectral power distribution. However, the scientific literature also includes reports with null and contradictory effects. This comprehensive review cover the period 1945-1993 and includes a critical appraisal of the methodology in each study.

Veitch, R. and D. Arkkelin (1995). Environmental psychology : an interdisciplinary perspective. Englewood Cliffs, N.J, Prentice Hall**:** xiii, 461.
Geographical Location:
Building Type: office, domestic, commercial, school
Data Type: literature review
Outcome Focus: occupant, health
occupant, productivity
occupant, well-being

Abstract

Veitch, J. A. and R. Gifford (1996). Assessing beliefs about lighting effects on health, performance, mood,and social behavior. Environment and Behavior, Sage Publications. **28:** 446-470.
Geographical Location: Canada
Building Type: various
Data Type: Questionnaire
Outcome Focus: occupant, response

Abstract

A study was conducted to describe the development and validation of a questionnaire to evaluate beliefs about the effects of common types of interior lighting on human health, work performance, mood, and social behaviour. Principal components analysis of the 32-item Lighting Beliefs Questionnaire was performed and disclosed six interpretable components. It is demonstrated that the questionnaire may be employed to examine responses to interior lighting and to reveal what beliefs are held by end users and that this data will help in calming unwarranted fears and concerns about new lighting technologies.

Veitch, J. A. (2001). Lighting Quality Contributions from Biopsychological Processes. Journal of Illuminating Engineering Society. **30:** 3-16.
Geographical Location: various
Building Type: various
Data Type: literature review
Outcome Focus: occupant, productivity

Abstract

Internal process, both biological and psychological, are thought to medicate the relationships between luminous conditions and such behavioural outcomes as task performance, mood, social behaviour, aesthetic judgements and satisfaction. This review paper summarizes the state of knowledge concerning mediating biopsychological process: visibility, photobiology, and stress and arousal. Visibility is well-understood and obviously relevant to lighting practice. Photobiology, however, is a new entrant to the realm of lighting research; its findings could have important implications for recommended illuminance levels if these were based on more than visibility. Stress and arousal, interrated concepts, are popular notions, but close examination reveals only weak support for these mechanisms as explanations of lighting effect on behaviour. The improved organization of research and increased predictive power that would result from clear expostion of theoretical mechanisms in lighting research holds promise for progress in linking research and application.

Verderber, S. (1983). Human Response to daylighting in the Therapeutic Environment. International Daylighting Conference.
Geographical Location: USA
Building Type: hospital
Data Type: interview, measurements, on-site
Outcome Focus: occupant, response

Abstract

A subset of results are reported from an empirical investigation on human response to key functions of the window. Daylighting was found to be one of an array of 20 cognitive dimensions of windowness in the therapeutic environment. The research was carried out in six hospital-based rehabilitation units in Chicago. Non-metric multidimensional scaling was utilized to distinguish an underlying conceptual structure. Among the findings, therapy treatment rooms whose windows allow for daylight penetration are perceived as desirable by patients and staff alike.

Vincent, D., I. Annesi, et al. (1997). Ventilation System, Indoor Air Quality and Health Outcomes in Parisian Modern Office Workers. Environmental Research. **75:** 100 – 112.
Geographical Location: not specified
Building Type: not specified
Data Type: questionnaires
Outcome Focus: occupant, health

Abstract

A cross-sectional study was carried out to determine the effect on health of exposure to different types of ventilation, taking indoor environmental measurements (IEMs) of major contaminants and aeroallergens into account. Three buildings ventilated with heating, ventilating, and air conditioning (HVAC), fan coil units (FCUs), and natural ventilation were selected. One thousand one hundred forty-four workers answered health questionnaires. After adjusting for potential confounders, HVAC and FCU systems were related to a slightly higher risk of non-specific symptoms (compared with natural ventilation), short-term throat irritation, work-related nasal discharge, nasal blockage on awakening, migraine, and usual coughing induced by cold air. Studying the potential effects of environmental contaminants and aeroallergens on

health outcomes, taking the floor and type of ventilation into account, did not explain the observed excess of non-specific symptoms.

Vine, Lee, et al. (1998). Office worker response to an automated venetian blind and electric lighting system: a pilot study. Energy and Buildings. **28:** 205-218.
Geographical Location: USA
Building Type: office
Data Type: survey
Outcome Focus: occupant, response

Abstract

A prototype integrated, dynamic building envelope and lighting system designed to optimize daylight admission and solar heat gain rejection on a real-time basis in a commercial office building is evaluated. Office worker response to the system and occupant-based modifications to the control system are investigated to determine if the design and operation of the prototype system can be improved. Key findings from the study are: (1) the prototype integrated envelope and lighting system is ready for field testing, (2) most office workers (N = 14) were satisfied with the system, and (3) there were few complaints. Additional studies are needed to explain how illuminance distribution, lighting quality, and room design can affect workplace illuminance preferences.

Walden, T. A., P. A. Nelson, et al. (1981). "Crowding, privacy and coping." Environment and Behavior **13**: 205-224.

Walinder, R., D. Norback, et al. (1997a). Nasal Congestion in Relation to Low Air Exchange Rate in Schools. Evaluation by Acoustic Rhinometry. Acta Oto-Laryngologica. **117:** 724-727.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Upper airway symptoms are common, but there is little information available on clinical findings in relation to indoor air pollution. This pilot study was conducted to test whether increased levels of indoor air pollutants in schools may correlate to a swelling of the nasal mucosa. The assumption was made that the degree of swelling could be related to the degree of decongestive effect of xylometazoline, and measured by acoustic rhinometry. The study was performed among 15 subjects in a school with low air exchange rate (0.6 air changes/h) and 12 subjects in a school with high air exchange rate (5.2 air changes/h). Hygienic measurements were performed in both schools. Acoustic rhinometry was performed for each individual under standardized forms. Cross-sectional areas and volumes of the nasal cavity were measured before and after decongestion with xylometazoline hydrochloride. Absolute values of the minimal cross-sectional area were lower in the school with poor ventilation. The decongestive effect of xylometazoline was significantly higher in the school with low air exchange, when correction for the influence of age was made. A diminished decongestive effect was seen with increasing age. The exposure measurements showed that indoor concentrations of volatile organic compounds, bacteria and moulds were higher in the school with low ventilation. In conclusion, raised levels of indoor air pollutants due to inadequate ventilation in schools may affect the upper airways and cause a swelling of the nasal mucosa, and acoustic rhinometry could be a useful objective method to measure human nasal reactions to the indoor environment.

Walinder, R., D. Norback, et al. (1997b). Nasal Mucosal Swelling in Relation to Low Air Exchange Rate in Schools. Indoor Air. **7:** 198-205.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Acoustic rhinometry and hygienic measurements of indoor air pollutants were applied in a field study on nasal congestion among 27 subjects working in two primary schools. One school had natural ventilation only and a low air exchange rate (0,6 ac/h); the other had balanced mechanical ventilation and a high air exchange rate (5.2 ac/h). The minimal cross-sectional area and volume of the nasal cavity were estimated with acoustic rhinometry. The degree of swelling of the nasal mucosa was measured as the increase of the cross-sectional area after standardized application of nasal spray containing a decongestive adrenergic substance. Reports on weekly symptoms of nasal congestion were similar (33%) in both schools. A significantly increased decongestive effect was noticed for the minimal crosssectional area (MCA2) among personnel in the school with a low air exchange rate. The difference between the schools in decongestive effect on MCA2 was 23%, corresponding to a 3% increase of MCA2 for a difference in personal outdoor airflow of one litre. Indoor concentration of volatile organic compounds (VOC), respirable dust, bacteria, moulds and VOCs of possible microbial origin (MVOC) were 2-8 times higher in the naturally ventilated school. In conclusion, inadequate outdoor air supply in schools may lead to raised levels of indoor air pollutants, causing a subclinical swelling of the nasal mucosa. Our results indicate that acoustic rhinometry could be applied in field studies, and that objective measurement of nasal decongestion might be a more sensitive measure of biological effects of indoor air pollution than symptom reporting.

Walinder, R., D. Norback, et al. (1998). Nasal Patency and Biomarkers in Nasal Lavage - The Significance of Air Exchange Rate and Type of Ventilation in Schools. International Architecture & Occupational Environmental Health. **71:** 479-486.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Objectives: The aim of the present study was to examine the relationships between the ventilation rate and the type of ventilation system, on the one hand, and objective nasal measures, on the other.

Methods: A standardized investigation, including acoustic rhinometry and nasal lavage, was performed in the school environment. All 279 school personnel working in the main buildings of 12 randomly selected primary schools in the municipality of Uppsala were invited, and 234 (84%) participated. The dimensions of the nasal cavity were measured with acoustic rhinometry. Eosinophil cationic protein (ECP), myeloperoxidase (MPO), lysozyme, and albumin were analyzed in the lavage fluid. The air exchange rate and the room temperature were measured in the classrooms. Relationships between nasal symptoms, nasal patency, and the concentration of biomarkers, on the one hand, and the type of ventilation system, the air exchange rate, and the temperature, on the other, were analyzed by both crude bivariate analysis and multiple regression models, controlling for the type of ventilation, the air exchange rate, room temperature, age, gender, smoking, atopy, and the urban vicinity of the school.

Results: A lower degree of nasal patency as measured by acoustic rhinometry and increased levels of ECP and lysozyme in nasal lavage were associated with a lower

air exchange rate in the schools. Although mechanically ventilated schools had higher air exchange rates, they were associated with more nasal symptoms, and nasal mucosal swelling and with increased lavage levels of ECP and lysozyme as compared with schools with natural ventilation only. In contrast, 12 subjects working in a school with mechanical displacement ventilation had more patent noses and lower levels of inflammatory markers as compared with the personnel in schools with natural ventilation only.

Conclusion: Our results indicate that both a low air exchange rate and mechanical ventilation systems based on dilution can be associated with reduced nasal patency and an inflammatory biomarker response of the nasal mucosa among school personnel. The only school with sufficient ventilation according to the current Swedish recommendations had a displacement system and the fewest signs of nasal reactions among the personnel.

Walinder, R., D. Norback, et al. (2000). Acoustic Rhinometry in Epidemiological Studies – Nasal Reactions in Swedish Schools. Rhinology, Supplement. **16:** 59-64.

Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

A cross-sectional study was performed on the relationships between hygienic measurements and nasal investigations in 234 personnel in 12 primary schools in mid-Sweden. Hygienic data included building characteristics, measurements of indoor air pollutants, air change rate, temperature and humidity. Clinical examinations included symptom reports, acoustic rhinometry and nasal lavage, with the determination of biomarker levels for eosinophil cationic protein (ECP), lysozyme, myeloperoxidase (MPO) and albumin. Subjective nasal obstruction was increased in schools with mechanical ventilation (adjusted prevalence OR=2.0; 95 CI1.1-3. 7) and subjects reporting nasal obstruction had higher levels of dust in the classroom, compared to those not reporting this symptom (p= 0.008 by Mann-Whitney U-test). Congruently, a decreased nasal patency measured by acoustic rhinometric minimum cross-sectional areas (MCAl and MCA2) was related to the use of mechanical ventilation (p=O.008 and p= 0.02 respectively, by Mann-Whitney U-test), dust levels (p=O.03 and p<O.001 respectively, by Kendall's tau correlation analysis), a lower cleaning frequency of desks (p<0.001 and p=O.02 respectively, by Kendall's tau correlation analysis), the use of wet mopping (p<O.001 and p=O.04 respectively, by Mann- Whitney U-test) and PVC floor material (p<O.O01 and p=O.034 respectively, by Mann-Whitney U-test). The cleaning frequency of floors was positively correlated with MCA1 (p=O.049 by Kendall's tau correlation analysis). In buildings with signs of water damage, flat roof or a concrete slab fundament the personnel had increased ECP, lysozyme or albumin levels in nasal lavage. A reduced nasal patency and an increased inflammatory biomarker response were seen for higher levels of formaldehyde (MCA1, MCA2, VOL1, VOL2, ECP and lysozyme) and nitrogen dioxide (MCA1, VOL2, ECP and lysozyme) in the classrooms. In conclusion, the results indicate that acoustic rhinometry in combination with the determination of nasal lavage biomarkers can be used to study effects on the upper airways of the indoor environment. Actual exposures to indoor air pollutants in Swedish schools can affect the occurrence of subjective nasal obstruction and give clinical signs of reduced nasal patency together with an inflammatory biomarker response in the nasal mucosa.

Walinder, R., D. Norback, et al. (2001a). Nasal lavage biomarkers: effects of water damage and microbial growth in an office building. Archives of Environmental Health. **56:** 30.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Selected nasal symptoms were studied in personnel who worked in a damp office building that had microbial growth (including Stachybotrys sp.) in mineral fiber insulation and gypsum board. There were also signs of dampness in the floor. Clinical examinations included nasal lavage and peak expiratory flow measurements in 12 subjects in the damp building; an additional 8 subjects in a control building (i.e., no signs of dampness or microbial growth) were also examined. Hygienic air measurements of microorganisms and volatile organic compounds were performed in both buildings. The concentrations of eosinophil cationic protein, myeloperoxidase, and albumin, and the number of subjects with eosinophils in lavage fluid, were higher among office workers in the damp building than among controls. The damp building had greater amounts of total moulds and bacteria in its construction than the building materials in non-damp buildings. In addition, an increase of 2-ethyl-1-hexanol in the indoor air was detected in the damp building-a sign of dampness-related alkaline degradation of diethyl-hexyl phthalate in polyvinyl chloride floor coatings. In conclusion, the results of this study indicate that exposures in a damp office building may cause an inflammatory nasal mucosal response. The results also support conclusions of earlier studies, indicating that building dampness is related to respiratory inflammation.

Walinder, R., D. Norback, et al. (2001b). Acoustic Rhinometry and Lavage Biomarkers in Relation to Some Building Characteristics in Swedish Schools. Indoor Air. **11:** 2-9.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

It has been suggested that certain building factors can be associated with specific exposures, such as dampness, chemical emissions and dust. The aim of the study was to examine the relationships between some selected building factors, on the one hand, and signs of inflammation or obstruction in the upper airways on the other. Acoustic rhinometry and nasal lavage were used in a field study among 234 school personnel in 12 randomly selected schools (participation rate 84%). Eosinophil cationic protein (ECP), lysozyme, albumin and myeloperoxidase (MPO) were analyzed in the lavage fluid. Building related factors selected for the study were: roof inclination, fundament, building construction, signs of water damage, floor material, building age, ceiling height, bookcases and plants in the classroom. Control was made for potential confounders. The results indicate a pattern of nasal responses less patent noses and an inflammatory biomarker response could be related to flat roof and a concrete slab fundament, factors that are known risk factors for water leakage, building dampness and possibly microbial growth. A reduced nasal patency without an inflammatory biomarker response was related to factors associated with plasticizers and dust. Positive effects were observed for plants in the classroom and in older buildings.

Wan, G.-H. and C.-S. Li (1999a). Dampness and Airway Inflammation and Systemic Symptoms in Office Building Workers. Archives of Environmental Health. **54:** 58 -63.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

To evaluate dose-response relationships between airway inflammation/systemic symptoms and dampness exposure, we conducted a self-reported questionnaire study on risk factors among 1237 employees in 19 air-conditioned office buildings in the Taipei area. The odds ratio for eye irritation was 1.34 when either stuffy odour or mould was present in the buildings. The odds ratio increased to 1.72 when both stuffy odour and mould were present, to 3.14 when water damage was also present, and to 5.03 when four dampness exposure factors were present. Dampness in the building had a dose-response effect on eye irritation, cough, and lethargy/fatigue.

Wan, G.-H. and C.-S. Li (1999b). Indoor Endotoxin and Glucan in Association with Airway Inflammation and Systemic Symptoms. Archives of Environmental Health. **54:** 172-179.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Indoor bioaerosols (i.e., bacteria, fungi, endotoxin, and ß3-1,3-glucan) were determined in daycare centers, office buildings, and domestic environments in the Taipei area. In addition, we used a questionnaire survey to determine associations between indoor dampness, bioaerosols, and airway inflammation and systemic symptoms. We demonstrated that the median levels of indoor bacteria and fungi were the highest in daycare centers, followed by those in homes and office buildings. Similar patterns were observed for endotoxin and ß3-1,3-glucan. The prevalences of airway inflammation and systemic symptoms were higher for females in office buildings than for employees in daycare centers; all symptoms were more prevalent in females than males. With respect to the relationship between bioaerosol exposure and airway inflammation and systemic symptoms, we found a strong association between ß3-1,3-glucan and lethargy/fatigue.

Wang, J., J.-l. Li, et al. (2002). A Case of Sick Building Syndrome Caused by Incorrect Ventilation Design of the Tight Building. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

In a newly opened office high-rise in downtown Beijing, most occupants were reportedly feeling uncomfortable everyday. It was a tight building of which the central ventilation system provided mechanic air supply but natural exhaust. A survey was conducted, which included a questionnaire to occupants and detection of indoor air pollutants. Results of the questionnaire indicated that 98.7 % of occupants had sick building syndrome, and that their symptoms were more severe in the afternoon than in the morning. Results of pollutant detection showed that the concentration of carbon dioxide in some rooms was as high as 700 to 1000 ppm. In most rooms, carbon dioxide and radon levels were higher in the afternoon than in the morning.

These data suggest that insufficient ventilation, likely as a result of the lack of exhaust duct system, causes accumulation of indoor pollutants that are associated with sick building syndrome.

Wargocki, P. (1998). Human Perception, Productivity and Symptoms Related to Indoor Air Quality. Centre for Indoor Environment and Energy, Technical University of Denmark**:** 244.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wargocki, P., D. P. Wyon, et al. (1999). Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity in an Office with Two Different Pollution Loads. Indoor Air. **9:** 165-179.
Geographical Location: Europe
Building Type: Office
Data Type: quantitative; survey, laboratory
Outcome Focus: occupant, health; occupant, productivity

Abstract

Perceived air quality, Sick Building Syndrome (SBS) symptoms and productivity were studied in an existing office in which the air pollution level could be modified by introducing or removing a pollution source. This reversible intervention allowed the space to be classified as either non-low-polluting or low-polluting, as specified in the new European design criteria for the indoor environment CEN CR 1752 (1998). The pollution source was a 20-year-old used carpet which was introduced on a rack behind a screen so that it was invisible to the occupants. Five groups of six female subjects each were exposed to the conditions in the office twice, once with the pollution source present and once with the pollution source absent, each exposure being 265 min in the afternoon, one group at a time. They assessed the perceived air quality and SBS symptoms while performing simulated office work. The subject-rated acceptability of the perceived air quality in the office corresponded to 22% dissatisfied when the pollution source was present, and to 15% dissatisfied when the pollution source was absent. In the former condition there was a significantly increased prevalence of headaches (P=0.04) and significantly lower levels of reported effort (P=0.02) during the text typing and calculation tasks, both of which required a sustained level of concentration. In the text typing task, subjects worked significantly more slowly when the pollution source was present in the office (P=0.003), typing 6.5% less text than when the pollution source was absent from the office. Reducing the pollution load on indoor air proved to be an effective means of improving the comfort, health and productivity of building occupants.

Wargocki, P., D. P. Wyon, et al. (2000a). Pollution Source Control and Ventilation Improve Health, Comfort and Productivity. Cold Climate HVAC 2000. Sapparo, Japan. **Proceedings of Cold Climate HVAC 2000:** 445-450.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wargocki, P., D. P. Wyon, et al. (2000b). Productivity is affected by the air quality in offices.
Geographical Location: Denmark
Building Type: Office
Data Type: Measurement, Laboratory
Outcome Focus: Occupant, Productivity

Abstract

The results of three independent experiments (Wargocki et al., 1999; Wargocki and Fanger, 1999; Lagercrantz et al., 2000) show that the performance of simulated office work improves (Fig. 1) when the air quality is increased (Fig. 2).

Wargocki, P., D. P. Wyon, et al. (2000c). The Effects of Outdoor Air Supply Rate in an Office on Perceived Air Quality, Sick Building Syndrome (SBS) Symptoms and Productivity. Indoor Air, Munksgaard International Publishers. **10:** 222-236.
Geographical Location: Denmark
Building Type: office
Data Type: measurement, on-site; questionnaire, on-site
Outcome Focus: occupant, well-being; occupant, productivity

Abstract

Perceived air quality, sick building syndrome (SBS) symptoms and productivity were studied in a normally furnished office space (108 m3) ventilated with outdoor airflow of 3, 10 or 30 L/s per person, corresponding to an air change rate of 0.6, 2 or 6 h-1. The temperature of 22 dc, the relative humidity of 40% and all other environmental parameters remained unchanged. Five groups of six female subjects were each exposed to the three ventilation rates, one group and one ventilation rate at a time. Each exposure lasted 4.6 h and took place in the afternoon. Subjects were unaware of the intervention and remained thermally neutral by adjusting their clothing. They assessed perceived air quality and SBS symptoms at intervals and performed simulated normal office work. Increasing ventilation decreased the percentage of subjects dissatisfied with the air quality

Wargocki, P., J. Sundell, et al. (2002a). Ventilation and Health in Non-Industrial Indoor Environments: Report from a European Multidisciplinary Scientific Consensus Meeting (EUROVEN). Indoor Air. **12:** 113-128.
Geographical Location: Europe
Building Type: office, schools, homes
Data Type: literature survey
Outcome Focus: occupant, well-being; occupant, productivity

Abstract

Abstract Scientific literature on the effects of ventilation on health, comfort, and productivity in non-industrial indoor environments (offices, schools, homes, etc.) has been reviewed by a multidisciplinary group of European scientists, called EUROVEN, with expertise in medicine, epidemiology, toxicology, and engineering. The group reviewed 105 papers published in peer-reviewed scientific journals and judged 30 as conclusive, providing sufficient information on ventilation, health effects, data processing, and reporting, 14 as providing relevant background information on the issue, 43 as relevant but non-informative or inconclusive, and 18 as irrelevant for the issue discussed. Based on the data in papers judged conclusive, the group agreed that ventilation is strongly associated with comfort (perceived air quality) and health [Sick Building Syndrome (SBS) symptoms, inflammation, infections, asthma, allergy, short-term sick leave], and that an association between ventilation and productivity (performance of office work) is indicated. The group also concluded that increasing outdoor air supply rates in non-industrial environments improves perceived air quality; that outdoor air supply rates below 25 l/s per person increase the risk of SBS

symptoms, increase short-term sick leave, and decrease productivity among occupants of office buildings; and that ventilation rates above 0.5 air changes per hour (h)1) in homes reduce infestation of house dust mites in Nordic countries. The group concluded additionally that the literature indicates that in buildings with air conditioning systems there may be an increased risk of SBS symptoms compared with naturally or mechanically ventilated buildings, and that improper maintenance, design, and functioning of air-conditioning systems contributes to increased prevalence of SBS symptoms.

Wargocki, P., D. P. Wyon, et al. (2002b). Call-Centre Occupant Response to New and Used Filters at Two Outdoor Air Supply Rates. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location: not specified
Building Type: office, call centre
Data Type: measurement, on-site
Outcome Focus: occupant, productivity

Abstract

A 2x2 replicated field intervention experiment was conducted in a call-centre providing a public telephone directory service: Outdoor air supply rate was 8% or 80% of the total airflow of 430 L/s providing 3.5 h-1; and the supply air filters were either new or used (i.e. used in place for 6 months). Each of these 4 conditions was maintained for a full working week at a time. Room temperature and humidity averaged 24°C and 27% RH. The 26 operators were blind to conditions and assessed perceived air quality (PAQ), the intensity of Sick Building Syndrome (SBS) symptoms and self-estimated performance. Increasing the outdoor air supply rate with a new filter in place significantly alleviated many symptoms, as did changing from used to new supply air filters at the low outdoor air supply rate, but filter condition made little difference at the high outdoor air supply rate.

Wargocki, P., L. Lagercrantz, et al. (2002c). Subjective Perceptions, Symptom Intensity and Performance: A Comparison of Two Independent Studies both Changing Similarly the Pollution Load in an Office. Indoor Air. **12:** 74-80.
Geographical Location: Europe, Denmark; Europe, Sweden
Building Type: office
Data Type: measurements, on-site
Outcome Focus: occupant, health; occupant, productivity

Abstract

The present paper shows that introducing or removing the same pollution source in an office in two independent investigations, one in Denmark and one in Sweden, using similar experimental methodology, resulted in similar and repeatable effects on subjective assessments of perceived air quality, intensity of sick building syndrome symptoms and performance of office work. Removing the pollution source improved the perceived air quality, decreased the perceived dryness of air and the severity of headaches, and increased typing performance. These effects were observed separately in each experiment and were all significant (P <= 0.05) after combining the data from both studies, indicating the advantages of pollution source strength control for health, comfort, and productivity.

Wargocki, P., Z. Biro, et al. (2002d). Air Quality in a Simulated Office Environment as a Result of Reducing Pollution Sources and Increasing Ventilation. Energy and Buildings. **34:** 775-783.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Air quality was studied in an office space classified as low-polluting and ventilated with outdoor air at a rate of 1 h (-1). The pollution load in the space was changed by introducing or removing common building-related indoor pollution sources (linoleum, sealant and wooden shelves with books and paper documents) so that the space could no longer be classified as low-polluting. The outdoor air supply rate in the office was altered from 1 to 3 h(1) (0.83 and 2.5 l/s per m2 floor, respectively) when sources were present and absent. Air temperature of 23 8C, relative humidity of 50% and noise level of 35 dB(A) remained unchanged. Under each of the four conditions of air quality in the office, concentrations of volatile organic compounds (VOCs) were measured and perceived air quality was assessed by a panel of 30 female subjects. Removing the sources reduced the chemical and sensory pollution load in the office, and increasing the outdoor air supply rate decreased concentrations of many VOCs, including those emitted by building materials and furnishing, and human bioeffluents. The perceived air quality in the office was consequently improved. The improvement in air quality obtained by removing the sources was similar to that obtained by increasing the outdoor air supply rate. The study, thus, confirmed that the systematic use of low-polluting building materials will lead to improved air quality.

Weiss, J. S. and M. K. O'Neill (2002a). Health Effects from Stachybotrys Exposure in Indoor Air: A Critical Review. Indoor Air 2002. Monterey, California,. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

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

Weiss, J. S. and M. K. O'Neill (2002b). Recall, Information and Ascertainment Bias – Fatal Methodological Flaws in Studies of Indoor Air Quality and Adverse Health. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This paper examines factors that influence the reliability of ascribing a causal relationship between subjective symptoms identified by questionnaire and the attribution of these complaints to particular problems observed in the indoor environment. Studies, both from the medical literature as well as independently commissioned by building owners were used to demonstrate common limitations in study design. Of the many sources of bias that may be introduced, the ones with the most influence to adversely impact the outcome of a study are ascertainment bias, recall bias and information bias.

Wessen, B., J. Honkanen, et al. (2002). Microorganisms, MVOC and the Health Complaints. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

In Scandinavian buildings, moisture related problems are the dominating factor in explaining "sick buildings". In this study 420 buildings with pronounced health complaints of the occupants were investigated. The results showed that there were prevailing moisture problems in 65% of the buildings. These moisture problems resulted in vivid microbial growth, with microbial/chemical emissions of building material and microbial metabolites. The other buildings (35%) could be explained by historical moisture damages, which were backdated several years in time. IAQ complaints were investigated through questionnaires. Microbial biomass was determined as viable (CFU) and non-viable microorganisms as direct count of acridine orange stained microbial cells. Through the technique of direct-count, the dried-out microbial damages could be detected. The use of direct-count alone made it possible to explain the cause of 147 problem buildings out of 420. These buildings had otherwise not been able to remediate in a proper way.

Wigo, H., I. Knez, et al. (2002). Effects of Velocity Variations in Ventilated Room on Comfort, Affect and Cognitive Performance. Indoor Air 2002. Monterey, California,. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

In many buildings there is no cooling system apart from a ventilation system. The only remedy available to remove excess heat is to supply large quantities of cold air. This may, however cause unacceptable draught problems. There are indications that intermittent variations in velocities can be beneficial to people's perceived comfort. By introducing velocity variations we hypothesised that people's sensation of a

pleasant indoor climate can be met at higher room temperatures than otherwise. The velocity variations were obtained by using commercial ventilation systems (mixing and displacement ventilation) and a ceiling fan. A between-subject design was employed in this study. The experiment lasted for 80 minutes, and the subject's perceived comfort and air quality, self-reported affect and cognitive (intellectual) performance were measured. The velocity variations did not have any effect on perceived thermal comfort. There were, however indications for an effect on perceived air quality, self-reported affect and cognitive performance.

Wineman, J. D. (1982). The office environment as a source of Stress. Environmental Stress. G. W. Evans. New York, Cambridge University Press.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wineman, J. D. (1986). Behavioral issues in office design. New York, N.Y., Van Nostrand Reinhold**:** xvii, 364.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wolkoff, P., P. Skov, et al. (2002). Eye Irritation Caused by Indoor Pollutants – An In-Depth Approach. Indoor Air 2002. Monterey, California. **Proceedings: 9th International Conference on Indoor Air Quality and Climate**.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

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

Wong, N. and S. Khoo (2003). Thermal comfort in classrooms in the tropics. Energy and Buildings. **35:** 337-351.
Geographical Location: Singapore
Building Type: school
Data Type: survey, measurements, on-site
Outcome Focus: occupant, response

Abstract

A field study was conducted in classrooms in Singapore, which were mechanically ventilated by fans, to assess their thermal conditions during the students' lesson hours. Thermal comfort variables were measured at the same time when students and teachers answered a survey on their perception/sensation of the indoor climate. Objective data analysis showed that none of the classes had thermal conditions falling within the comfort zone of ASHRAE standard 55. Occupants found temperature range beyond the comfort zone acceptable. This suggests that the standard is not applicable in free-running buildings in the local climate. A new PMV model, which incorporates two common forms of adaptation-reducing activity pace and expectation, still showed discrepancy in predicting actual thermal sensations, especially at lower temperatures. Comparison of the various methods of assessing thermal acceptability showed that they produce widely disparate results, with the Bedford scale giving the highest level of acceptability. Classroom occupants generally accepted cool thermal sensations more readily than warm thermal sensations.

Wong, N. H. and W. L. S. Jan (2003). Total building performance evaluation of academic institution in Singapore. Building and Environment. **38:** 161-176.
Geographical Location: Singapore
Building Type: school
Data Type: model
Outcome Focus:

Abstract

Over the years, the concept of total building performance and its application to commercial and residential buildings has been of great interest among researchers in this field. In a country such as Singapore, whose society is paying increasing attention to paper qualifications, the evaluation of academic institutions using this concept may provide a gateway to critical issues related to the learning environment. In an attempt to understand the conduciveness of classroom environments towards learning, a study is done to investigate the performance of classrooms in a typical secondary school in Singapore. Performance is indicated by the measurement and evaluation of six mandates, namely thermal, spatial, visual, acoustic, indoor air quality, and building integrity. The usage of both objective and subjective methods gave rise to interesting and sometimes conflicting results with regards to the classrooms' performance.

Woods, G. (1994). Productivity and Indoor Air Quality. Specifier. **3:** 65-67.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Woods, J. E., B. A. Penney, et al. (2002). Health, Energy and Productivity in Schools: Overview of the Research Program. Indoor Air 2002. Monterey California**:** 56-61.
Geographical Location: USA, Maryland, Montgomery County

Building Type: School, Primary
Data Type: quantitative, survey, measurement, on-site; observation
Outcome Focus: occupant, productivity

Abstract

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

Workplace Health and Safety Council (1995). Indoor Air Quality: A Guide, Workplace Health and Safety Council, Department of Training and Industrial Relations, Australian Government.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

This guide has been produced by the Workplace Health and Safety Council to provide employers with information on the considerations needed when assessing the need to introduce control measures to provide a healthy and comfortable working environment for their employees. The guide aims to help improve the quality of work environments by outlining factors affecting indoor air quality and suggesting ways of managing the quality of indoor air for all workplaces.

Wyon, D. P. (1969). The effects of classroom temperatures on school performance: studies in the field. Nordisk hygienisk tidskrift. **50:** 20-23.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (1970). Studies of children under imposed noise and heat stress. Ergonomics. **13:** 598-612.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (1973a). The effects of ambient temperature swings on comfort, performance and behaviour. Archives des sciences physiologiques (Paris). **27:** 441-458.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (1973b). The effects of moderate heat stress on typewriting performance. Archives des sciences physiologiques (Paris). **27:** 499-509.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (1974a). The effects of moderate heat stress on typewriting performance. Ergonomics. **17:** 309-318.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (1974b). Thermal Aspects of the Environment in Buildings. Journal of Architectural Research. **3:** 12-17.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P., I. Andersen, et al. (1979). The effects of moderate heat stress on mental performance. Scandinavian journal of work, environment & health. **5:** 352-361.
Geographical Location: not specified
Building Type: school
Data Type: quantitative, measurement, laboratory
Outcome Focus: occupant, comfort; occupant, productivity

Abstract

Moderate heat stress is believed to affect mental performance by lowering levels of arousal. Conscious effort can counteract this effect. In most experiments, raised temperatures are perceived at the start by subjects and can act as a stimulus to exert conscious effort. In practice, temperatures usually rise slowly and may therefore have a more marked effect. Thirty-six male and 36 female 17-year-old subjects in standard cotton uniforms (0.7 clo) were exposed in groups of four in a climate chamber to rising air-temperature conditions typical of occupied classrooms, in the range 20--29 degrees C. The maximum rate of rise was 4 degrees C/h. Each group performed mental work during three successive periods of 50 min with 10-min breaks between. During each break the air temperature was reduced by 3 degrees C. Sentence comprehension was significantly reduced by intermediate levels of heat stress in the third hour. A multiplication task was performed significantly more slowly in the heat by

male subjects, showing a minimum at 28 degrees C. Recognition memory showed a maximum at 26 degrees C, decreasing significantly at temperatures below and above, and an independent measure of degree of certainty in recall showed a maximum at 27 degrees C. These findings are in accordance with the hypothesis of reduced arousal in moderate heat stress in the absence of conscious effort.

Wyon, D. P., I. Andersen, et al. (1981). The Effects of Moderate Heat Stress on Mental Performance. Bioengineering, Thermal Physiology and Comfort. K. Cena and J. A. Clark. New York, Elsevier. **10:** 251-267.
Geographical Location: not specified
Building Type: not specified
Data Type: theory, literature survey
Outcome Focus: occupant, comfort

Abstract

PROVINS (1966) has suggested that the effect of moderate heat stress is to lower levels of arousal, while higher levels of heat stress tend to increase arousal. A similar suggestion had earlier been made by POULTON and KERSLAKE (1965) in the context, of rapidly rising body temperatures. The effect is believed to be a largely unconscious adaptive behavioural response: as thermal stress rises beyond the range in which vasodilatory control of the heat balance is effective, sweating must progressively increase and take over control of the heat balance. However, as the onset of sweating takes time and tends to be aversive for clothed, sedentary workers, the immediate conscious or unconscious response is to relax as much as possible, thus immediately reducing bodily heat production and perhaps postponing or avoiding the onset of sweating.

Wyon, D. P. (1993). Healthy Buildings and their Impact on Productivity. Indoor Air 93. **Proceedings of Indoor Air 93:** 3-13.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Healthy buildings differ from other buildings in terms of the heat and cold stress, humidity, airborne particulates and VOCs to which their occupants are exposed. Published evidence is reviewed for an effect of these indoor climate factors on some of the 14 most useful measures of productivity which were identified at a recent ASHRAE Workshop. SBS and sensations of dryness are treated as intervening dependent variables, and evidence for their influence on productivity is first reviewed. The effects of IAQ. temperature and vertical temperature differences on SAS and sensations of dryness are then documented. Direct effects of IAQ and thermal climate parameters on productivity are treated separately, as are vehicle climate effects on driver performance. Individual control of the microclimate at the workstation is shown to be a cost-effective means of maintaining productivity. It is concluded that a sufficient number of reliable studies have been carried out to support the claim that healthy buildings will have an effect on productivity.

Wyon, D. P. (1996). Indoor Environmental Effects on Productivity. IAQ 96. **Proceedings of IAQ 96: Paths to Better Building Environments:** 5-15.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Thermal conditions within the thermal comfort zone can reduce key aspects of individual human efficiency such as reading, thinking logically, and performing arithmetic, by 5% to 15%. Poor air quality, which gives rise to headaches and fatigue, may have similar effects. Vertical temperature differences may cause air quality problems at head height. The published evidence for such effects is reviewed. Case studies of indoor environmental quality (IEQ) and productivity in the field can sometimes quantify outcomes but seldom prove causation. A new approach to productivity research is presented that can determine nut only whether, but also how and how much, productivity is affected by specific aspects of IEQ. Claims that architectural or engineering design features impact productivity would be tested by formulating specific mechanisms in terms of chains of linked hypotheses. If any hypothesis in the chain is untrue, the mechanism is invalid. Seven mechanisms by which the office environment might affect productivity are defined. The 48 falsifiable hypotheses involved can be tested in the field using existing outcome metrics in experiments that do not involve any long-term decrease in overall productivity.

Wyon, D. P. (1998a). Individual Control at Each Workplace for Health, Comfort and Productivity. INvironment. **4:** 3-6.
Geographical Location: U.S.
Building Type: Office
Data Type:
Outcome Focus:

Abstract

We all have days when the office environment is the problem. Whether the problem comes form lighting, temperature, or some other physical factor, if you can't change anything, the only remaining option is to change everything by going to a different location to work. Even in the rare circumstances when Such a change is an option, it has many obvious disadvantages.

Wyon, D. P. (1998b). Documented Indoor Environmental Effects on Productivity. Green Buildings. Danvak.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Wyon, D. P. (2000a). Enhancing Productivity While Reducing Energy Use in Buildings. E-Vision 2000. Washington D.C., U.S Department of Energy.
Geographical Location: USA
Building Type: Office, School
Data Type: theory, survey
Outcome Focus: occupant, productivity; building, energy

Abstract

Indoor air quality (IAQ) and air temperature (T) have powerful effects on the efficiency

with which work can be performed in schools and offices. Huge amounts of energy are used to keep these parameters constant at levels which represent a compromise between group average requirements for subjective comfort and energy conservation. Human requirements change with task requirements and from hour to hour. so the levels at which T & IAQ are maintained are at best a crude approximation to what would be the most efficient use of energy in buildings. Different individuals have very different requirements for health, comfort and efficient performance-the three ascending levels of the human criteria hierarchy. Symptoms of ill health and discomfort have powerful effects on the efficiency with which work can be performed in schools and offices, so even a narrow economic focus requires that indoor environmental effects at all three levels be considered.

Wyon, D. P., K. Tham, et al. (2000b). The Effects on Health and Self-estimated Productivity of Two Experimental Interventions which Reduced Airborne Dust Levels in Office Premises. Healthy Buildings 2000. Seppanen and J. Sateri. Espoo, Finland,. **1:** 641-646.
Geographical Location: UK, London
Building Type: Office
Data Type: quantitative, measurement, on-site
Outcome Focus: occupant, well-being; occupant, productivity

Abstract

Airborne dust levels in a central-London office were reduced over an 18-week period by means of two reversible interventions, each applied for a week at a time in a balanced design: I) replacing well-used supply-air pre-filters (P-filters) with new ones; and 2) operating free-standing electrostatic filters (E-filters). Occupants, who were blind to the interventions, marked a set of 27 Visual-Analogue Scales (VA-scales) each week to indicate indoor environmental quality, SBS-symptom intensity, and self-estimated productivity. New P-filters produced the following significant effects (P<O.O5): humidity seemed lower, eyes ached less, head felt clearer; subjects felt better, less tired and more positive and they found it easier to concentrate; their self-estimated productivity was 5.7% higher. IEQ responses indicated that room temperatures had been higher (by chance) when the E-filters were in operation. On another floor served by the same P-filters, subjects also tended to feel better (P<O.06) and self-estimated productivity was higher (P<O.O5) with new P-filters.

Xia, Y., J. Niu, et al. (2000). Effects of Turbulent Air on Human Thermal Sensation in a Warm Isothermal Environment. Indoor Air. **10:** 289-296.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Air movement can provide desirable cooling in "warm" conditions, but it can also cause discomfort. This study focuses on the effects of turbulent air movements on human thermal sensations through investigating the preferred air velocity within the temperature range of 26æC and 30.5æC at two relative humidity levels of 35% and 65%. Subjects in an environmental chamber were allowed to adjust air movement as they liked while answering a series of questions about their thermal comfort and draft sensation. The results show that operative temperature, turbulent intensity and relative humidity have significant effects on preferred velocities, and that there is a wide variation among subjects in their thermal comfort votes. Most subjects can achieve thermal comfort under the experimental conditions after adjusting the air velocity as they like, except at the relative high temperature of 30.5 degrees C. The results also indicate that turbulence may reduce draft risk in neutral-to-warm conditions. The annoying effect caused by the air pressure and its drying effect at

higher velocities should not be ignored. A new model of Percentage Dissatisfied at Preferred Velocities (PDV) is presented to predict the percentage of feeling draft in warm isothermal conditions.

Xu, T., E. Arens, et al. (1995). The Effects of Highlevel Air Humidity on Subjective Perception of Comfort. 2nd International Symposium on Heating, Ventilation and Air Conditioning. Beijing, China. **Proc. of the 2nd International Symposium on Heating, Ventilation and Air Conditioning:** 81-91.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Yang, C., M. Lin, et al. (1998). Childhood Asthma and the Indoor Environment in a Subtropical Area. Chest. **114:** 393-397.
Geographical Location:
Building Type:
Data Type:
Outcome Focus:

Abstract

Study objectives: The objective of this study is to examine the relationship between indoor environmental factors and childhood asthma in a subtropical area. Design: A case-control study was performed using participants of a prevalence survey that included 165 schoolchildren with asthma and 165 age- and gender-matched control subjects. Setting: The study was confined to 4,164 schoolchildren aged 6 to 12 years attending eight primary schools in Kaohsiung County rural municipalities who participated in a prevalence study concerning the health effects of the indoor environment. Participants: Cases (n=165) were dermed as children with current asthma conrInned by a physician. Control subjects (n=165) were selected from the same school and class and matched for age and gender, and they did not have a previous diagnosis of asthma, history of physician confirmed atopic diseases, persistent wheezing, cough, or phlegm, or reported chest illness, pneumonia, or bronchitis. Measurements and results: Information regarding the home environment was obtained using a structured written questionnaire, completed by the parents of the children. Of the many indoor environmental factors included in this study, only home dampness showed an association with asthma (odds ratio=2.65). Conclusions: We conclude that dampness in the home is a new public health issue in subtropical areas.

Yang, C., M. Cheng, et al. (1999). Effects of Indoor Environmental Factors on Risk for Acute Otitis Media in a subtropical Area. Journal of Toxicology and Environmental Health. Part A. **56:** 111-119.
Geographical Location: Kaohsiung
Building Type: school; domestic, house
Data Type: quantitative, questionnaire, measurements, on-site
Outcome Focus: occupant, health

Abstract

The objective of this study was to examine the relationship between indoor environmental factors and acute otitis media in a subtropical area. A case-control study was performed using participants from a prevalence survey that included 219 school children with acute otitis media and 219 age- and gender-matched controls. The study was confined to 4164 primary school children aged 6-12 yr attending 8

primary schools in Kaohsiung rural municipalities who participated in a prevalence study of the health effects of an indoor environment. An acute otitis media case was defined as a child with acute symptoms (presenting with earache, fever, irritability, and/or discharge from the ear) diagnosed by a physician in the previous year. Controls selected from the same school did not have chronic or acute respiratory illness or an ear-related illness during the same period. Information regarding the home environment was obtained using a structured written questionnaire, completed by the parents of the children. Of the many indoor environmental factors included in this study, only living in a home with indications of dampness (mould, flooding, home dampness) showed an association with acute otitis media. It was concluded that dampness in the home is a new public health issue in subtropical areas.