BOOK OF ABSTRACTS

HEALTHY BUILDINGS 2023 EUROPE

BEYOND DISCIPLINARY BOUNDARIES

JUNE 11-14, AACHEN, GERMANY

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Content

From the President of Healthy Buildings 2023 Europe

Dear all, welcome to Healthy Buildings 2023 Europe, welcome to Aachen!

Healthy Buildings 2023 Europe is the continuation of the renowned ISIAQ Healthy Buildings conference series travelling around the world and connecting international and local experts.

The last decades offered a multitude of knowledge gained and solutions developed within individual disciplines. The sensible application thereof however requires a holistic understanding of interdependencies between and across disciplines. At the same time, current crises, such as climate change and the COVID-19 pandemic, show the need for inter- and transdisciplinary collaboration to shape the future of healthy and stimulating built environments – a task all of us, organizing and attending this conference are striving for. This rationale also led to this year's conference theme „Beyond disciplinary boundaries – Transdisciplinary perspectives on multisensory stimulation for innovative and creative solutions in a post-Covid era" and we hope you will engage with participants beyond your own disciplinary background to exchange knowledge, methods and ideas.

We, the organizing committee, are honoured by the extraordinary interest demonstrated by more than 400 registered participants, over 390 abstracts submitted leading to 256 contributions presented as oral or poster presentations, 13 interactive workshops, 6 keynotes and 1 panel, all taking place during the 3 main conference days. This interest also shows the need and desire to get together on-site, to support established contacts and to create new ones, to present and to discuss the latest results and to give and to receive feedback from peers. These numbers and the desired compactness also provide some challenges, e.g., with respect to the time available for presentations and poster sessions. We made the greatest effort to accommodate everyone's wishes and hope you will enjoy your conference visit.

We would like to thank all the volunteers and our sponsors; such event would not be possible without their support. At the same time, we already thank all of you for your contributions and active participation in this conference to make it a great success for everyone.

Also, on behalf of the organizing committee

Marcel Schweiker,

President Healthy Buildings 2023 Europe

University Hospital RWTH Aachen

Maps and guidance

Overview map

Main Venue

DAS LIEBIG
Liebigstrasse 19, 52070 Aachen

Welcome Reception

The Healthy Buildings 2023 Europe Welcome Reception will be held at the SuperC building.

SuperC
Templergraben 57, 52062 Aachen

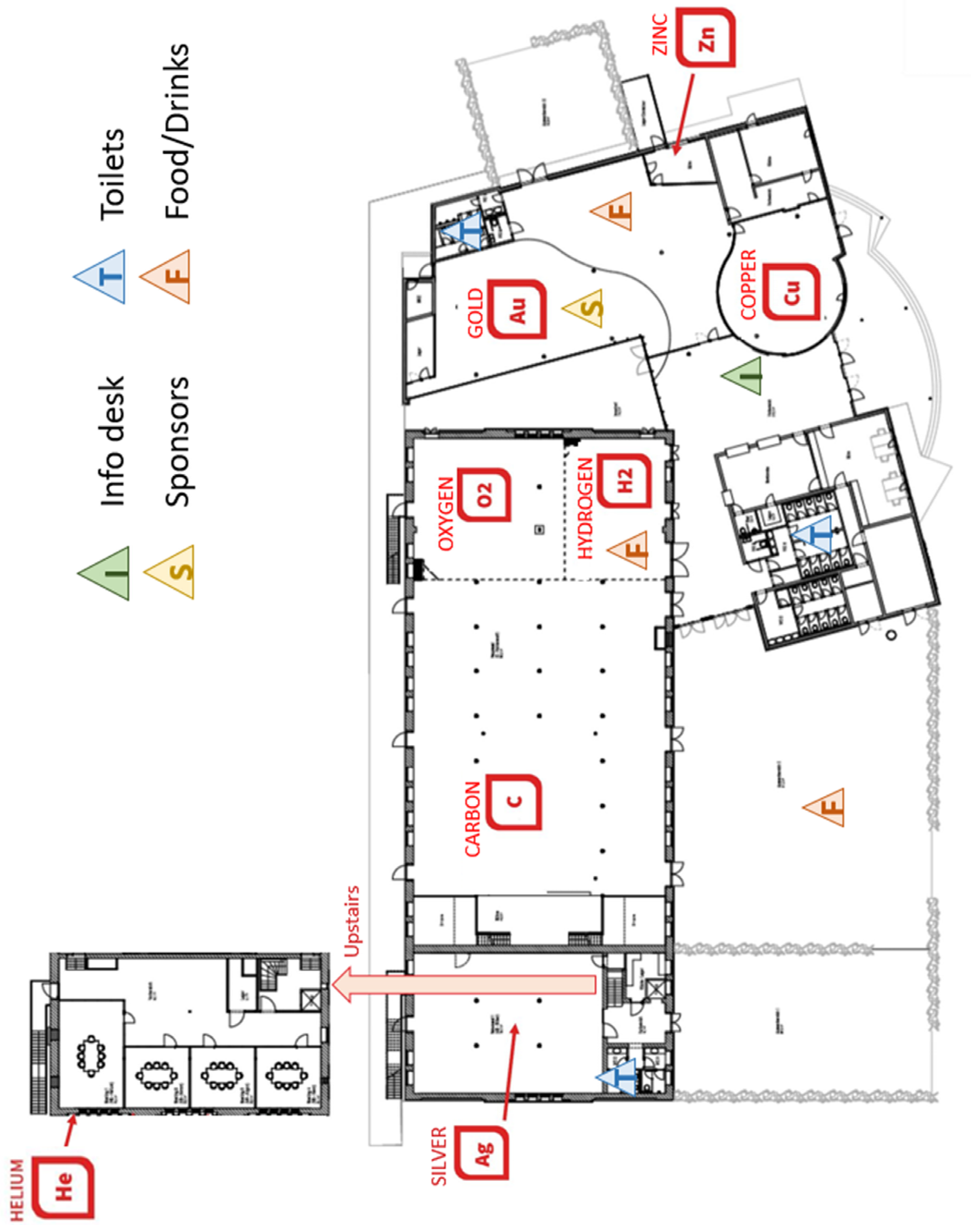
Banquet

Erholungs-Gesellschaft Aachen 1837 (Stadtpalais)
Reihstraße 13, 52062 Aachen

Directions:

Starting from Das LIEBIG, the closest bus stop is Liebigstraße. From there, you can take any bus (11,21,31) going to the bus stop Elisenbrunnen. Alternatively, you can take a bus going to Aachen Bushof (1, 220, SB20) and walk approximately 500 meters to the Erholungs-Gesellschaft Aachen 1837.

Conference Venue DAS LIEBIG



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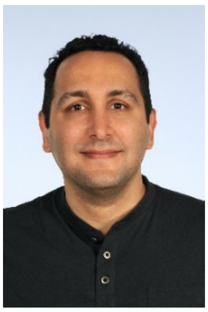

Peiman Pilehchi Ha

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- Wim Zeiler, TU Eindhoven, Eindhoven, Netherlands
- Jiaxu Zhou, University College London, London, United Kingdom
- Yiding Zhou, The Chinese University of Hong Kong, Shatin, N. T., Hong Kong
- May Zune, Brunel University London, London, United Kingdom

Tours

Technical tours

Melaten campus lab tour

The heart of the tour will be the Urban Energy lab 4.0 (UEL 4.0), a joint facility by the Institute for Energy Efficient Buildings and Indoor Climate (EBC) and the Institute of Energy Efficiency and Sustainable Building (E3D). The Urban Energy lab aims to simulate city's energy systems into the laboratory setting to explore user comfort (for more information, please visit: www.uel4-0.de). Highlights of this tour include an indoor climate laboratory, an innovative heat pump system based on geothermal energy coupled with a photovoltaic power plant and the iCare test bench, in which the institute uses Augmented Reality to evaluate individual user comfort.

Uniklinik & City center lab tour

The heart of this tour will be the immersion into different experiences. First step, the Aachen workplace simulation laboratory offers the possibility to simulate realistic occupational conditions, in which thermal, lighting and air quality properties can be controlled, to explore how indoor environmental conditions could influnce participants' comfort, health and well-being. Additionally, a visit will be offered to the Perception lab situated in the University Hospital RWTH Aachen (UKA), one of the historical landmarks in Aachen and one of Europe's largest hospital buildings. The Perception lab aims to investigate human perception processes of low frequency and static electric fields.

Cultural tours

Guided tour of the old town

During the tour around Aachen's historic old town you will get to see historical places and buildings such as Aachen cathedral, old town houses and beautiful fountains. During the guided tour you will learn lots of exciting history facts and stories about Aachen.

Networking-Walk to the "Dreiländereck"

After a short bus ride to Vaals in the Netherlands, a guide will lead you to the "Dreiländereck" – the tri-state-area where the Netherlands, Belgium, and Germany meet. While you can learn about the history about the Dreiländereck once you have arrived, this walk is meant to be a networking-walk where you will have the opportunity to get in touch with other HB23 Europe attendees. In the spirit of the Dreiländereck, why don't you join this networking-walk to come together and establish new contacts?

Conference programme

Programme overview

Start	Sunday			Monday	Tuesday	Wednesday
08:30				Welcome note		Parallel sessions
08:45						
09:00		PhD Summer School Day		Keynote 1	Keynote 3	
09:15						
09:30				Q&A Keynote 1	Q&A Keynote 3	
09:45				Keynote 2	Keynote 4	room changes
10:00						Parallel sessions
10:15				Q&A Keynote 2	Q&A Keynote 4	
10:30				Coffee break	Coffee break	
10:45						
11:00				Parallel sessions	Parallel sessions	
11:15						Coffee break
11:30						
11:45						
12:00	Pre-conference meetings					Keynote 5
12:15						
12:30				Lunch	Lunch	Q&A Keynote 5
12:45						Keynote 6
13:00						
13:15						Q&A Keynote 6
13:30				Poster session + Sponsor worksh.	Parallel sessions	Closing session
13:45						
14:00				Parallel sessions		Farewell lunch
14:15						
14:30						
14:45					room changes	
15:00			Pre-conference cultural and technical tours		Parallel sessions	
15:15						
15:30				Coffee break		
15:45						
16:00				Parallel sessions		Post-conference cultural and technical events (external)
16:15					Coffee break + poster session	
16:30						
16:45					Parallel sessions	
17:00						
17:15						
17:30						
17:45						
18:00		Welcome reception				
18:15					room changes	
18:30				Banquet (Erholungs-gesellschaft, Stadtpalais)	ISIAQ AGM	
18:45						
19:00						
19:15						
19:30					Chair dinner (Room Gold or external)	
19:45						
20:00						

Sponsor Workshop HTx

Monday, 12.06.2023 13:15-14:00 Room O2 Oxygen

Heinz Trox Foundation: 'Good Learning in schools' and cooperation opportunities

HEINZ TROX STIFTUNG

This workshop presents the non-profit Heinz Trox Foundation which has been promoting scientific activities in the field of air-conditioning and ventilation technology and supporting social and cultural activities since 1991. The main recipient of funding in the scientific field is the Heinz Trox Wissenschafts gGmbH (HTG), also a non-profit research institute based in Aachen, which deals with the "well-being of people in indoor spaces" within the framework of externally funded as well as independently conducted research projects with changing thematic focuses.
After a brief overview of HTG's research activities, the workshop will focus on the topic "Good Learning Climate in Schools" and the presentation of the HTxCube including a live demo:

Research focus "Good Learning Climate in Schools".
Schools are a particularly important area of research with regard to indoor environment quality (IEQ). Results will be presented from

1) a field study in about 50 classrooms, which revealed deficits in all aforementioned areas
2) an intervention study in which four classrooms were refurbished with a ceiling ventilation unit, acoustic ceiling and modern lighting.

Based on these studies, HTG is working on a guideline for classroom refurbishment that takes a modular and integral approach. The aim is to show that there is a way to simultaneously improve air quality, thermal comfort, acoustics and lighting for every classroom in the existing building with satisfactory results!

HTxCube
The HTxCube is a mobile measurement unit that was developed to collect comfort-relevant data in various indoor spaces to compare objective measured data with subjective user feedback. It is equipped with sensors for air quality, thermal comfort, lighting and acoustics as well as a touch screen for user surveys. Measurement results from a school will be presented as an example. An HTxCube will be available for demonstration in the event room.
We look forward to networking and discussing the use and further development of HTxCubes as well as finding multipliers in the field of school refurbishment.

Our speakers:
Minsheng Xu, Tobias Burgholz, Christine Roßkothen

Sponsor Workshop Swegon

Monday, 12.06.2023 13:15-14:00 Room Ag Silver

The impact of relative humidity indoors on human health – workshop and opposing discussion with Swegon

Low relative humidity levels indoors in winter should be discussed more thoroughly in the IAQ scientific community. In Northern Europe and areas in higher altitudes in Central Europe the relative humidity indoors can drop below 20% for long periods. In many regions the relative humidity indoors drops below 30% RH when the temperature outside drops under 5°C. Especially in modern buildings with mechanical ventilation. The more we ventilate, the dryer indoor air during winter. Humans do not have humidity sensors. Yet, low relative humidity may have consequences for our health as documented through physiological measurements. Should the physiological effects be more taken into account when talking about IAQ and healthy buildings? This workshop will try to initiate such a discussion with two speakers taking opposing view – one from the medical side and one from the engineering side

Our two speakers:
Dr. Med. Walter Hugentobler who has long experience studying the impact of dry indoor air on human health. He will take the position that low RH should be avoided and show data of the physiological impacts of the respiratory tract.
Assoc. Prof. Pawel Wargocki , DTU . He will take the opposite position by presenting the results from studies performed in the buildings.

After their presentation there will be time for Q&A with the audience.

The workshop will be chaired by Mr Timo Schreck from Swegon.

Sponsor exhibition

Time:
Monday through Wednesday

Room: Au Gold

Visit the sponsor booths to get informed about latest developments in industry.

HEINZ TROX STIFTUNG

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Keynotes

Monday, 12.06.2023 09:00-09:45 Room C Carbon

From planetary boundaries to human behaviour in buildings: reflections on the human dimension

Hubacek, Klaus

University of Groningen, Netherlands

Human activities have resulted in the exceeding of several planetary boundaries, such as the loss of biosphere integrity, land system alteration, biogeochemical cycle disruption, chemical pollution, and the most frequently discussed issue - climate change. These impacts are driven by human production and consumption activities, as well as an ever-growing human technosphere that encompasses buildings, infrastructure, and artifacts interacting with their natural environments. To address these issues, a variety of technical solutions have been developed to tackle one problem at a time, often neglecting the interactions with other issues, long-term consequences, and human behavior, aspirations, and limitations, which may conflict with the proposed solutions. In this talk, we will investigate the role of human behavior and its potential to reinforce or counteract such solutions in optimized systems. We will explore potential trade-offs related to time, space, and the economic, social, and environmental impacts of these decisions. Additionally, we will examine the effects of these decisions on various social groups, recognizing that normative considerations are often present, even if unintentionally. We will also delve into the importance of involving a wide range of diverse people in the planning process and draw insights from past research experiences.

Monday, 12.06.2023 09:45-10:30 Room C Carbon

The Luminous Environment, Well-being and Health

Heschong, Lisa

FIES, Santa Cruz, California

Over twenty years ago we began to learn about the key contribution that the light received at our eyeballs made to our body's overall circadian rhythm, such as daily patterns of sleep and alertness. We are now learning how the interaction of the luminous environment with our physiology reaches far beyond sleep quality to include, for example: eye health, mood, temporal and spatial orientation, memory formation, metabolic and thermal regulation, and immune response. Scientists are rapidly decoding the neural, molecular and genetic mechanisms involved to reveal both surprising complexity and logical elegance.

However, our modern luminous environment is very different than the conditions under which humans evolved. Previously, just like all other life forms, our lives were largely spent outdoors under the bright daytime skydome and the inky black night sky. The naturally rhythmic light signals provided by the sun and moon varied enormously in intensity and spectrum, by time of day, month and season. But now, most of us spend a majority of our lives under electric lighting, both dimmer during the day and brighter at night, with a restricted spectrum, determined primarily by technological efficiency. Thus, the biological signals we receive from the planet's luminous rhythms have been greatly diminished.

As designers, engineers, and policy makers, we must ask: how can the luminous design of future cities and buildings best support our fundamental biological needs? Planetary health? How should we prioritize our luminous design strategies? First and foremost, our daytime environments must provide equitable, population-wide access to sunlit outdoor spaces, brightly daylit interior spaces, and ample window views to the sunlit world beyond. We need to figure out how to achieve this most effectively via urban planning, building design, and glazing technologies, while balancing pressing needs for more housing, greater energy efficiency, and climate resilience. Secondly, at night we all need biologically dark homes and places to sleep; both humans and animals! Growing levels of light pollution are having major biological consequences. Thus, we should look for ways to minimize the use of electric lighting, both day and night. Likewise, whenever possible, we should try to reduce the unintended negative consequences of electric lighting and digital devices, indoors and out. Finally, we can consider supplementary electric lighting strategies for unusual circumstances, such as underground buildings, artic research stations, or extended shift work, where humans must function far removed from their evolutionary native habits and habitat.

Given both the predominance of visual information for human cognition, and our deep biological ties to light signals, creating both a beautiful and healthful luminous environment should be one of our top environmental design priorities.

Tuesday, 13.06.2023 09:00-09:45 Room C Carbon

How hot do you feel? Novel insights on individual variability in thermosensing in health and disease

Filingeri, Davide

THERMOSENSELAB, Skin Sensing Research Group, School of Health Sciences, The University of Southampton, Southampton, United Kingdom

For the first time in history, we have an ageing population faced by the threat of climate change. This means that we are all going to experience extreme weather events such as heat waves, more often and for longer in our lives. Hot weather and heat extremes severely limit people's work and exercise capacity, with consequent detrimental effects on individuals' health, comfort, and productivity. This is translating in a growing social and economic burden on healthy and vulnerable groups, as well as on businesses and health services worldwide.

Our thermal behaviours (e.g., changing the thermostat's temperature in an office) represents the most effective mechanisms to maintain thermal comfort and ensure heat-stress resilience. Remarkably, these behaviours are entirely dependent on the ability to detect variations in our internal (i.e., body) and external environment, via sensing changes in body temperature and skin wetness. Over the past 30 years, we have seen a significant expansion of our understanding of the molecular, neuroanatomical, and neurophysiological mechanisms that allow humans to sense temperature and wetness, i.e., thermo- and hygro-sensing. However, we still lack comprehensive knowledge on how perceptual and behavioural responses to temperature and wetness vary at an individual level, for example as a function of sex, age, and clinical status.

The knowledge gaps highlighted above pose a significant challenge to the development of sustainable thermal comfort solutions, particularly within the built environment. In 2021, the built environment sector alone was responsible for ~40% of global energy-related CO_2 emissions, with a large amount of these emissions arising from heating and cooling buildings to maintain occupants' thermal comfort. While thermal comfort models for building occupants are available, these do not often and fully capture how individual differences in thermosensing contribute to our responses, preferences, and vulnerability to different thermal environments. As a result, we are still far from reaching thermal comfort, thermal health, and thermal safety for all in buildings.

This keynote talk will present both established and novel evidence on the physiological and perceptual mechanisms underpinning thermo- and hygro-sensing in healthy individuals as well as in those affected by pathology such as neurodegeneration. It is hoped that this overview will stimulate the development of novel approaches and solutions to sustainable, person-centred thermal comfort in the built environment at a time of climate change.

Tuesday, 13.06.2023 09:45-10:30 Room C Carbon

Links Between Indoor Acoustic Conditions and Human Well-Being and Performance

Wang, Lily

University of Nebraska–Lincoln, United States of America

In current times, humans spend much of their time within built environments, and the acoustic conditions within those environments can have significant impacts on human comfort and performance. Existing acoustic guidelines for assorted types of spaces (offices, classrooms, hospitals, etc.) typically recommend upper limits for background noise levels and reverberation times, but much of the guidance in the past has been set empirically rather than supported by direct evidence-based research. Recent investigations at the University of Nebraska have focused on obtaining more data linking acoustic conditions to human performance outcomes to guide the acoustic design of built spaces. Two main research thrusts will be reviewed: 1) linking in-situ measurements of classroom acoustics to student learning outcomes; 2) investigating how room acoustics impact speech comprehension by non-native English-speaking listeners (a group that includes 21% of children in the United States K-12 school systems) and of non-native English-speaking talkers (commonly found in the professoriate at English-speaking universities), compared to native English-speaking listeners and talkers. Concluding thoughts are presented on how we should move from setting guidelines of acceptability instead to designing multi-sensory environmental conditions, including acoustics, for human well-being.

Wednesday, 14.06.2023 12:00-12:45 Room C Carbon

Relating the exposome to child mental health and cognitive development: methodological challenges

van Kamp, Irene

National Institute for Public Health and the Environment, The Netherlands

There is increasing evidence that a complex interplay of factors within environments of children contributes to children's mental health and cognitive development. The concept of the life-course exposome allows for studying the holistic impact of the physical and social environment on mental health and cognitive development over time. The H2020 project Equal-Life develops and tests combined exposures and their effects on children's mental health and cognitive development. A distinction is hereby made between external (physical and social) and internal exposome. The main domains discerned are indoor and outdoor environmental quality, the built and natural environment, lifestyle and social circumstances at family, neighbourhood and societal level. The main challenge is on the one hand how to unravel the influence of these different exposures on mental health and cognitive development and on the other hand how to integrate the combined/cumulated effects of different exposures. To obtain a full picture of child exposures, activities, settings, periods and social groups should be accounted for. The advantages and disadvantages of different approaches will be discussed. Taking urban environmental quality and mental health as a point of departure, some examples will be presented of how to deal with these challenges.

Wednesday, 14.06.2023 12:45-13:30 Room C Carbon

Impact of climate change on indoor air quality from regional and global perspectives

Salthammer, Tunga

Department of Material Analysis and Indoor Chemistry, Fraunhofer WKI, Germany

Today, serious discussions do no longer deal with the question of whether climate change will happen, we are already in the midst of it. One also has to realize that the goal of a maximum global warming of 1.5 °C by 2100 is at the lower end of the actual forecast by the International Panel on Climate Change (IPCC) and can probably not be achieved. It is therefore advisable to consider the possibility of more pessimistic scenarios. The fatal thing about the situation is that we know very well what climate change will do to the ecosystem and thus to human society. There are enough examples of the consequences of extreme and slowly developing weather events.
Various organizations have drawn up action plans to protect humans from extreme heat. This is certainly a step into the right direction, but the information chain often requires complex logistics, what takes time and makes such procedures unnecessary difficult. Ultimately, it is local authorities who must implement the appropriate measures. However, the latter often do not even know that such plans exist. In addition, most of the available recommendations only refer to the temperature, but the human heat balance and heat stress is also dependent on the air humidity. There are many other events associated with climate change and affect the indoor environment. This includes extreme cold, the risk of mold formation through condensing water, the formation of photo smog, in particular tropospheric ozone and OH radicals through UV radiation as well as other air pollutants such as NOx, particles and organic compounds. In order to be able to meet short and long-term climate events with regard to the living environment, valid predictions and recommendations are necessary. In the short term, residents need to know how to protect themselves against extreme temperatures, moisture and air pollutants in the current situation. If necessary, decisions have to be made on a daily basis as to whether it is better to stay at home, how and at what time of day the living space can be ventilated. In the medium and long term, practically implementable information on structural thermal insulation ventilation and heating as well as protection from mold and bioaerosols is required. Reliable estimates can be made with the help of suitable models, which provide valuable assistance for a better assessment of upcoming climate events and for the development of preventive measures.

Panel discussion

Wednesday, 14.06.2023 10:00-11:15 Room C Carbon

Using Health based metrics to improve IAQ management strategies

Laverge, Jelle (1); De Jonge, Klaas (1); Jones, Benjamin (2); Wargocki, Pawel (3)

1: Ghent University, Belgium; 2: University of Nottingham, UK; 3: Danish Technical University

ID: 493 Workshop and practice session suggestions - final
Topics: 09. Public health, occupational & environmental health
Keywords: IAQ metrics, Health, IAQ management

Since the landmark paper by Logue et al. (2012), the use of DALY's been adopted as the most comprehensive way of shifting the focus of the discussion on the appropriate levels of IAQ to an approach based on health outcomes. The paper quantified the expected burden of disease related to exposure to indoor air pollutants and thereby allowed to compare the impact of IAQ to other causes of reduced health. For this application, the proposed methodological framework that was borrowed from epidemiology is relatively straightforward and proved to be extremely valuable in identifying priority pollutants.

Using this framework to assess the potential of strategies to improve IAQ, however, is problematic. The epidemiological and or toxicological background knowledge that underpins the non-linear dose-response relationships for the pollutants, does not allow to compare the impact of a peak exposure to a constant exposure with the same total dose without making assumptions that are not evidence-based.

Secondly, the burden of disease, expressed as DALY's / 100 000 per year on population level, needs to be approached stochastically when applied to a specific building, occupant or household when comparing IAQ management strategies and options. Therefore, this requires an inherently stochastic assessment method and associated UA/SA techniques to discuss the results.

In this panel discussion, we outline these methodological issues based on an illustrative example for a single flat in Belgium and, based on these results, map the research challenges to be addressed in order to implement health based metrics to improve IAQ management strategies and discuss with the audience what the priorities need to be.

Workshops

W1_Mon_Cu: Workshop 1 Monday Copper - Costs of unhealthy buildings
Monday, 12.06.2023 11:00-12:30 Room Cu Copper

Who bears the costs of an (un)healthy building?

Flagner, Stefan (1,2); Durán, Nicolás (3); Christoforou, Rania (4); Eilts, Jacob (4)

1: Department of Nutrition and Movement Sciences, Faculty of Health, Medicine, and Life Sciences, Maastricht University, The Netherlands; 2: Department of Finance, School of Business and Economics, Maastricht University, The Netherlands; 3: Bartlett Real Estate Institute University College London, United Kingdom; 4: Healthy Living Spaces, Uniklinik RWTH Aachen, Germany

This workshop aims to expose participants to and invite them to reflect about the financial costs of owning and occupying a building which does not fulfil specific health standards for landlords, tenants and occupiers. We will present a Harvard business case study titled "A Tower for the People: 425 Park Avenue[1]" to facilitate the discussion. This case study presents the trade-offs inherent to investing in bringing an office building to a higher health standard from an engineering, health, and financial perspective. Participants should take productivity benefits for workers into account and how these benefits can be translated into financial results. This should stimulate the discussion about the costs of a healthy building from the perspective of its owner (investor), the firm that operates in it (tenant), and the workers that work in it (occupiers). A central question is who has the strongest incentive to make a building healthier. While there is a vast amount of research about the negative health effects of a suboptimal building environment, rarely is this knowledge considered in financial returns. However, this step is necessary to incentivize financial markets and corporations to invest in the building design and ultimately the health of workers.

The workshop is targeted to everyone who wants to understand how to promote investments in healthy buildings and make them attractive for corporations and investors and to apply for funding for related research. Health and engineering scientists are invited to join because the workshop stimulates them to discuss how their knowledge about healthy buildings can be translated into financial returns. To create a diverse group and thus a fruitful discussion, economics and finance researchers are invited as well to learn more about the health and technological aspects of healthy buildings.

The workshop will start with a 10 minutes presentation about the case study. Nicolás and Stefan will give auxiliary knowledge on the basics of finance. Rania and Jacob will present current research on the impact of buildings on human productivity. Then, participants work together on the case in small groups for 30 minutes. After this, the groups will present their results (20 minutes in total).

Learning objectives of the workshop
1. How do we make investments into healthy office buildings attractive for employers and real estate investors?
2. How do the different stakeholders (investor, employer, occupants) benefit from a healthy building design? Who benefits the most, who the least?
3. How do we translate the benefits of a healthy building into financial figures?

Agenda with speakers
1. Introduction presentation – 10 minutes
2. Presentation on basics of investment decision-making by Stefan Flagner and Nicolás Durán – 10 minutes
3. Presentation on productivity benefits of healthy buildings by Rania Christoforou and Jacob Eilts – 10 minutes
4. Participants go into small groups (max 3 different groups, 3 to 5 person per group, a diverse expertise background of participants within a group is preferable) – 30 minutes
5. The groups present their solutions – Each group has 7 minutes to present and 3 minutes if questions, thus the block takes 30 minutes assuming 3 groups

References
[1] John D. Macomber, Joseph G. Allen, Emily Jones, A Tower for the People: 425 Park Avenue, Harvard Business School, Mar 5, 2020, New York, https://hbsp.harvard.edu/product/220065-PDF-ENG

W2_Mon_He: Workshop 2 Monday Helium - Resilience & design framework
Monday, 12.06.2023 11:00-12:30 Room He Helium

Design frameworks to improve the indoor thermal resilience of low energy buildings using ventilative cooling approaches

Sohail, Maha (1,2); O'Donovan, Adam (1,2); O'Sullivan, Paul D. (1,2)

1: Department of Process, Energy and Transport Engineering, Munster Technological University, Cork, Ireland; 2: MaREI, the SFI Research Centre for Energy, Climate and Marine, Ireland

A critical review of building design processes studied in the context of ventilation in the built environment reflects a lack of consensus among building design stakeholders in properly accounting for cooling needs of the building against future climate threats, such as heatwaves, at conceptual and pre-design phases, in advance of the detailed design. Participatory methods, which offer a better mode of understanding the context of how a non-domestic building is designed and at what stage the decision about "cooling the building" is taken, have received less attention in this perspective. For instance, RIBA Plan of Work (2020) shows various stages of the Architectural Design Process as pre-design, schematic design to design development stages but it does not indicate a stage where cooling or indoor thermal resilience is considered. Likewise, Polat Darcin (2020) developed a conceptual architectural design process for ventilation in the built environment from a research perspective but did not apply it to design practice. Ahmed A.Y. Freewan (2018) showed an integrated design approach for passive cooling devices by a design matrix named SARS (Storing, allowance, removal or slowing) but did not demonstrate its application in architectural practices. A brief review of building design and airflow modelling tools (Building Energy Software Tools, 2023) also suggests that there is no clear design process developed that can be followed in design practices that would improve the uptake (and by extension performance) of ventilative cooling strategies from early design stages. Therefore the workshop will aim to bring together approximately 10 building design practitioners with hands on experience in building design at architectural practices/engineering consultancies to replicate the design process through a focus group activity.

Target audience: Building design stakeholders such as Architects, Building Performance Engineers/Analysts, HVAC Engineers, Design Managers, Researchers, former or current architects with experience in building design, technical groups involved in updating resilient cooling standards.

The key areas to be explored in the focus group session and a few examples of questions which would be asked from participants are listed below;

1. Discussion of the early stage conceptual framework. Can a process developed for early stages in the building design like this facilitate all stakeholders for resilient cooling in built environment? Why or why not?
2. What innovative cooling solutions do you use for resilient natural ventilation or resilient cooling in your building designs?
3. Should all stakeholders be part of the early stage conceptual building design process? Why or why not? Would the approach described in the diagram suit all stakeholders in practice? How might the approach differ across different stakeholder groups?
4. On from this, what are the key gaps to implementing the framework in design practice? and important areas for future research?

Agenda

15 minutes: A brief introductory presentation by the PhD researcher and workshop co-persons on the topic and purpose of the workshop. The PhD student will also give an overview of the findings of a recent survey directed at building design practitioners on the same topic.

5 minutes : Explanation of the debriefing procedure of the workshop, such as activities to be followed and ethical considerations to be fulfilled. For example, the workshop will be audio recorded but no pictures of participants themselves will be taken. The pictures of design activities may be taken

25 minutes: The participants will be asked to sketch their conceptual design framework as a design team; to design a case study building (such a small dental clinic built inside a home) if they were to improve the ventilative cooling uptake through its design without the use of simulation or advanced design tools. In considering the case study building they will develop a VC strategy and document how they arrived at this strategy and what tacit sources of knowledge were used. This activity will promote an interactive discussion between people from interdisciplinary backgrounds.

25 minutes: In this stage, the participants will be presented a brief framework developed by the research team based on work from IEA EBC Annex 62, the ongoing CEN/TC 156 Technical Writing Groups and findings from initial survey conducted by PhD student. They will be asked to comment on its applicability in an architectural design practice.

W3_Mon_Cu: Workshop 3 Monday Cupper - Thermal comfort for children
Monday, 12.06.2023 14:00-15:30 Room Cu Copper

Thermal comfort for children: can we adopt the evaluation framework used for adults?

Babich, Francesco (1); Torriani, Giulia (1); Lamberti, Giulia (2); D'Avignon, Katherine (3); Kazanci, Ongun Berk (4)

1: Institute for Renewable Energy, Eurac Research, Bolzano, Italy; 2: School of Engineering, University of Pisa, Pisa, Italy; 3: École de technologie supérieure, Montreal, Quebec, Canada; 4: Technical University of Denmark, Lyngby, Denmark

Thermal comfort has been extensively studied leading to the development and evidence-based evaluation of thermal comfort models such as adaptive and PMV/PPD models. Despite being considerably different in terms of underlying assumptions, inputs and outputs, these models have one big common point: they have all been developed for adults. However, standards and regulations dealing with thermal comfort requirements largely refer to these models, and little to no adaptation is included for children even when applied to schools.

Thus, the overall research question tackled in this workshop is: “Can the evaluation framework used for adults be adopted for children?”. To do so, the workshop will be divided into five sections plus conclusions. A 10-minute presentation by Francesco Babich will open the workshop to provide background on international standards, review of recent and ongoing research on pupils’ thermal comfort and information about age and educational stages in different countries. Then, four 15-minute sections will aim at interactively discussing four themes. In each section, an initial 3-minute presentation by one speaker will introduce the research question, and then the attendees will work (supported by all speakers) on a possible answer with the support of tools such as sticky notes, pens, and measurement devices. To include multiple perspectives, the target audience will be both researchers and practitioners. To ease the answering process, the attendees will be split into different groups, who will each be invited to empathize with a specific child (e.g. a sample child from each age category) or with a given actor (e.g. teacher, pupil, facility manager). Lastly, a recap (by Francesco Babich) of the main outcomes and possible future directions will be done to close the workshop. Thus, 64% of the workshop time will be dedicated to interaction (12x4 minute), presentation time (10+3x4+5 minute) accounting for the other 36%.

The first interactive session, led by Katherine D'Avignon, will focus on one of the most used thermal comfort models, namely the PMV/PPD model (Fanger, 1970), and discuss the question: “To what extend is the PMV/PPD model applicable to children?”.

After an initial 3-minute presentation introducing the model, participants will be asked to calculate the PMV for a specific room and sample child, and discuss the difficulties encountered. The expected outcomes are: (i) highlight PMV/PPD limitations and possible solutions, (ii) spot discrepancies between academics/researchers and practitioners, and (iii) identify tools/info needed by practitioners.

The following section, led by Ongun Berk Kazanci, will discuss the complexity of getting subjective feedback from children on their thermal environment, asking: “Which are the most effective means to collect personal feedback from children?”. Participants will be introduced to different techniques and asked to evaluate their usability for different children’s age. The discussion will seek to highlight pros and cons per means per age group and identify the most “likely to be effective” means at each age.

In the third section, led by Giulia Lamberti, adaptive opportunities in different educational stages will be explored considering also the fact that pupils share their spaces with adults (teachers, etc.) that might have different views. Focus questions will be: “What are the most common means for adaptation in the different educational stages/ages? How much are these influenced by teachers and by school regulations? Which adaptive features make an indoor environment thermally suitable for both children and teachers?”. Participants will be asked to think about different adaptive actions (e.g. clothing behaviours, window and door operation, etc.) that sample children of different ages may adopt to achieve comfort. The discussion is expected to lead to the following outcomes: (i) ranking of means for adaptation in order of likelihood, and (ii) identifying potential conflicts between teachers’ and children’s needs.

The fourth theme, led by Giulia Torriani, will centre on the control that children have and perceive to have over their thermal environment, answering the questions: “Is there any correlation between students’ control over their thermal environment and their thermal comfort? Do the standard methods of HVAC control make sense for schools?”. In this section, participants will be split into three groups and assigned a given actor (i.e. pupil, teacher, facility manager of a school). They will be asked to highlight the different perspectives about control of the indoor parameters by means of post-it attached on a poster (different colours for pupils/teachers/facility managers). As a result, this section will enable the comparison of pupils, teachers, and facility managers perspectives about the control of indoor parameters in schools, and to identify possible solutions to guarantee both means of thermal comfort control in schools and energy savings.

W4_Mon_Cu: Workshop 4 Monday Copper - INCHEM-PY
Monday, 12.06.2023 16:00-17:30 Room Cu Copper

An interactive introduction to INCHEM-Py

Shaw, David; Carter, Toby J; Harding-Smith, Ellen; Carslaw, Nicola

Department of Environment and Geography, University of York, United Kingdom

This workshop will interactively introduce the capabilities of INCHEM-Py (the INdoor CHEMical model in Python) and is aimed at anybody who would like to add to or enhance the modelling aspect of their indoor air chemistry research. No modelling or coding experience is needed. Participants are required to have a computer with Python installed to fully participate in the workshop and will require an internet connection to download INCHEM-Py and dependencies. Those without access to a computer with Python can still attend and gain an insight into the model.

INCHEM-Py is an open-source community model that simulates atmospheric chemical concentrations and reactions in the indoor environment. It tracks over 6,500 species through over 20,000 reactions and processes including photolysis transmitted through windows and from indoor lighting, surface deposition and air exchange with outdoors. The core of the model is the MCM (Master Chemical Mechanism), an explicit chemical mechanism that considers the step by step degradation of around 150 common volatile organic compounds.

At time of writing INCHEM-Py is the core modelling component of over £3.5 million of UK Research Innovation funding and is being utilised by research groups in both Europe and the United States. As the code is fully available online there is no restriction on numbers of users or community developers.

Within the 75 minute session users will download INCHEM-Py, change settings and inputs, create custom emissions and processes, run simulations and access and interpret outputs. Throughout this interactive session, the model processes and functions will be described in detail, alongside model validation studies and comparisons with experimental data.

This workshop aims to grow the INCHEM-Py community and make modelling easier to access for indoor air chemists and experimentalists. The workshop will be facilitated by Dr David Shaw, the author of INCHEM-Py, aided by current model users. Time will be allocated for participants to feedback on the model and prioritise future developments that they would like to see.

The demonstrations will be done using the Spyder IDE and an Anaconda install of Python 3. To download Anaconda go to www.anaconda.com/products/distribution where a download link is found, once installed you will have both the Spyder IDE and Python 3 and be able to run INCHEM-Py. A quick start guide for INCHEM-Py is available in the manual at https://github.com/DrDaveShaw/INCHEM-Py

W5_Mon_He: Workshop 5 Monday Helium - Indoor winter warmth
Monday, 12.06.2023 16:00-17:30 Room He Helium

Indoor winter warmth: what is good enough and how do we achieve it?

Hellwig, Runa (1); Teli, Despoina (2); Ly, Cynthia (3); Luo, Wei (4)

1: Aalborg University; 2: Chalmers University, Sweden; 3: Maastricht University; 4: Eindhoven University of Technology

Upper indoor temperature limits for summer and lower indoor temperature limits for winter have long been the subject of thorough investigation and inclusion in standards, guides and regulations due to their assumed impact on health and well-being and their fundamental importance in HVAC design. These limits have also been debated, following the emergence and influence of adaptive comfort theory. It is now clear that buildings' indoor climate and human comfort are the result of multiple influencing factors, including technical, socioeconomic, geographical, climatic as well as cultural, and therefore one solution does not fit all. At the same time, thermophysiological research has found positive responses from repeated mild cold and warm exposures such as increase in metabolism and insulin sensitivity, showing benefits from indoor thermal variations. In this context, the proposed workshop wishes to ask the questions: What is good enough when it comes to winter warmth? Where do we draw the line? Should we even draw the line, if no issues of cost (environmental or else) exist? What is sufficient? What is healthy? What is comfortable? What is convenient? Is there such thing as "winter overheating"?

Initial short presentations will cover topics such as:

- Current trends on winter indoor temperature around the world (geographical/climatic aspects) and technical aspects [introduction]
- Health aspects and temperature as a lifestyle factor
- Social and cultural aspects/history of heating

The workshop will involve 3 short presentations of research experiences and discussion based on questions and points/statements prepared by the workshop chairs and speakers. The subject will be discussed from a transdisciplinary perspective, exploring how indoor winter warmth is seen through different lenses. The proposed workshop has links to previous work within IEA-EBC Annex 69 and activities within the ongoing IEA-EBC Annex 79.

Depending on the number of participants, we intend to use online polling/ interaction to discuss a specific scenario and come up with possible approaches to address it from different perspectives. The scenario will be centred around the context of the 2021-23 energy crisis and the associated impacts on household heating.

Presentations will be given by the chairpersons (short introduction) and invited speakers:

- Jenny Palm, Professor and Jenny von Platten, Postdoc, IIIEE, Lund University, Partner in project “Looking back to move forward: a social and cultural history of heating (JUSTHEAT)”.
- Wouter van Marken Lichtenbelt, Professor and leader of the research group Thermophysiology & Metabolism Maastricht University.

Time allocation

- 10 min introduction
- 10 minutes slots for presentations
- 45 min interactive discussion, scenario setting, polling (mentimeter, Wooclap, possibly Jeopardy style answer and question)

Target audience

Researchers, practitioners, engineers, facility managers, real-estate owners, building product suppliers, architects, building designers, HVAC engineers, policy makers.

W6_Tue_Cu: Workshop 6 Tuesday Copper - PECS
Tuesday, 13.06.2023 11:00-12:30 Room Cu Copper

Personalised Environmental Control Systems: Potentials for Well-being and Energy in Buildings

Khovalyg, Dolaana (1); te Kulve, Marije (2); Boerstra, Atze (2,3); Kazanci, Ongun (4); Luna Navarro, Alessandra (3); Bivolarova, Mariya (4)

1: École polytechnique fédérale de Lausanne EPFL, Switzerland; 2: bba binnenmilieu, Netherlands, The; 3: Technical University of Delft; 4: Technical University of Denmark DTU, Denmark

Comfort provisions in buildings are supposed to serve occupants; however, the entire building industry has focused so far on conditioning spaces rather than people. Such a practice is mainly due to the average consideration of people in the current building design practice that is guided by the standards on ergonomics of the indoor environment. An alternative approach to increase the rate of satisfaction of building occupants, comfort and well-being is targeted conditioning by using personalized environmental control systems (PECS) that can successfully address inter-individual differences that arise from individualized physiological and psychological responses to environmental stimuli. Creating a localized environment around each occupant could also be beneficial in reducing the energy demand of buildings by better matching the supply and the need. The energy benefits are greatest when there is relatively low occupancy. The present trend of working remotely and from home is causing office occupant density to decrease, thereby increasing this energy potential as compared to total volume conditioning.

In the past, a people-centered approach to the indoor environment was limited by the lack of technologies capable of tracking individuals and their physiological and psychological parameters. These limitations are less pertinent nowadays with the advancement of IoT devices, wearable sensors, and computer vision-based non-invasive recognition of individuals, thus, opening the possibility to use the real-time data from occupants to advance the development of PECS.

This interactive workshop aims to introduce the efforts of IEA EBC ANNEX 87 “Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems” and to discuss the evidence from laboratory and field studies that support the benefits of PECS regarding comfort, health, and productivity of occupants, along with the energy reduction potential. Then, the objective of this interactive workshop is to discuss the issues that stand in the way of widespread implementation with experts from different fields to obtain an integral perspective on how to address these.

Therefore, we strive for a broad audience, including indoor climate specialists, physiologists, psychologists, designers, architects, HVAC specialists, and experts in the field of lighting and acoustics, both from research institutions and from the practical field, to participate in this workshop.

The detailed planning of the workshop is following:

- Welcome & Introduction (~5 min). Moderator - Atze Boerstra1. Definition of Personal Environmental Control System. Introduction on the potential for occupant comfort and energy efficiency and aim of Annex 87.
- Presentation on the advancements in PECS research (~7 min). Presenters - Dolaana Khovalyg2 & Alessandra Luna Navarro3. Recent advancements in technology for heating, cooling, ventilation, lighting and facades, control and user interaction strategies. For each application, summary of benefits, limitations and challenges for each system.
- Presentation on the application of PECS in actual buildings (~7 min). Presenters - Ongun Berk Kazanci4 & Marije te Kulve2. Example of applications of PECS in real buildings, preliminary feedback from case studies and results.
- Interactive discussion with the audience (~30 min). Moderator - Atze Boerstra. Open questions for the audience along the three following themes by the moderator: (i) current experience with PECS from the audience; (ii) perceived limitations and barriers, (iii) perceived potential, (iv) information and knowledge needs to expand application of PECS.
- Summary and wrap-up of the workshop (~5 min). Moderators - Atze Boerstra and Dolaana Khovalyg. Summary of the discussions, invitation to join the Annex 87 expert meeting in Fall’2023.

W7_Tue_He: Workshop 7 Tuesday Helium - Audio-visual perception in VR
Tuesday, 13.06.2023 11:00-12:30 Room He Helium

Portable lab to study audio-visual perception in virtual reality

Heck, Jonas; Llorca-Bofí, Josep; Aspöck, Lukas; Loh, Karin; Breuer, Carolin; Seitz, Julia; Dreier, Christian; Schäfer, Philipp; Yadav, Manuj; Vorländer, Michael; Fels, Janina

Institute for Hearing Technology and Acoustics, RWTH Aachen University, Germany

Noise and its multifarious effects on productivity, wellbeing, and health within the built environment are general knowledge. Within the continuum of ecological validity, transferring the 'in the wild' noise scenarios to laboratory conditions offers a tremendous degree of control that is generally offset by the accompanying lack of 'realness' of laboratory simulations. At our institute (IHTA), we have been pushing the boundaries of what is possible in laboratory conditions, in terms of representing the complexities of human interactions with noise in certain contexts.

This is made possible by integrating state-of-the-art audio-visual simulation methods. The visual models run on game engines, e.g., Unreal Engine, while the acoustic simulation is performed with the open-source software Virtual Acoustics (VA), which has been developed at our institute. Regarding the visuals, the game engine can apply physics-based renderings (PBR), which allow photorealistic rendering of materials, direct and indirect illumination, and weather effects. From the acoustic perspective, VA includes the main effects of sound propagation in the atmosphere as well as reflection, absorption, and diffraction due to ob-jects. By using a head-mounted display and headphones for the immersive audio-visual playback and by running the software on a portable computer, the whole laboratory becomes highly portable.

Participants of the workshop will be able to interactively explore the lab. Examples are:

Urban planning: Urban planners and architects are interested in the effects the environment they design has on inhabitants, clients or future users. The lab can be used to collect subjective evaluations of different designs of an urban area, e.g., a public space or a park surrounded by buildings. For this purpose, study participants are shown a graphical user interface (GUI) within the virtual scene which allows for interaction, e.g., change the design or weather conditions, and to answer embedded questionnaires.

Classroom / open-plan office acoustics: In the context of indoor scenarios, we focus on characterizing the effect of noise and other indoor environmental quality factors on the cognitive development and mental health of children in classroom conditions in Germany. Our approach is to characterize auditory distraction and speech communication for office employees within audio-visual simulations of the respective contexts. Using the lab, virtual classroom or open-plan office representations can be used to put study participants in the position of a plausible learning/working environment. In such an environment, the performance of cognition tasks (via a GUI) under multiple auditory stimuli can be studied in detail.

W12_Tue_Cu: Workshop 12 Tuesday Copper - IEQ & schools
Tuesday, 13.06.2023 13:30-14:45 Room Cu Copper

Indoor environmental quality in schools

Carslaw, Nicola (1); Burridge, Henry (2); Fabian, Patricia (3); Roberts, Katherine (2,4)

1: University of York; 2: Imperial College London; 3: Boston University School of Public Health; 4: TAPAS, University of Cambridge, United Kingdom

The Tackling Air Pollution at School (TAPAS) Network brings together over 300 stakeholders across academia, education, public policy, civil society and business. We are working together to develop the research base to support the development of healthy schools by improving air quality. Our wide breadth of expertise and connections internationally puts us in the perfect position to host this workshop and showcase the various indoor environmental projects our members are involved with in the UK and across the globe.

We propose to host a workshop to discuss 'Indoor Environmental Quality in Schools'. Speakers could cover a range of indoor air research in schools – IAQ and interventions, IAQ and energy (sustainability), exposure and health disparities, and community engagement and communications.

This workshop is targeted at delegates who have an interest in designing healthy schools, improving air quality in schools, enhancing education on air quality, and changing behaviour in schools.

For this workshop, we propose holding 4 x 7 min talks followed by a panel discussion to allow the audience to ask questions and share their experiences from their own school research projects. The session will be chaired by Nicola Carslaw, Professor in Indoor Air Chemistry at the University of York; Henry Burridge, Senior Lecturer in Civil and Environmental Engineering at Imperial College London; and Patricia Fabian, Associate Professor of Environmental Health, Boston University School of Public Health. This conference workshop provides a fantastic opportunity for the international air quality community to hear about the school projects being undertaking in our research community and will facilitate a cross-border transfer of knowledge.

Additional information on speakers and workshop content:

The first half of the workshop will be presentations from 4 invited speakers.

- Speaker 1: Dr Sarah West, Director of SEI York, UK, a Centre of the Stockholm Environment Institute, a science-to-policy research institute based at the University of York. Sarah is currently leading the schools engagement part of the SAMHE project (Schools Air quality Monitoring for Health and Education) in the UK and will talk on the project.

- Speaker 2: Professor Runming Yao, Prof in Sustainable Built Environments, University of Reading, UK, and Guest Professor of Chongqing University, China. Prof Yao will talk on 'Prioritising actions for improving school classroom air quality based on the Analytic Hierarchy Process – Case studies in China and the UK'.
- Speaker 3: Professor Jørn Toftum, Professor in ventilation at the technical University of Denmark. Prof Toftum will summarize the results of some intervention studies he has done in the past years, how the interventions affected pupil well-being and performance, and how the wider benefits from the improvement compare against pupil's well-being and running costs. Suggested talk title: “Effects on pupil well-being of improving classroom ventilation".
- Speaker 4: Dr Koen Tieskens, Postdoctoral Associate at the Boston University School of Public Health. Dr Tieskens will talk on indoor air quality projects as part of the Boston Public Schools programme.

The remaining half of the workshop will be a panel discussion involving questions and discussion from the audience, chaired by Dr Burridge, Dr Fabian, and Prof Carslaw.

W9_Tue_Cu: Workshop 9 Tuesday Copper - Thermal physiology database
Tuesday, 13.06.2023 15:00-16:15 Room Cu Copper

Global Database of Thermal Comfort Physiological Responses

Wu, Zhibin (1); Wagner, Andreas (1); Jia, Hongyuan (2); Schiavon, Stefano (3); Wargocki, Pawel (4); Schweiker, Marcel (5); Dong, Bing (6); Koth, Sebastian Clark (7); Kobas, Bilge (7); Vellei, Marika (8); Pigliautile, Ilaria (9); Toftum, Jørn (4); Rupp, Ri

1: Karlsruhe Institute of Technology, Building Science Group, Karlsruhe, Germany; 2: Chongqing University of Science and Technology, Chongqing, China; 3: Center for the Built Environment, University of California, Berkeley, CA, USA; 4: International Centre for Indoor Environment and Energy, Technical University of Denmark, Denmark; 5: Institute for Occupational, Social and Environmental Medicine, Medical Faculty, RWTH Aachen University, Germany; 6: Mechanical and Aerospace Engineering, Syracuse University, NY, USA; 7: Technical University of Munich, Munich, Germany; 8: Laboratoire des Sciences de l'Ingénieur pour l'Environnement (LaSIE) - UMR CNRS 7356, France; 9: Department of Engineering Department, University of Perugia, Italy; 10: Department of Civil and Mechanical Engineering, Technical University of Denmark, Denmark

We aim to develop a global database of physiological responses in the built environment. This workshop aims at creating a coordination about this and attracting new participants. This workshop will summarize the current state-of-the-art research on physiological responses to changing thermal environments and discuss it with the participants. Perspectives and challenges for this topic will also be discussed and delineated.

Having prior knowledge of thermal comfort is essential for building an optimal indoor climate. Merging real-time thermal comfort votes from occupants and physiological responses may lead to better models because there is a close association between human thermal comfort and physiological responses. Setpoint temperature adjustment with occupants' feedback and personal comfort system for individual thermal comfort have been widely investigated, but based mainly on the feedback of occupants. Many researchers have been developing personal comfort models using various physiological responses. Skin temperature has been widely investigated and its feasibility as a thermal comfort indicator will be discussed. Recent studies indicate that several physiological responses, such as pulse rate and skin conductance, could be used to model thermal comfort, and thus potentially also to control HVAC systems. Existing research exploring physiological responses in the built environment is not sufficiently systematic or conclusive and is limited to local characteristics. Hence standard approaches and the development of a global database on physiological responses in the built environment are needed to improve the generalizability of findings.

The workshop is split into two parts: The first half will have inputs from the workshop chairs highlighting the current state of knowledge and of the database. In the second half, a guided discussion with participants will engage interaction regarding existing knowledge, limitations of the approach, and future needs directed to the database.

Key learnings:

1. Getting insights into work done so far on the global database, its logic, and future steps;
2. Gaining knowledge of the fundamental, mechanism and application of physiological responses in built environments;
3. Providing perspectives to help formulate more effective control strategies of HVAC systems with physiological responses.

Target audience:

Researchers who are interested in the interdisciplinary area in the built environment (i.e., psychology, physiology, and data science). Practitioners who would like to learn new insights on building design, construction, and operation.

W13_Tue_He: Workshop 13 Tuesday Helium - Well-being network
Tuesday, 13.06.2023 15:00-16:15 Room He Helium

An International Network of Networks for Well-being in the Built Environment (IN2WIBE)

O'Neill, Zheng (1); Becerik-Gerber, Burçin (2); Wen, Jin (3); Hoque, Simi (3); Wu, Teresa (4); Pedrielli, Giulia (4)

1: Texas A&M University, United States of America; 2: University of Southern California; 3: Drexel University; 4: Arizona State University

Building design, construction, operation, and use strategies that benefit occupant health and wellbeing is recognized as a grand challenge, thus calling for convergent efforts from multiple disciplines. These include building science and technology, public health, medicine, measurement and data science, design and architecture, human-building interaction, social science, systems design and control, and computer science. This workshop will present the ongoing efforts of the International Network of Networks Wellbeing in the Built Environment (IN2WIBE) to promote and coordinate research on healthy buildings across the globe. The effort is supported by the US National Science Foundation (NSF) AccelNet project (https://in2wibe.net/). IN2WIBE aims at connecting and educating future building scholars, at the crossroad between well-being and built environment, for informed decisions (building design, construction, operation, and use). IN2WIBE leverages resources from 33 existing networks and partners in 5 continents (N. America, Africa, Europe, Australia, and Asia), comprising a total of 17 countries. The goal of IN2WIBE has been to foster international collaboration and this workshop presents an opportunity to further strengthen our network and scholarly exchange among international scholars.

The workshop will include three themes, i.e., Artificial Intelligence for Healthy Buildings (AI4HB), Future of Workspace for Well-being and Productivity, and Well-being Centric Building Operations and Controls. For each theme, we will present the state of the research and future directions within the theme followed by interactive break-out sessions. The interactive sessions will be planned to solicit ideas from the international participants about synergies between IN2WIBE and European healthy building initiatives, including collaborative projects and funding opportunities. The sessions will be documented and the results will be disseminated in a white paper.

At the end of the proposed workshop, we hope to expand our network initiating new directions and opportunities and further expanding the scope and reach of healthy buildings. The IN2WIBE will support up to 8 U.S. scholars to attend the Health Buildings Europe 2023.

Workshop schedule:

1. Introduction (10 minutes, IN2WIBE steering committee and scholars)
    a. Briefly introduce the topic of healthy buildings and the application of artificial intelligence (AI) in that domain.
    b. Provide a brief overview of the different types of buildings (care home for the elderly, residential buildings, schools, hospitals, and office spaces) and their unique health and well-being considerations.
    c. Discuss how AI can be leveraged to improve health and well-being outcomes in each of these building types.
    d. Outline the objectives of the workshop and what participants will be doing.
2. Small Group Activity (40 minutes, workshop participants)
    a. Divide participants into small groups (ideally 4-6 people per group) and assign each group a specific building type to focus on.
    b. Provide each group with sticky notes and other materials (such as markers or pens) to help them brainstorm and develop their proposed solution.
    c. Provide each group with a set of general problem prompts (office space, schools, hospitals, retirement home, residential house) for their specific building type that focus on health and well-being outcomes. Encourage groups to explore the use of AI and other technologies in their proposed solutions.
    d. Allow time for each group to discuss and develop their proposed solution.
3. Group Presentations and Discussion (20 minutes, workshop participants)
    a. Each group presents their proposed solution for their assigned building type, including the use of AI and other technologies to improve health and well-being outcomes.
    b. After each presentation, encourage other groups to ask questions and provide feedback on the proposed solution.
    c. Summarize the key takeaways from the group presentations and discussion and highlight any remaining questions or areas of further exploration.
4. Conclusion (5 minutes, IN2WIBE steering scholars)
    a. Recap the main themes and insights from the workshop.
    b. Provide any next steps or actions that participants can take to continue learning and exploring the intersection of healthy buildings and AI.

W10_Tue_Cu: Workshop 10 Tuesday Copper - Smart buildings & comfort
Tuesday, 13.06.2023 16:45-18:15 Room Cu Copper

ARE YOU COMFORTABLE?: People's Comfort and Health in Smart Buildings through Monitoring IEQ and Interacting with the Environmental Control Systems

Di Santo, Nicole (1); Guglietti, Ambra (2); Sarran, Lucile (2); Kacel, Seda (3)

1: Politecnico di Milano - VELUXlab, Italy; 2: VELUX A/S, Knowledge Centre for Daylight, Energy & Indoor Climate, Denmark; 3: UCLouvain, Belgium

People experience and interact with the indoor environment, which affects their comfort and health. Human comfort is a complex concept in which individual differences, personal preferences and adaptive behaviour play significant roles. In the face of the current energy crisis and climate change, comfort is sometimes considered to be “sacrificed” in favour of energy efficiency and reducing emissions. Can we achieve an indoor environment promoting human comfort and environmental sustainability? Indoor Environmental Quality (IEQ) is a measure of a building related to thermal, air, acoustic and visual environments and the spatial context. The Internet of Things (IoT) devices can play an essential role in mediating the relationship between people and IEQ, measuring and monitoring the indoor environment, and ensuring that people experience comfort and health indoors while enabling co-benefits such as energy efficiency. Smart buildings can provide real-time IEQ data, allowing occupants and stakeholders to make informed decisions and to adapt their behaviour to improve IEQ.

The proposed workshop aims to enhance the understanding of the communication between users and indoor spaces and to identify the role of smart devices and digitalisation in promoting healthy, sustainable, and smart buildings. Participants will discuss; i) human factors and IEQ in energy-efficient and smart buildings, including inter-individual differences that affect comfort, ii) the concept of “active users”, and iii) brainstorm solutions to provide occupants with reliable and actionable information and recommendations. The integration of these concepts into legislation and investments to promote healthy, sustainable, and smart buildings will also be debated. This discussion is essential because we occupy 90% of our time indoors, and 90% of the operational costs of buildings are related to people (Allen and Macomber, 2020).

Workshop activities

The workshop will consist of four main activities:

- “Introduction” features icebreaker activities (e.g., short quizzes) using interactive tools like Mentimeter and Miro.
- “Lectures” consist of three presentations given by the workshop convenors covering the following topics:
  - Lecture 1: Human factors and IEQ in buildings
  - Lecture 2: Digitalisation and IoT in smart buildings
  - Lecture 3: Building design practices for sustainable living
- “Brainstorming” will allow us to discuss some opportunities for monitoring the indoor environment using smart devices. For each small breakout group organised and facilitated by the workshop convenors, some devices (e.g., sensors, wearables) and their user platforms (e.g., smartphone applications) will be provided to support the simulation of real-life situations. The usability of devices will be discussed. Participants will explore their physiological parameters through real-time monitoring. Personal comfort systems (PCS) will be provided to discuss adaptive opportunities. Participants will fill in surveys to evaluate their comfort, adaptive behaviour, and spatial experience before and after interacting with these devices and systems. Participants are expected to share their case studies and experiences to learn from each other. The integration of these concepts into legislation, such as the revision of the Energy Performance of Buildings Directive (EPBD), will be discussed. Paper-based tools like posters and post-its, as well as digital tools like Miro and XMind, will be used by each group.
- “Plenary discussion” will allow each breakout group to present elaborations and outcomes. All workshop participants will comment on these outcomes and discuss the topics as a larger group. A short online questionnaire will request participants` feedback on the workshop.

Learning outcomes

Learning about human factors, IEQ, and smart and energy-efficient buildings will be facilitated. Participants will be able to test different devices and observe real-time data to enhance their understanding of future research and practices.

Target audience

The target audience includes architects, engineers, facility managers, researchers, and end-users.

11_Wed_Cu: Workshop 11 Wednesday Copper - Soundscape & ventilation
Wednesday, 14.06.2023 08:30-09:45 Room Cu Copper

Indoor soundscape and ventilation: how to cross disciplinary boundaries

Torresin, Simone (1); Harvie-Clark, Jack (2)

1: University of Trento, Department of Civil Environmental and Mechanical Engineering, Italy; 2: Apex Acoustics Ltd, UK

Indoor soundscape research addresses people's perception of the acoustic environment in order to design buildings that 'sound good' to their occupants. Moving beyond a focus on 'noise' and 'noise annoyance' requires a new mindset in the design and evaluation of buildings, which can lead to novel acoustic indicators and design solutions, or the reinterpretation of existing ones, with a focus on 'sound as a design resource' for people's health and well-being.

Natural ventilation can be a sustainable strategy for building ventilation. However, the soundscape inside buildings can be impacted by the outdoor acoustic environment. Even in the case of mechanical ventilation, this comes with consequences for the acoustic environment. Despite the interrelationships between indoor soundscape and ventilation, the two domains are often dealt with independently, by different professionals, and with often distinct assumptions.

Picking up on the conference theme, the workshop aims to establish a discussion among researchers, designers and practitioners on the urgency of crossing disciplinary boundaries between acoustics and ventilation and integrating the soundscape approach into a multi-domain research perspective for healthy building design.

Objectives

1) to raise awareness of indoor soundscapes among those working in the field of indoor environmental quality design
2) to promote a discussion on regulatory harmonization in acoustics, ventilation and thermal comfort, across disciplinary boundaries
3) to illustrate examples of multi-domain integration from both research and practice.

Questions addressed by the workshop include: how to 'measure' the soundscape in the built environment? How to integrate acoustics and window opening requirements for ventilation and thermal comfort? Can natural ventilation be adopted to improve indoor soundscapes?

Program

After a workshop introduction, short talks will introduce the concept of indoor soundscape, previous experiences of soundscape evaluation in real buildings and in virtual reality, examples of regulatory integration, and results from multi-domain research in the field of indoor soundscape and ventilation. This will be followed by an interactive session in which participants will take part in an indoor soundwalk in two indoor spaces within the venue with different acoustic characteristics (e.g., a quiet area, and a lively space near the café area). The soundwalk will be organised in two groups of up to thirty people. Each participant will listen to the surrounding sound environment and express their evaluation in a soundscape questionnaire through an online form from their cell phones. This will be combined with in-situ binaural recordings.

The workshop will conclude with a collective discussion, highlighting the potential of soundscape methods in relation to current protocols of post-occupancy evaluation of buildings, and outlying current challenges and a future agenda for research and practice in the fields of acoustics and ventilation. Digital tools (e.g., online blackboards) will be used to collect and organize ideas and comments from the participants.

Target audience

The workshop is designed to be multidisciplinary, and participation is encouraged for students, researchers, and practitioners working in the fields of building physics and architecture, indoor environmental quality and social sciences, acoustics and building services design.

Detailed schedule

- 5 min: Welcome and introduction by the workshop chairs
- 30 min: Short talks
    - Dr. Simone Torresin, University of Trento
      "Indoor soundscape in the built environment: definition and measurement methods"
    - Jack Harvie-Clark, Apex Acoustics
      "Acoustics, ventilation and overheating: from standardization to practice"
    - Dr. Chiara Visentin, Eurac Research (online/in-person)
      "Indoor soundscape and ventilation in schools: results from experimental campaigns"
- 25 min: Indoor soundwalks
- 15 min: Interactive discussion, closing of the workshop

W8_Tue_Cu: Workshop 8 Tuesday Copper - Occupant behaviour
Wednesday, 14.06.2023 08:30-09:45 Room He Helium

Occupant-centric building design and operation – Discussion on lessons learned from IEA EBC Annex 79

Wagner, Andreas (1); Mahdavi, Ardeshir (2); Day, Julia (3); Dong, Bing (4)

1: Karlsruhe Institute of Technology, Germany; 2: Technical University of Graz; 3: Washington State Ubiversity; 4: Syracuse University

It is common sense that occupants have a strong influence on building performance. Research has provided insight into this topic from different angles since many years and various occupant behavior models for buildings simulation are principally available. However, design and building operation practice shows that many of the models do not represent the manifold human interactions with a building appropriately enough, and that there is no guidance for designers and building managers on how to apply occupant behavior models in standard practice. To overcome this deficit IEA EBC Annex 79 focused on the integration and implementation of knowledge and models of occupancy and occupant behavior into the design process and building operation. With the overall goal to improve both energy performance and occupant comfort, Annex 79 established four working groups (subtasks) to address the following research fields:

1. Multi-aspect environmental exposure, building interfaces, and human behavior
2. Data-driven occupant modeling strategies and digital tools
3. Applying occupant behavior models in a performance-based design process
4. Development and demonstration of occupant-centric building operating strategies

This workshop will provide an opportunity to critically assess and discuss some of the major outcomes of the Annex, which are related to the conference themes. The workshop will be structured into three main blocks, which will address the following topics:

1. Do we need new paradigms / standards / codes to implement occupant behavior sustainably in building design? How would they have to look like? (Moderated by Ardeshir Mahdavi, TU Graz, Austria)

Work in the Annex has highlighted a number of essential gaps in our understanding of the occupants' role in buildings' energy and indoor-environmental performance, corresponding to the following questions: To what level of detain must building design and operation professionals know about occupants' needs, preferences, and actions?

What factors, both physical and psychological, influence occupants' perception and evaluation of indoor environments? Do building codes, standards, and guidelines provide sufficient information to guide practitioners in accommodating occupants' requirements? Do standards provide explicit scientific evidence for the indoor-environmental quality mandates they entail? Where do we need more research, and how can we more effectively transport research results into practice?

2. How do building interfaces influence interactions between occupants and buildings, and how can we better design interfaces to facilitate comfort, health, and energy savings? (Moderated by Julia Day, Washington State University, USA)

There are many points in a building where occupants may interact with interfaces or controls (e.g. windows, doors, thermostats, etc.). Work in the Annex further expanded on human-building interaction (HBI) research while offering insights into current challenges of incorporating interfaces (and related occupant behaviors) into simulation. This segment of the workshop aims to spark discussion surrounding how current building interfaces may not support the needs or health of building occupants. What can we do better from both a design and operation standpoint to support building occupants? Energy goals? Comfort? What are the key characteristics of building interfaces that must be addressed or defined? What is needed in the field to further advance this domain?

3. What are the requirements (hardware, e.g. sensors, BMS, organizational, etc.) needed to implement data-based, occupant-centric control strategies successfully in building operation? (Moderated by Bing Dong, Syracuse University, USA)

Prior research in both Annex 79 and 66 showed that there have been many efforts to develop accurate occupancy sensing systems, collect occupancy behavior data and use those data for building controls. Based on those efforts, we would like to discuss a few research gaps: What are the minimum requirements (sensors, hardware and software) to implement for occupant-centric control strategies? How urgent is this issue and/or do facility mangers/building managers desire or need such system? How much effort are facility managers willing to spend to setting up such system (within a day or a week or a month)? What is the acceptable $/m² or ROI to implement such occupant-centric control system in buildings? How can we use what we learned in research studies for best practices?

After a short presentation of Annex 79, representatives of the different Annex Subtasks will shortly introduce into their topics and key questions, which is followed by a moderated interactive discussion of each block. The workshop participants will be asked to engage, discuss, and participate in lively conversations about each of the key topics Each topical block will last 20 minutes. Scientists from the fields of comfort and human behavior, as well as practitioners from building design and operation, are expected as the target audience.

ISIAQ Events

ISIAQ Events

ISIAQ_STC34: ISIAQ STC 34: IEQ guidelines database updates
Tuesday, 13.06.2023 12:45-13:30 Room C Carbon

ISIAQ STC 34: IEQ guidelines database updates

Dudzińska, Marzenna Roza (1); Haverinen-Shaughnessy, Ulla (2)

1: Lublin University of Technology, Poland; 2: University of Oulu

Welcome to participate in our STC34 meeting! You will hear about latest updates on the expanding database and ongoing/future activities, including reviews of the existing guidelines. You can also sign up as a national contact point, become a working group member (outdoor air, ventilation, thermal conditions, acoustics, lighting) and/or become a member of the STC. Our meetings are open to everyone.

ISIAQ_Ch_Tue_He: ISIAQ Chapters meeting
Tuesday, 13.06.2023 16:45-18:15 Room He Helium

ISIAQ Chapters meeting

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Eindhoven University of Technology, Netherlands, The

ISIAQ has five National Chapters who organize activities in their country for their members (a member of a National Chapter doesn't have to be a member of ISIAQ).

This meeting gives you the opportunity to meet representatives from the existing National Chapters, discuss the possibilities and benefits of Chapters or even get an advise how to set up a new National Chapter.

All ISIAQ members interested in knowing more about ISIAQ National Chapters are welcome.

Tuesday, 13.06.2023 18:30-19:30 Room C Carbon

ISIAQ Annual General meeting

Online only contributions

Time:
View pre-recorded videos anytime via conftool

Internet of Things and Machine Learning to address poor Indoor Air Quality in NZ schools.

Sallaber, Bastien (1); Boulic, Mikael (2); Mandin, Corinne (3); Cunningham, Chris (1)

1: Research Centre for Hauora and Health (RCHH), Massey University, Wellington, New Zealand; 2: School of Built Environment, Massey University, Albany, New Zealand; 3: Scientific and Technical Centre for Buildings (CSTB), France

Monitoring of Indoor Air Quality (IAQ) in New Zealand (NZ) school classrooms has shown widespread non-compliance with both NZ and international standards, especially for CO2 levels. Using an Internet of Things approach coupled with Machine Learning Modelling we have been able to produce a forecasting model to predict CO2 levels in classrooms before they breach NZ guidelines. Key features of the model were prior CO2 levels, student occupancy and the presence of cross ventilation. Further, our predictive model can be used by our IoT devices to provide a warning system for school teachers. As NZ relies heavily on natural ventilation our monitoring/modelling approach provides a low-cost and practical solution to support better environmental control within existing classroom design limitations. Our current research has provided proof of concept and we are now widening our monitoring and modelling to cover a diversity of NZ classroom settings.

Influence of sonic environment on the fruit juice drinking experience

ISTIANI, Noor Fajrina Farah (1); MASULLO, Massimiliano (1); RUGGIERO, Gennaro (2); MAFFEI, Luigi (1)

1: Department of Architecture and Industrial Design, University of Campania "Luigi Vanvitelli", Aversa, Italy; 2: Department of Psychology, University of Campania "Luigi Vanvitelli", Caserta, Italy

Presently, more than half of the European countries' population does not meet the recommendation for daily consumption of fruits and vegetables. In this case, people choose half or one glass of unsweetened 100% fruit or vegetable juice to fulfil their daily fruit and vegetable requirement of five portions. Instead, excessive sugar consumption of the beverage has become a concern and is argued to be a significant cause of obesity. Interestingly, evidence has shown that auditory stimuli can modulate flavour perception. However, limited research has focused on the multisensorial aspect of an indoor environment, which focuses on building physics: audio, visual, correlated colour temperature of lighting, and room temperature that can play a relevant role in affecting taste perception of healthy beverages. This research aims to understand how the environmental sound can influence the taste perception of fruit juice. To this end, we conducted an experiment focusing on individuals' flavour perception by including a sonic environment created in a multisensory lab (Sens i-lab). The result showed that the sweet flavour of orange juice was highly noticeable under the natural sound of the urban park environment; meanwhile, the vending machine space sound was the most influencing the bitter taste of orange juice.

Examining the concentrations and trends in indoor air quality in existing UK social housing dwellings

Gupta, Rajat; Berry, Chloe

Low Carbon Building Research Group, Oxford Brookes University, United Kingdom

While outdoor air quality is regulated, indoor air quality (IAQ) in homes has been relatively neglected despite the links between IAQ and health. This paper empirically examines the concentrations and trends in indoor temperature, relative humidity (RH), carbon dioxide (CO2), Particulate Matter ($PM^{2}.5$ and PM10), VOCs (EtOH) and Isobutylene across a sample of 42 existing social housing dwellings located in West Midlands (UK). Time series data were recorded continuously at 15-minute intervals from 1 February 2022 to 30 April 2022, using Airthinx sensors located in the living rooms of each dwelling. Contextual data about the physical and household characteristics were gathered using in-person surveys. Statistical analysis revealed that under heating was dominant, with eight dwellings failing to reach the recommended 18°C indoor temperature, due to poor insulation levels and high heating costs. Mould was present in 61% of dwellings, despite mean RH values remaining below 65%. CO2 concentrations were related with occupancy, with mean values frequently above 900ppm and as high as 3,092ppm in some dwellings, due to limited ventilation to conserve heat. High PM levels were generally associated with indoor smoking, with $PM^{2}.5$ concentration rising to 202ug/m^3, substantially above the 15ug/m^3 limit.

Poster session

Poster session

Time:
Monday, 12.06.2023 13:30-14:00
Tuesday, 13.06.2023 16:15-16:45
And any other time as posters will be available throughout all days

Room: C Carbon and beyond

Monday, 12.06.2023 13:30-14:00 Room C Carbon

How the built environment is linked to mental health and wellbeing – results of a cross-sectional analysis using secondary data

Huebner, Gesche M (1,2); Oreszczyn, Tadj (1); Hamilton, Ian (1)

1: UCL Energy Institute, Bartlett School of Environment, Energy and Resources, Faculty of the Built Environment, University College London, London, UK.; 2: UCL Institute for Environmental Design and Engineering, Bartlett School of Environment, Energy and Resources, Faculty of the Built Environment, University College London, London, UK.

ID: 1122 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: wellbeing, mental health, buildings, households, neighbourhood

The built environment influences human health in many ways, for example, in how it allows or limits activity and in its environmental conditions such as temperature and air quality. In this contribution we discuss relationships between the built environment, in particular residential homes and their surroundings, and mental health and wellbeing.

The secondary data analysis was based on the English Housing Survey, 2017: Housing Stock Data and the English Housing Survey: Fuel Poverty Dataset, 2017, collected in the period April 2016 to March 2018. In one analysis (N ~ 9000 individuals), we linked subjective wellbeing as measured with four variables – life satisfaction, the perception of things being worthwhile in life, feeling happy and feeling anxious -to personal factors, building variables and neighbourhood variables. A second analysis used the presence of a mental health disorder as the outcome variable; this analysis made additionally use of the nested data structure of individuals in households that had not been available for the wellbeing analysis (N = 28,000 individuals). All analyses have been prespecified prior to being carried out to avoid cherry-picking of results.

The wellbeing analysis showed that personal variables are most strongly related to wellbeing but that both housing and neighbourhood variables also play a significant role. Being less able to keep the home warm, being in fuel poverty, struggling in meeting fuel costs and experiencing dampness were associated with lower wellbeing. The analysis for mental health is ongoing but initial analysis again points to personal variables being of greatest importance.

We discuss limitations of cross-sectional data as used here but also highlight how cross-sectional data can play an important role in targeting dwellings and environments in greatest need of interventions, irrespective of causal drivers. We also reflect on how self-reported and objectively assessed data can impact on results, for example, around overcrowding, and how wellbeing itself is not a concisely defined concept.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Integrate bio-based concrete in wall panels: is it a practicable solution from an olfactive point of view?

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ID: 1142 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: flax fibers-based concrete; odorous VOC, GC-olfactometry, vapothermal curing

The need to build a more sustainable future leads us to reduce human greenhouse gas emissions and energy consumption. The building sector is one of the biggest emitters of greenhouse gases. Besides, requirements in terms of comfort and air quality continuously increase to achieve the target of healthy and sustainable buildings. Therefore, there is no denying the urgent need to develop new eco-materials with the slightest ecological footprint and in the same time complying the IAQ standards.

Bio-based concrete produced through a vapothermal curing process are good potential candidates to address this challenge. Nevertheless, they have to be validated from an IAQ point of view and more especially from an olfactive point of view. Flax fibers have gained popularity due to their good mechanical properties, low density, and wide availability in Europe. However, integrating flax fibers to concrete materials through a vapothermal curing process may cause the degradation of the fiber components and the formation of low-molecular-weight compounds that can be responsible for undesirable odors.

This work investigates the odorous VOC emissions from new flax fibers-based concrete. Our approach combines (i) olfactive analyses of concrete samples at different stages of the process and the senso-instrumental characterization of emissions though a GC-O analysis. The goal is first to identify the contribution of the vapothermal curing process on odorous emissions; secondly this work deals with the identification of odorous key compounds which may affect the olfactive comfort indoors.

The olfactive analysis protocol followed the ISO 16000-28 standard. Bio-based concrete blocs were placed in a 225L-CLIMPAQ chamber under controlled temperature and humidity for 28 days. The olfactive profile was established by 4 trained panelists through an olfactive port connected to the chamber using the Langage des Nez® method. Additionally, the volatile fraction was also sampled on Tenax sorbent tubes and analyzed by TD-GC-MS-FID-Olfactometry following the aroma extract dilution analysis method.

These combined analyses evidence that the vapothermal curing process is responsible for the modification of the olfactive profile of the material. Aromatic-like and pyrogenic-like olfactory notes mainly characterized the volatile fraction of processed concrete blocs, while non-processed material is characterized by an amine-like note. About 25 odorous VOCs were identified in the emissions of flax concrete with a high occurrence of aldehydes, acids, phenols, furans and pyroles.

These results point to the need to integrate olfactive analysis to the characterization process of this kind of material before their implementation in buildings.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Chamber comparison for the determination of initial VOC emissions from consumer products

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ID: 1143 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 11. All other IEQ, ergonomics & health topics
Keywords: volatile organic compounds, exposure assessment, emission test chamber

Volatile organic compounds (VOCs) emitted from consumer products can accumulate in the indoor air. Humans are exposed to these substances via inhalation, which may cause adverse health effects. Typical exposure scenarios focusing on long-term emissions as anticipated for construction materials are not necessarily valid for consumer products such as toys, decorative or scented articles and textiles. Here, the initial VOC emissions immediately after e.g., unwrapping of such products after purchase are of importance for a realistic inhalation exposure assessment. Existing methods to determine long-term VOC emissions need to be verified for their suitability to reliably detect emissions within the first hours of product use.

For this purpose, a test sample (rain poncho) emitting several different VOCs was tested in a large-scale emission test chamber (chamber volume: 270 L). A loading factor of 0.07 m² m-3, a temperature of 23 °C, an air change rate of 0.5 h^{-1} and a relative humidity of 50 % were applied to simulate realistic indoor environmental conditions. Additionally, experiments were conducted in a µ-chamber applying the same temperature and relative humidity and similar area-specific airflow rates to demonstrate the comparability of results and the suitability of micro-scale emission test chambers in this context. µ-chambers might represent a good alternative, featuring much smaller volumes that better fit the size of many consumer products and being more affordable for investigatory and official control laboratories. The emitting VOCs were sampled on Tenax® TA within the first hours until three days after loading of the chambers. Analysis was performed via thermal desorption gas chromatography mass spectrometry (TD-GC-MS).

The maximum air concentrations of selected VOCs were detected after two hours in the large-scale chamber and decreased to less than 30 % of the maximum after one day for most of the substances. In the µ-chambers the maximum air concentration was already reached at the first sampling time point (5 min) and after four hours the emission profiles of both chamber types approximate to each other. This demonstrates that large- and micro-scale emission test chamber experiments are suitable to estimate the inhalation exposure to VOC emissions from consumer products within the first hours of use.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

The effect of the indoor environment quality (IEQ) on cognition and health

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ID: 1147 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Humidity, Temperature, Cognition, Health, IEQ

Intro: With global warming, average outdoor temperatures experienced during spring and summer are rising along with humidity levels. The changes in outdoor temperatures greatly affect older buildings that do not have mechanical systems to regulate indoor temperatures. As humans spend the majority of their time indoors (cooking, exercising, sleeping, and working), the internal environment affects health and performance. Human thermoregulation is not only influenced by the environmental exposure and duration, but also activity.

In order to reduce energy use and carbon emissions, older homes need to be renovated to meet new energy labels. The indoor environment of homes would greatly change with added insulation. A well-insulated home loses less heat, reduces energy use and heating costs during the winter. However, this may cause overheating due to inability to lose heat quickly during the summer. The indoor environment quality (IEQ) encompasses temperature, humidity, light, sound and air quality.

When a home has a higher insulation value, there is a reduced natural ventilation capacity and this may lead to an increase in moisture in rooms due to activities like cooking, exercising and showering. A reduced ventilation capacity leads to an increase in moisture and pollution within the indoor environment and a perceived lower quality of the indoor air, which can be further exasperated with an increase in the number of occupants and occupancy duration. Moreover, the body’s ability to lose heat through evaporation and convection is dependent on temperature, airflow and humidity levels. In hotter (>32 ºC) and more humid environments (>70%), detrimental effects on cognitive and physical performance have been shown in shorter exposures lasting less than 3 hours.

Objective: The primary objective of this study is to investigate the isolated effect of a warm, humid, indoor environment for the duration of 8 hours on cognitive function compared with a lower humidity level at the same ambient temperature and high humidity at a neutral temperature. Additionally, the effects of high humidity on various physiological parameters and its effects on decision-making and bias behaviour will be explored.

Study design: Each participant will be exposed to the 3 conditions in randomized order: neutral temperature and high humidity, warm temperature and low humidity, and warm temperature and high humidity. The primary outcomes are cognitive performance scores. Secondary outcomes include thermophysiological responses and environmental perception and preferences as well as decision-making and bias behaviour.

Study population: 25 healthy participants - aged between 20 and 40 years, BMI >18.5 and <26 kg/m² will be included.

Main study parameters/endpoints: Cognitive performance (cognitive tasks and subjective workload and motivation); Secondary parameters are physiological parameters (skin temperature, skin blood flow, heart rate, core temperature, blood pressure, urine hydration, salivary cortisol) and perceptual evaluations of the environment (thermal, air quality and wetness sensation, comfort, acceptance, preference, pleasure). Moreover, the influence of humidity on decision-making and bias behaviour will also be explored.

In this study, participants will be exposed to three different conditions on three separate days in the respiration chambers of the Metabolic Research Unit at Maastricht University (MRUM). The complete experimental procedure for each experiment is shown in consisting of a screening day (screening, baseline measures and cognitive practice, 3 hours) and three testing sessions (11 hours each test day).

In all conditions, participants will spend 8 hours in the respiration chamber, conducting cognition tests, stepping activities, and questionnaires. The three conditions differ only in the exposure level of indoor relative humidity (HIGH/LOW) and temperature (NEUTRAL/WARM). The difference between the conditions is the level of humidity in the chamber, which is either 30% of RH (LOW) or 70% of RH (HIGH) and temperature, which is either 25ºC (NEUTRAL) or 32ºC (WARM). In the LOW-WARM condition, level of RH in the chamber remains at 30% RH and the temperature is 32ºC for the 8 hours, while participants are staying in the chamber. In the HIGH-WARM condition, the concentration of RH in the room remains at 70% and the temperature is 32ºC, while the HIGH-NEUTRAL condition is a relative humidity of 70% and a temperature of 25ºC.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Health in growing districts – neighborhood as a prospect for well-being

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ID: 1156 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: Health in growing districts, neighborhood as a prospect for well-being, healthy living environment, urban and public health, user in the focus, inter- and transdisciplinarity, place-based & person-based perspective, multi layered planning approach

Structural, natural, and social environmental conditions have a direct impact on everyday life and human health. Especially in urban, densely populated areas, extreme situations can have devastating health effects on residents. Densification processes, environmental stress and the increase in social inequalities lead to fast-paced development dynamics in cities and urban regions. The constant urbanization (densification, conversion, replacement…) provides the opportunity for a sustainable transformation of the tension between health-promoting and health-damaging factors (psychological, physical, environmental, socio-economical, individual…). When it comes to well-being in the growing city, holistic measures in terms of environmental justice, mental and physical health as well as eco and urban health solutions for the local population are needed. By getting a better understanding of health challenges and judiciously combining health resources, one can turn new districts on the outskirts into test fields for social, spatial and ecological innovations and investments. However, the pursuit of these innovations and investments demands integrative methods and planning approaches for urban redevelopment, that dynamically illustrate processes of well-being while also accounting for them in the multidimensionality of planning factors of living environment. The lack of health as an architectural, urban, social quality is difficult to identify and operationalize. In particular, its immaterial, dynamic condition is not easy to integrate into urban development processes. Previous work, relegates or reflects health as a relation to the built and lived environment through one-sided and sectoral planning methods. To embrace the different angles of well-being, it is valuable to link different scales (from the interior space to larger city building blocks) and temporal dynamics (short, medium, long-term) as well as inter- and transdisciplinarity.

The consideration of health implies the permanent entanglement of the built, social, and natural dimensions of living environment as well as the dualism of a person-based perspective (human sensory, individual and collective sensing of well-being according to user groups, user-specific requirement…) and a place-based perspective (spatial access to health in form of room types / characteristics and design principles). With a specific focus on the concept of the neighborhood (as a triad of interaction, motion, perception) depicts an interesting lever of health promotion in new housing areas. The ‘living’, ‘moving’ and ‘sensing’ spheres of neighborhood can initiate health promoting impulses and involve people actively in the process of the growing city. In a process-based, learning approach, individuals and neighborhoods have an active role in discovering, exploring, and appropriating space and also giving feedback.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Semi-volatile organic compounds (phthalates, alternative plasticizers and organophosphate flame retardants) and trace metals in air cleaner captured house dust

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ID: 1159 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: alternative plasticizers, phthalates, air cleaner captured dust, OPFR

Semivolatile organic compounds (SVOCs) and trace metals are found anywhere in modern indoor environment. This study aimed to characterize phthalates, alternative plasticizers (APs), organophosphorus flame retardants, and trace metals in air cleaner captured house dust (ACCD) and identify determinants associated the chemical contaminants. In total, 120 ACCD samples were collected from 120 houses that had used air cleaner filters for more than a year in Korea. All study participants completed the questionnaire comprised of housing, behavior, and life-style related factors. The samples were analyzed for 16 phthalates, 5 APs, 18 OPFRs, and 7 trace metals. There were seven chemicals in phthalate, three in AP, and eighteen in OPFR with a detection rate of 80% or more. None of trace metal elements were detected more than 65%. Among the three chemical groups, phthalates were detected at the highest concentrations (geometric mean [GM] (geometric standard deviation, [GSD]): 575 (4.6) µg/g in total), followed by APs (GM (GSD): 389 (5.3) µg/g in total) and OPFRs (GM (GSD): 290 (3.6) µg/g in total). Lead and manganese in ACCD were the highest concentrations (GM (GSD): 24.8 (8.1), 24.2 (7.6) µg/g, respectively) with a detection rate of ~60% followed by arsenic (GM(GSD): 2.9(17.7) µg/g). The levels of phthalates and APs measured in ACCD are comparable to concentrations found in previous investigations of settled dust collected in houses of Korea. The concentrations of BBzP, DnBP, and ATBC in homes using diffusers were significantly higher than in homes without diffusers ($p<0.05$). No other determinants were associated with the contaminants. Since residents are persistently exposed to these ubiquitous contaminants by inhalation, appropriate measures are needed to reduce potential exposures.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

MQTT-based monitoring system for indoor environmental quality in multi-domain

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ID: 1171 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: indoor climate, IEQ, sensor, voxel, spatial distribution

Especially since Covid-19, indoor environmental quality (IEQ) has become a focus of attention again. In addition to thermal comfort, indoor air quality (IAQ), lighting conditions, and noise greatly influence people's satisfaction and performance. In this paper, a modular monitoring system based on ESP32 microcontroller and Raspberry Pi was developed, which integrates spatial information of room and measurement modules. The system allows comprehensive real-time monitoring of indoor environmental variables in multi-domains, such as air temperature, humidity, wind speed, carbon dioxide (CO2), volatile organic compounds (VOCs), lighting conditions, and noise through modular nodes with corresponding sensor technology. The collected information is aggregated, transmitted via WLAN (IEEE802.11) based on Message Queuing Telemetry Transport (MQTT) Protocol running in the gateway, and stored in a SQL database. When using multiple node modules, IEQ data can be accurately obtained in inhomogeneous environments at different locations in the room. The validation of thermal comfort using the PMV/PPD model revealed differences in the predicted comfort votes in a small room (PMV error 0.62, PPD error 8.7 %, room volume 43.2 m^3).

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Removal of bacterial and fungal bioaerosols using air purifiers under real room conditions – a case study

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ID: 1188 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: air purifier, bioaerosols, desinfection, HEPA filters, UVC, photocatalysis

Air purifiers are devices that have become very popular in recent years, not only in residential houses but also in public facilities. They can be found in offices, schools and even hospitals. One of the potential functions of purifiers may be disinfection and even sterilization of the air. Due to the SARS-CoV-2 virus pandemic, this type of purifier currently dominates the market. Manufacturers declare that their models are almost 100% effective in removing bioaerosols from the air. Most of these declarations are not supported by any expert opinions.

The aim of this study was to evaluate the effectiveness of bacterial (psycho- and mesophilic bacteria) and fungal bioaerosol removal by two new models of portable air purifiers as a function of time (0 - 210 min with a measuring step every 30 minutes). It was also assessed how the concentration of bioaerosols in the room changes depending on the distance from the operating purifier (air outlet, 0.5 m, 1.0 m and 1.5 m) and air flow. The first model was equipped with a prefilter, a HEPA filter (H13) and a UVC lamp. The second, in addition to a similar set of filters as in the first model and the UVC lamp, had a photocatalytic filter. The research was carried out in the office of a university employee over a period of 6 months. The room has mechanical ventilation. The window and door to the room were closed while the purifier was in operation. The obtained results show a strong correlation between the decrease in the concentration of bacterial bioaerosol depending on the increase in the distance from the purifier – in the range from 99% to 40%. The purifiers were much less effective at removing fungi – in this case, the efficiency did not exceed 50% at a distance of 1 m, even after 3.5 hours of operation. No effect of the photocatalytic filter on the reduction of the concentration of both bacterial and fungal bioaerosols was observed. The purifiers disinfected the air more effectively at lower air flow rates.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Reference products for quality assurance and quality control measures in material emissions testing

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ID: 1195 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: reference materials, emissions, air quality, VOC

Since nowadays people spending most of their time indoors, a healthy environment is essential. Volatile organic compounds (VOCs) emitted from furniture and building materials are reported to cause health complaints. Therefore, the usage of low emitting materials will improve the indoor air quality. Quantitative VOC emission testing is usually conducted in emission test chambers under specified controlled conditions as described in DIN 16000-9 and DIN EN 16516.

For reasons of quality control/quality assurance (QC/QA) and for a better comparability of test results of different laboratories, suitable emission reference materials (ERM) are needed. To ensure comparability of test results between different test laboratories these emission reference materials (ERMs) are required. Here, it is important to have a homogenous material with known emission rates over a specific time. Different approaches can be found in literature, inter alia polymer films loaded with the target compound to be released again, or a lacquer material to which a VOC mixture is added. After curing of the lacquer, the material can be loaded into a test chamber. Drawback of those approaches are their relatively fast decreasing emission profiles. For QC/QA purposes according to the test standards, VOC sources with constant emission profiles are desirable. Also here, useful approaches can be found in literature, but which are only designed for the emission of single compounds.

The EU-founded research project MetrIAQ “Metrology for the determination of emissions of dangerous substances from building materials into indoor air” is working on a multi-component ERM with an envisaged instability of ≤ 10 % in the emission rate over at least 14 days.

Within a doctoral thesis porous materials are impregnated with VOCs. Supercritical CO2 is used as solvent. Thus, the impregnated material does not contain any solvent that may show a measurable amount of emission in the emission test chamber.

Furthermore, CO_2 has the benefits to have a good availability and low costs. For the selection of porous materials several properties like the pore size, the surface and the interaction with the components in the atmosphere need to be considered. The pores need to be able to large enough for the VOC molecules but should not be too large to ensure the constant release in the test chamber.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Evaluating the Impact of Natural Ventilation on Indoor Environmental Quality During the Heating Season in Energy-Efficient Residential Buildings

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ID: 1199 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: IEQ, IAQ, Thermal Comfort, Natural Ventilation, Occupant Behaviour

The aim of applying energy-efficient measures in buildings is to decrease energy consumption. However, improvements in energy performance have increased thermal and insulation characteristics, which introduces the risk of overheating and the requirement for a cooling mechanism during the summer (potentially increasing energy consumption). A key strength of natural ventilation lies within offering passive cooling and increased air change opportunities during the summer period. However, a negative consequence is reduced airflow in winter, especially in energy-efficient buildings that apply airtightness measures to reduce heat loss. As a result, pollutants, heat, and moisture may build up to levels beyond the guideline thresholds, especially under the impact of climate change, elevating risks on health and occupant performance. The International Energy Agency refers to the inadequacy of the existing IAQ database for low-energy buildings, this study aims at filling the relevant knowledge gaps within the Irish context, and provides a description of the energy-efficient buildings performance in terms of indoor environmental quality (IEQ). This research describes a longitudinal monitoring campaign for semi-detached naturally-ventilated energy-efficient dwellings (a primary energy consumption of up to 75 kWh/m²) in Ireland. The study assesses the effectiveness of natural ventilation in maintaining acceptable IEQ levels, while simultaneously monitoring energy consumption, by evaluating indoor air quality and thermal comfort, across both summer and winter periods. Thus, trade-offs between IEQ, overheating and energy consumption are determined. The methodology utilises high-grade research

instruments (SidePAK AM520 and GrayWolf DSII Probe) for performing precision measurements, collecting short-term data for particulate matter ($PM^2.5$), carbon dioxide (CO2), total volatile organic compounds (TVOCs), temperature, and relative humidity (RH). Additionally remotely-operated consumer-grade ‘low-cost’ sensor devices (Airthings View Plus and Foobot SAT), are used for acquiring time series data to map the longer-term trends for $PM^2.5$, CO2, TVOCs, radon, temperature, and RH. Sensor devices are installed in the main rooms of the houses (living room, kitchen, and bedroom). The results, presented at the conference, will focus on the winter-heating season monitoring data, and an analysis of data trends for the above parameters. The project aims to cover the wider perspective of natural ventilation in energy-efficient buildings, where in order to avoid policy failure and adverse human health effects, there is a need to ensure that regulatory measures understand the trade-offs between thermal comfort, human health, and energy performance.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Determining Chemical Emissions from Paint Products in Singapore to Guide Source Control Measures

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ID: 1206 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Building materials, Emission rates, Chamber testing, Formaldehyde, VOCs, Emission test standard

A recent nationwide indoor air quality (IAQ) risk assessment programme in Singapore revealed that formaldehyde was the most common indoor pollutant. In 10% of the 412 surveyed premises, formaldehyde concentrations exceeded the acceptable limit stipulated by the national standard. As part of the source control measures, National Environment Agency (NEA) of Singapore has embarked on a study on formaldehyde and volatile organic compounds (VOCs) emissions from common building products available locally. This is to support the development of legal emission limits on the emissions of hazardous chemicals from building products. The study started with the testing of interior paint products due to their prevalence and large indoor surface coverage. We tested representative paints from a range of local products including water-based (mostly for walls and ceilings) and solvent-based (mostly for metallic and wooden surfaces) paints.

We next developed an emission testing methodology by referencing Singapore Standard (SS) 150 as well as methods recommended by various international standards (ISO, EN, ASTM, etc.) taking into considerations of the feasibility, costs, and capability of local testing laboratories. By using an emission test chamber system in NEA's in-house laboratory, the emission profiles of formaldehyde and volatile organic compounds (VOCs) were determined for up to 28 days of test duration. In addition, the effects of various test conditions, such as air change rate, loading factor, temperature, and relative humidity, on the emission rates were investigated. The resulting emission rates of formaldehyde were compared against international regulatory limits and those outlined by eco-labelling schemes. In addition, the types and levels of the VOCs emitted from each paint type were compared against those reported in the literature.

The emission data gathered in this study served as valuable references in the development of regulatory limits in Singapore regarding the emissions of harmful chemicals from paint products. Currently the policy framework for the control of formaldehyde emission in paints is being developed and is targeted to be announced in late 2023 to early 2024.

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A handy tool enhancing the general public's awareness of impact of climate change on IAQ - Interactive web information platform

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ID: 1211 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: Science communication, future indoor climate, resident behavior, building simulation, exposure

The IPCC report (2021) predicts a global average temperature increase of 1.4-4.4°C by 2100, with more frequent extreme weather events. As more extreme weather events such as unusual heat waves, floods, and wildfires occur, climate change gradually becomes accepted as fact by the general public. Nevertheless, people rarely realize that atmospheric changes also affect indoor microclimate and indoor air quality, which is closely related to people's daily life due to the long time they spend indoors.

As part of a three-year research project funded by the German Federal Environment Agency, a detailed, holistic model, the Indoor Air Quality Climate Change (IAQCC), is being developed to predict the effects of climate change on indoor air. It considers heat and moisture exchange in different building envelopes, emission of gases and particles, physical-chemical reactions, mold growth risk, and comfort and exposure assessment. However, such a complex modeling system requires a multidisciplinary team with a high level of expertise to operate and interpret the simulation results.

In order to raise awareness of the impact of climate change on the indoor environment and to transfer knowledge to a broad public in an easily understandable way, an interactive web information platform is to be created based on the IAQCC model system within the project. The web information platform is to be freely accessible and, through simple, intuitive usability, enables the user to engage with the topic in a playful way. Due to the long computation time of the IAQCC model system, online simulation of the model is not practical. Representative parameters and cases must be selected in advance and the simulation results will be stored in a database. This allows the user to quickly query and display the results after entering or changing certain parameters. With the current setup, users can enter the parameters of their living environment -

including location, building type and geometry, ventilation concept and household work intensity - and explore various aspects of indoor climate, air quality, health, etc. under different climate change scenarios with the help of a detailed user guide.

The interactive web information platform will be a convenient and powerful tool to address the complexity and importance of climate change impacts on indoor air to the public through a simple, visually appealing presentation, and to inspire interest in the subject area.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Evaluating Indoor Environmental Quality and Comfort in the Pre-Retrofit Schools and Offices

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ID: 1212 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Energy Efficient Building, Indoor Air Quality, Deep Energy Retrofit, Non-Domestic Building, Offices.

There is an internationally recognised need to improve the energy efficiency of the entire building stock. In Europe, roughly 75% of the built environment is energy inefficient with buildings reported as the single largest energy consumer sector accounting for 40% of energy consumption. In Ireland, an ambitious target is in place for public sector bodies to achieve a 50% improvement in energy efficiency by 2030 by meeting higher energy performance standards and increasing retrofit activity. The Energy Performance of Buildings Directive (EU 2018/844) sets out to address these challenges, but it documents that if energy efficiency measures are improperly implemented, they can have negative impacts on indoor air quality. To date, there are only a limited number of publications relating to indoor air quality in non-domestic buildings which have undergone energy efficiency retrofits, and none in an Irish context. The current project focuses on evaluating indoor air quality and occupant comfort pre/post energy efficiency improvements in non-domestic Irish buildings (offices and schools) to assess the impact of any potential changes in buildings' airtightness and ventilation characteristics. Research-grade equipment and passive sampling will collect minimum week-long data on key indoor air pollutants ($PM^2.5$, CO2, TVOCs, radon, formaldehyde, BTEX, CO, NO2 and SO2). In addition, remotely operated sensors will collect long-term indoor environmental quality (temperature, humidity, carbon dioxide, VOC, lux levels, etc.) to benchmark the precision measurements against long-term trends. Supplementary information on thermal comfort, building/ventilation characteristics, and activity/occupancy levels, obtained using questionnaires and activity diaries, will further enhance the dataset. Similarly, an evaluation of indoor air quality and occupant comfort will be carried out post-retrofit. Concurrently, the dataset will be analysed to identify differences in indoor environmental quality and occupants between retrofits. Meteorological conditions and outdoor pollutant concentrations will be obtained from the nearby monitoring stations, separating the contribution of indoor and outdoor air pollution sources. The data presented at the conference will focus on the pre-retrofit measurements providing an indication of the IAQ in buildings with a poor energy rating that currently reflects most of the building stock in their respective categories. Statistical analysis will be carried out to identify any factors affecting indoor environmental quality and occupant comfort in non-domestic buildings. Finally, the project will focus on developing solutions and recommendations to support the development of specific retrofitting guidelines.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Practical Demand Side Management: One Day Case Study

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ID: 1265 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 10. Community- and urban-scale challenges and solutions
Keywords: Demand Side Management, Artificial Intelligence, Energy Efficiency

The situation with the sudden redistribution of energy sources and suppliers and the resulting volatility in the energy market that ensued in Europe has resulted in an energy crisis. In the paper, a Demand Side Management (DSM) solution is proposed that considers data-driven estimations of a building’s inertia in order to shift loads in response to fluctuations in energy market prices without compromising indoor comfort. One of the most important functions of DSM is to help Commercial Real Estate owners to take control over their buildings’ energy consumption by reacting proactively to energy price fluctuations. At the same time, indoor climate should not at all be compromised. Accordingly, the paper presents a detailed case study of DSM during one extreme day on the example of several commercial buildings in Estonia. The influence of DSM on indoor climate has also been studied in the paper. On August 17, 2022, Baltic Countries experienced the most expensive electricity price that peaked at 4 000 EUR/MWh between 18:00-19:00 local time. That day was thus the ultimate stress test for the technology considered in the paper. The DSM algorithm was able to reduce electricity consumption at the peak hour by 26.8%.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Case Study of the Dispersion of Exhaled Particles in a Graduate Student Office by Computational Fluid Dynamics Simulations

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ID: 1267 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor air quality, computational fluid dynamics, exhaled particles, ventilation, partition

Airborne infectious diseases transmission in indoor environments has been inextricably linked to our daily life since the pandemic. Computational fluid dynamics (CFD) simulation based on real-life scenarios usefully assists researchers to visualize and analyze the exhaled particle dispersion indoors. This study focuses on the CFD simulations of airflow and temperature distributions as well as the transport of exhaled particles using the Lagrangian tracking in a graduate student office with window air-conditioners. The thermofluidic boundary conditions were measured in the office and used as inputs for the simulations. Furthermore, field measurements were conducted to validate the CFD model. With the validated model, this study numerically investigated the effectiveness of using partitions and air cleaners on reducing person-to-person infectious particle transport in the office. The results show that using partitions could reduce the direct exposure to exhaled particles when the persons were seated nearby. Furthermore, using air cleaners with proper location can effectively reduce the concentration of exhaled particles in the office. In summary, this study obtained close-to-reality simulation results in a graduate student office and assessed the effectiveness of using partitions and air cleaners to reduce the airborne infectious diseases transmission.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Moisture damage in the most common risk structures in Finnish homes

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ID: 1278 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: dwelling, moisture, mould, risk structure

During the decades, even centuries, of a building's lifecycle, unexpected accumulation of moisture can occur in structures. Accumulation of moisture in building structures can lead to damp and mould, with implications for occupant health and wellbeing.

Indoor moisture damage is a common issue in Finland. A report to the Finnish parliamentary audit committee estimated that the prevalence of significant damp and mould damage is 6–10% of the floor area in houses, 12–18% in schools and kindergartens, 20-26% in care institutions and 2.5–5% in offices.

This study describes results from 14 996 Finnish detached and semidetached houses, surveyed between 2016-2019 as part of a standardized pre-sale condition assessment. The survey data was used to investigate the prevalence of moisture and mould, with a particular focus on those prespecified structures considered to be at increased risk of moisture damage. Houses were inspected in accordance with technical guide KH-90–00394, a Finnish national guideline which defines the content and scope of the survey, the measurements to be made, and the reporting and responsibilities of the inspector. Our analysis excluded damages observed in wet rooms, basement structures or non-risk structures.

Based on our results, 15% of small houses have definite moisture damage and about 40% have either definite damage or the need for additional research in the most common risk structures. The prevalence of damage in the homes increased with building age, from 5% in post-2000 dwellings to 80% in pre-1939 dwellings.

Older detached houses had significantly more damage compared to newer buildings. This can be attributed to differences in construction methods and the presence of different moisture risk structures, such as false plinths, basement walls and wooden ground floors, that were more common in different older construction eras. The difference between age groups may also be due to older buildings having been damaged or exposed to environmental moisture for a longer period compared to newer buildings.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Analyzing different peak shaving control strategies of a short-term thermal energy storage in a district heated office building

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ID: 1287 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 10. Community- and urban-scale challenges and solutions
Keywords: District heating; Thermal storage; Peak shaving

The application of a short-term thermal energy storage can be an effective approach to realize peak shaving in district heating systems. However, the centralized storage is most integrated into the system. Thermal energy storage is often not installed in district heating substations with conventional high temperatures. In addition, there is still a lack of analysis of different water temperature control strategies effects on heating power variation. The purpose of this article is to study the characteristic of different peak shaving control strategies impacts on heating power variation and assess the possibilities for peak shaving by combining short-term thermal energy storage in a district heating substation in Finland. A 5 m³ hot water storage tank was installed to deliver heat to a Finnish office building. Dynamic simulation software IDA ICE was employed to establish and simulate the substation with the stratified tank and the building. District heating supply water was used to charge the water tank directly for supplying heat. The control strategies were designed to control the storage tank temperature. Different control strategies effects were analyzed, and the results also indicate that it reduced the daily heating peak power from 125.2 kW to 85.7 kW during the heating season.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Associations Between Residential Indoor Temperatures and Self-Reported Sleep Problems in UK adults: a cross-sectional study

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ID: 1291 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: Indoor temperature, sleep problems, self-report, residential, NSHD

Sleep is a critical physiologic state and a complex behavior that is fundamental for overall physical and mental health as well as survival. It is influenced by multiple levels of factors including individual, environmental and social factors. The thermal environment is an important but sometimes overlooked factor affecting human sleep in ways which may be mediated by adaptive behaviors and/or design features of the built environment. Excessively high or low ambient temperatures may disrupt sleep, even in healthy people who do not suffer from insomnia. However, sleep is affected by complex interactions of environmental and individual factors, whereby limited observational studies currently exist on the impact of indoor temperatures within housing under real-life situations.

In this research, a cross sectional analysis of the 1989 NSHD (National Survey of Health and Development) cohort will be conducted, to evaluate associations among outdoor temperature, dwelling's indoor temperature and self-reported sleep quality outcomes. Dwelling indoor temperatures were objectively recorded by thermometers during nurse visits. Historical data of monthly mean outdoor temperatures will be downloaded directly from the Met Office.

To test the association of indoor temperatures and the sleep-related questions, multinomial logistic regression models will be used. With indoor temperature as a continuous explanatory variable and self-reported sleep problems as a categorical outcome variable, covariates will include demographics, health status, health behaviors, and housing variables. As a sensitivity analysis, the models will be stratified by three categories of indoor temperature (low temperature≤18℃, 18℃＜temperature＜24℃, high temperature≥24℃) to assess whether the association differs across the range of indoor temperature.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Combining consultation surveys with qualitative discussion and quantitative multi-criteria decision-making workshops to engage stakeholders within the design process for healthy net-zero whole life carbon buildings.

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ID: 1293 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia, 06. Heating, ventilation, air conditioning & cooling
Keywords: Net-zero, carbon, engagement, environment, social

Achieving net-zero whole life carbon buildings will become a prominent objective in architectural practice as the built environment endeavours to curtail greenhouse gas emissions. Recent studies across net-zero research have evidenced that a technical focus on energy and carbon performance neglects consequential impacts on occupant's health and the building's environmental and social performance. In the context of whole life carbon building design, we argue that collecting stakeholder perspectives and preferences on building principles in a holistic and timely manner through a series of stakeholder engagement methods will inform technical design decisions to ensure sustainable, healthy building designs. This research comprises multiple stages of surveys and workshops, applied to case studies with net-zero, social and environmental excellency aspirations in different Köppen-Geiger climatic zones, namely temperate (UK) and semi-arid (Jordan). It aims to provide design teams with rich technical and non-technical stakeholder engagement data and achieve collaborative levels of participation, with mechanisms of evaluation embedded into the engagement processes to ensure refinement opportunities. Stakeholders will first complete a consultation survey to assist framework refinement and screen framework evaluation criteria. An interactive workshop will then explore the stakeholder's perceived drivers and barriers to building high-performance, net-zero buildings. An element of the multi-criteria decision-making method (MCDM), the Analytic Hierarchy Process (AHP), will be completed in a second workshop, to elicit the relative importance of technical, environmental, economic, and social building design principles to the stakeholders. Ultimately, cross-case synthesis of results will be used to analyse the differences and similarities within and between stakeholder groups and case studies. Thus, the contextual data collected for two climatically and culturally distinct case study buildings will enable a deeper insight into global/intercontinental architectural design practices and stakeholder design preferences, knowledge of which may prove crucial to ensuring healthy net-zero whole life carbon buildings of the future.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

A study of the user behavior and effects of local cooling equipment among the elderly.

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ID: 1300 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Thermal comfort, elderly people, behavior, local cooling device

In order to study the control behavior of people on cooling equipment or systems, numerous scholars have conducted research in office buildings, residential buildings, and classrooms; however, the participants in the study are usually young adults. The accepted conclusion of the current research on thermal comfort is that the elderly are less sensitive to heat and have a narrower thermal acceptance range than the young, therefore, their needs and behavior patterns regarding cooling devices may differ from those of the young. Considering that the majority of the existing behavioral studies of the elderly are field studies, which may contain confounding variables, this study recruited the elderly to participate in a climate chamber experiment. The experiment required older adults to adjust local cooling devices (table fan, evaporative cooling fan, and air-cooled jacket) based on their own thermal comfort in different warm conditions. During the experiment, questionnaires were used to record the elderly's adjustment to the device mode and thermal sensation at various time intervals. By analyzing the collected data, the use pattern of different local cooling devices and the impact of these devices on the thermal comfort of the elderly in warm conditions were investigated.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Impact of UVC treatment devices on indoor air quality

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ID: 1302 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor Air Quality (IAQ), UVC Air cleaners, Volatile Organic Compounds (VOCs), Formaldehyde

With the COVID 19 pandemic, sales of ultraviolet (UV) air treatment devices have exploded. If they have been shown to be effective in inactivating microorganisms, air-cleaning technologies based on UVC irradiation may also induce chemical reactions. Because indoor air also contains, along with particulate matter and microorganisms, gaseous compounds including volatile organic compounds, UVC treatment devices may have adverse effects on indoor air quality by potentially producing unintended indoor air contaminants. To examine the potential impact of using UV air cleaners on indoor air chemistry, we performed experiments in a 570 L close loop reactor equipped with 3 UVC lamps emitting at 254 nm and delivering a dose of 100 $J.m^2$ as implemented in the INGENICA Flow-R device. The air flow rate was fixed at 60 $m^3.h^{-1}$. The temperature was comprised between 20 and 25°C and the relative humidity was set at 50%. A mixture of 4 volatile organic compounds (acetone, toluene, heptane and acetaldehyde), at concentrations in the ppb range was generated into the pilot thanks to a gas cylinder and mass flow meters. Experiments with acetaldehyde and toluene individually were also carried out. The gaseous compounds were identified and quantified by adsorption on Carbopack B and DNPH cartridges followed by TD-GC-FID-MS and HPLC-UV analyses. Accordingly to the literature, UV degradation of acetaldehyde, toluene and acetone could be observed. During the degradation of the mixture and during the degradation of acetaldehyde alone, the formation of formaldehyde was measured. Other by-products such as benzene and benzaldehyde were observed during the degradation of toluene alone, but the concentrations were very low and could not be quantified.

More specifically concerning the degradation of the mixture and under fixed experimental conditions, the rate of formaldehyde production in µg. h^{-1} was estimated. Considering this rate and doing a mass balance on formaldehyde concentration in a room, also taking into account the surface emission rate of formaldehyde and the air exchange rate of the room, we showed that the formaldehyde concentration in a room due to the UVC air cleaner is not significant.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Overheating risk assessment in elderly houses of Finland for current and future hot summers associated with climate change

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ID: 1306 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: elderly house, overheating risk, climate change, hot summer

Climate change is associated with more frequent hot summers, especially in Nordic countries where the climate change effects are faster. This may cause overheating in Nordic non-mechanically cooled residential buildings. Elderly people are the most vulnerable to overheating. The main purpose is to estimate overheating risk under the effects of climate change-associated hot summers in new and old elderly houses in Helsinki, Finland via simulations. Thus, thermal comfort and indoor temperature conditions with and without space cooling systems are evaluated for the actual weather conditions of hot summer 2018, as well as the projected weather conditions of hot summer 2050 with three emission scenarios RCP 2.6, 4.5, and 8.5. Based on the results, the degree hours above 25 °C in the warmest room of the new elderly house without mechanical cooling systems is 1900-4000 Kh depending on the emission scenarios and the maximum indoor temperature slightly exceeds 27 °C. While this number in the old elderly house is 10000-15000 Kh and the maximum indoor temperature significantly exceeds 30 °C which is the action limit of indoor temperature based on requirements of the Finnish Ministry of health and social affairs. However, a split cooling unit in the room can provide thermal comfort category I and II of EN standard 15251 even with the highest emission scenario (RCP 8.5). Therefore, relatively small electricity consumption is needed, (2.9-4.8 kWh/m², a) in the new elderly house and 4.1-6.5 (kWh/m², a) in the old elderly house, depending on the emission scenarios.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

The role of CO2 and PM in the definition of IAQ in schools

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ID: 1308 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: iaq, CO2, PM, evaluation, guidelines

The relationship among microclimatic conditions, PM and CO2 is crucial for this evaluation. Particularly, CO2 is an inert gas, odorless and colorless, and is naturally present in atmosphere. Basically, CO2 concentrations in indoor are higher as they are emitted mainly through the respiratory acts of the occupants.

This communication would like to discuss the results of a study conducted on CO2 and PM10 levels measured in real time in hot and cold season in different classrooms of primary and secondary schools present in a large Italian urban area in order to understand the IAQ, the importance of windows opening (natural ventilation), state and identify possible improvement actions to be taken.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Indoor humidity in Finnish day care in winter

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ID: 1317 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Indoor humidity, cold season, winter, day care

Comfortable indoor conditions are usually considered to be in the humidity range between 30% and 60%. It has been established that the relative humidity (RH) of the indoor air drops even below 10% in school and day care buildings in Finland during the winter. The purpose of this study is to study the possibilities to improve the humidity conditions safely. In this paper, we utilize data collected from one Finnish day care building during the cold season (January – April) in 2022, focusing on the coldest period in February 2022. There were two groups of children and personnel occupying separate wings, where the conditions of the control group (children 3-6 years old) were not changed. In the study group (children under 3 years old), indoor air relative humidity (RH) was raised to 25% during operating hours. A steam humidifier and moisture-transferring heat recovery system were added to the ventilation system. Humidification was not used after operating hours and weekends. The indoor air RH of the control group followed the absolute water content of the outdoor air, being on average 15%. The measurements consisted of temperature (T), relative humidity (RH), concentration of carbon dioxide (CO2), volatile organic compounds (VOC) and particulate matter (PM). A standard occupant survey was carried out among the personnel before and after the changes. In the wing occupied by the control group, the designed maximum supply airflow in the children's rooms was 4,7-5,6 l/s, m² (average 4,9 l/s, m²), while it was 3,9-7,6 l/s, m² (average 5,1 l/s, m²) in the wing occupied by the test group. The designed maximum air exchange rate in the rooms was, on average 1.74 1/h in the control wing and 1.99 1/h in the test wing. The day care had a demand-controlled variable air volume system (VAV) according to the CO2 concentration. 100% air volume corresponded to a CO2 concentration of 900 ppm. The room temperature average was 19.8°C. We will report preliminary results from this study.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Are particle sensors able to correctly report different indoor air particle emission scenarios?

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ID: 1318 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: particulate matter, air quality sensors systems, PM exposure

The democratization of the use of multi-sensor devices for air quality assessment has contributed to their wide deployment on the field and their massive use by people to monitor their own microenvironment. Among all the devices available on the market, only few are dedicated for IAQ assessment. Particle sensors are the most widely used, and commonly found in field studies. Since their detection principle is based on optical counting, the quality of data they provide is often questioned, especially when sources are dealing with different types of particles. In this study, we compared the behaviour of two commercial devices exposed to three different scenarios of particle generation. The first one is RUBIX POD (22 copies) dedicated to the measurement of indoor air quality, including an Alphasense OPC N2. The second one, is an OEEIL (for Outil d'Evaluation de l'Exposition Individuelle – 10 copies), especially designed for the individual exposure assessment, including a Winsen Sensor ZH03A.

The 32 devices are placed together in an experimental room, in controlled conditions (temperature regulation by air conditioning, air renewal rate 0.3 h^{-1}). They were exposed to three types of indoor particles pollution scenarios: (i) the infiltration of Arizona dust 10µm (composed of 90% SiO_2 and 10% NaCl), (ii) the re-suspension of mortar dust during a sweeping activity and (iii) the re-suspension of vacuum cleaner dust. A mini WRAS measures the size distribution, and an aerosol spectrometer (FIDAS) is used as a reference instrument to follow the dynamics and the mass distribution of the suspended particles. Three parameters are studied: i/the time shift between injection peaks and first variations or sensors, ii/the decay time Dt needed to decrease from 100% to 10% of the maximum concentration value, iii/ the concentrations measures at the maximum peak.

The response time of the sensors is shifted 50 minutes for RUBIX POD, whatever the kind of particles but up to 30 min for the OEEIL only for re-suspension of motar and vacuum dust. Likewise, the Dt of POD sensor is about 1.8 times slower than the Dt of FIDAS, while the OEEIL is 0.4 times slower to the same instrument. The fluidics of the system seems to be a key element for these both parameters. Finally, the POD as well as the OEEIL present a global underestimation of $PM^2.5$ concentration, but the values depend on the nature of the particles, implicitly from their distribution.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Real-Time Sensing of VOCs via PID and PTR-TOF-MS During Building Disinfection Events

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ID: 1332 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: volatile organic compounds, online mass spectrometry, surface disinfection, low-cost sensors, chemical emissions

Real-time monitoring of indoor air quality is critical to reducing occupant exposure to health hazardous air pollutants as humans spend 90% of their time indoors. As the awareness of indoor air monitoring has increased over the past few decades, many commercialized low-cost sensors (LCSs) are becoming available to measure indoor air pollutants, including particulate matter, CO, CO2, O3, SO2, NO2, and volatile organic compounds (VOCs). Compared to other LCSs, such as metal oxide semiconductor- and electrochemical-based sensors, photoionization detectors (PIDs) are the most widely used for real-time VOC monitoring in buildings. Total VOC (TVOC) concentrations are used as an indicator of the abundance of VOCs as detected by PIDs.

Many studies have evaluated PIDs based on laboratory experiments and field measurements. Compared to laboratory-based evaluation experiments, field measurements may better simulate indoor environmental pollution scenarios and, thus, provide a better PID evaluation. However, in-situ studies that evaluate PID performance for real-time VOC monitoring during chemical disinfection and surface cleaning in buildings are lacking. Moreover, a reference instrument with high time-resolution (for example, one data point every second) is also essential for evaluating the ability of PIDs to capture transient variations in VOC concentrations during short-time-scale processes and episodic VOC emission events in buildings, such as during surface disinfection.

A field measurement campaign was conducted to evaluate the performance of a PID in measuring TVOC concentrations at high time-resolution during building disinfection events through tandem measurements with a state-of-the-art proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS). The campaign evaluated a variety of commonly used surface disinfectants that included ethanol, isopropyl alcohol, thymol, triethylene glycol, peracetic acid, acetic acid, and/or lactic acid as active ingredients.

We evaluated the ability of the PID to capture both the magnitude and temporality in the TVOC concentration time-series during the disinfection events with respect to the PTR-TOF-MS. The PID was found to successfully detect all emission events, however, its performance varied when monitoring the VOC mixtures released by the different disinfectant products. For example, PID and PTR-TOF-MS TVOC data were highly correlated for ethanol- and thymol-based disinfectants, however, the PID underestimated TVOC concentrations emitted from the thymol-based disinfectant by almost 70%. This finding indicates that PIDs may provide a cost-effective, real-time solution for detecting VOC source events, however, the accuracy of the reported TVOC concentrations is sensitive to the major VOCs released by surface disinfectants and their respective ionization potentials.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Coupling an Olfaction Chamber with Proton Transfer Reaction Mass Spectrometry for Evaluating Human Response to Scented Product Emissions

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ID: 1333 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 08. Psychology, psychophysics, performance & productivity
Keywords: volatile organic compounds, olfaction, online mass spectrometry, human response, personal care products

Household and personal care products are important sources of indoor air pollution. These products are often classified as volatile chemical products (VCPs). Those that are intentionally fragranced are considered scented volatile chemical products (sVCPs). Humans as consumers incorporate sVCPs into their daily lives in the form of deodorants, detergents, soaps, colognes, air fresheners, and cleaning agents, with familiar scents such as lavender, lemon, mint, and rose. These alluring smells and associated feelings create desired smellscapes for the consumer. These sVCPs are known to release volatile organic compounds (VOCs), some of which are highly reactive with indoor oxidants, causing VOCs to undergo complex transformations in built environments over time. It is established that inhalation exposure to sVCP emissions can impact human health, however, there is limited knowledge on how VOC emissions from sVCPs alter the chemical composition of indoor air and how olfactory detection of sVCP emissions influence human emotional and cognitive response. This study aims to develop a controlled environmental chamber for concurrent evaluation of VOCs emitted from sVCPs and human response to those VOCs as evaluated through odor assessment and biometric data.

To isolate and identify the VOCs emitted from sVCPs, this study created and utilizes a controlled environmental chamber to be used in congruence with human participants. VOCs are measured in real-time (1 Hz) with a high-resolution proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS). By placing sVCPs inside the chamber, the PTR-TOF-MS monitors the chemical composition of the inside air altered by the product emissions. The chamber utilizes pollutant free air to ensure that the intake air is free of detectable VOCs, ozone, and particulate matter that could influence the experiments. By utilizing pollutant free air, the chamber dilutes the VOC emissions produced by the sVCPs and directs the variable dilution airflow to a sniffing port for human response assessment. At various intervals, the participant's heart rate and blood-oxygen saturation are monitored concurrently with their odor assessment using the Geneva Emotion and Odor Scale (GEOS). The high-resolution PTR-TOF-MS data captures the complexity of the VOC emissions from the sVCPs and is related to the biometric data and olfactory assessment for each level of dilution established by the chamber. The integration of the olfaction chamber and PTR-TOF-MS will contribute to the literature considering the relationship between indoor atmospheric conditions influenced by sVCP emissions and human physiological and emotional outcomes.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Evaluation of Long-Term Changes in HVAC Filtration Efficiency and Airflow Resistance

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ID: 1334 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: particulate matter, aerosol filtration, building ventilation, HVAC systems, filter performance

HVAC filters are an effective COVID-19 mitigation strategy in commercial buildings. However, HVAC filter performance is dynamic, not static, and changes and evolves over time. There is limited information on what happens to HVAC filters as they naturally age over extended periods during their service life and how efficiency changes impact their ability to remove aerosols in buildings. The aim of this study is to evaluate long-term, multi-year changes in HVAC filtration efficiency (size-resolved efficiency, ePM, in-situ MERV rating) and airflow resistance (ΔP) during natural aerosol ageing. A custom-built ventilation system was built at the Purdue University Ray W. Herrick Laboratories to evaluate HVAC filter performance under controlled conditions over two years of continuous operation. The ventilation system includes three independently controlled 2 ft by 2 ft ducts operating at a constant 2000 CFM volumetric airflow rate. Each duct includes a pleated MERV8 pre-filter and either a pleated MERV8, electret MERV13, or V-cell MERV14 final filter. Aerosol size distributions from 10 to 10,000 nm were measured across each pre- and final filter using a scanning mobility particle sizer (SMPS) and an optical particle sizer (OPS). The airflow resistance (ΔP) of each filter was monitored with digital pressure transducers.

The airflow resistance of the MERV8 pre-filters exhibited an exponential rise due to loading with sub- and super-micron aerosol, increasing by more than 200% over one year of loading across all three ducts. The final filters exhibited varying trends in airflow resistance, with the MERV14 increasing by more than 65% after one year, and the MERV8 and MERV13 showing small changes in pressure drop. Thus, final filters, despite their higher initial efficiencies, contribute less to overall filter bank airflow resistance compared to more heavily loaded pre-filters. Long-term trends in size-resolved filtration efficiencies varied among the filters. The MERV13 final filter became significantly less efficient across all size fractions after a half year of loading, whereas the MERV8 pre-filters became more efficient from 10 to 10,000 nm over time. In contrast, the size-resolved efficiency of the MERV14 final filter remained nearly constant during the extended loading period. Similar temporals trends were observed for ePM1, ePM^{2}.5, and ePM10. Interestingly, the in-situ MERV rating of the MERV8 pre-filters increased to a MERV14 after one year of loading, whereas the MERV13 dropped to a MERV10. Thus, pre- and final filters can become more or less efficient over time due to variations in loading kinetics.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Indoor thermal environment and carbon dioxide concentrations seven years after energy retrofits

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ID: 1341 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Thermal conditions, CO2, energy retrofit

Impacts of energy retrofits on indoor thermal environment, i.e. temperature (T) and relative humidity (RH), as well as carbon dioxide (CO2) concentrations, were assessed during 2010-2015 in 39 Finnish multi-family buildings (about five apartments per building) before energy retrofits and about one year after the retrofits. Follow-up measurements were performed in 17 buildings at least seven years after the retrofits. All measurements were performed during heating seasons. This paper presents results from the buildings where all three measurements have been performed (before retrofits PRE, one year after retrofits POST1 and seven years after retrofits POST2). The number of measured apartments is 42. Two months continuous monitoring of temperature (T) and relative humidity (RH) was performed in each apartment by loggers (T accuracy ± 1 °C; RH accuracy ± 3%). The logger was placed in the occupied zone, e.g., middle of the living room (height of 1.2–1.5 m above ground, i.e. human breathing zone as seated). Carbon dioxide (CO2) and carbon monoxide (CO) concentrations were measured every minute during a 24-h period using calibrated sensors (accuracy ± 50 ppm or ± 3%). Based on follow-up measurements there were no remarkable changes in indoor temperatures. The average indoor temperatures in the occupied zone were quite high in all the measurements, about +22,4…22,7 °C, differences between PRE, POST1 and POST2 are inside the limits of logger accuracy. Overheating is therefore common in retrofitted buildings in Finland. The average relative humidity varied between 25,4…27,3 RH%, the outdoor conditions (T and RH) during measurements were significantly associated with indoor RH. The CO2 concentration were quite low in apartments (N=35) with mechanical ventilation, both before and after retrofits, averages 686 ppm (PRE), 695 ppm (POST1) and 679 ppm (POST2), correspondingly. In six apartments with natural ventilation, the maximum

nigh time CO_2 levels were about 98 ppm lower one year after retrofits (POST1) and seven years after retrofits (POST2) they were still about 32 ppm lower than before retrofits.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

The impact of the classroom indoor environment quality on pupils with autism: A systematic review

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ID: 1347 Extended Abstract
Topics: 08. Psychology, psychophysics, performance & productivity, 11. All other IEQ, ergonomics & health topics
Keywords: Indoor environment, Autism, classroom, sensory processing, behaviour outcomes

School environment is critical for children to establish a foundation for their future educational experiences. Children with Autistic Spectrum Disorder (ASD) have different abilities to engage within the school environment from typical children. ASD is a complex developmental disorder marked by social and communication deficits, repetitive behaviours, sensory processing difficulties, and cognitive inflexibility.

The built environment interacts with individuals and has physiological and psychological impacts on their health and wellbeing. It is therefore essential to create a suitable built environment that responds to the great range of all pupils' needs. Careful design of the school space is particularly critical for pupils with autism who frequently have challenges with sensory processing.

This paper aims to synthesize and critically review all the relevant literature on the influence of indoor environment on pupils with autism outcomes in the classroom by a systematic review approach. The review has identified eighteen most relevant studies on the theme of indoor environment quality and autistic pupils in the classroom. The key findings are 1) Acoustics is the most indoor environment parameter that has been studied and had a significant impact on ASD outcomes. 2) The methodologies applied in these studies are limited and qualitative rather than quantitative; 3) The design practice for guiding indoor environment design in the autistic classroom is limited and not evidence based.

In conclusion, there is a lack of quantitative data that describe the correlation between autistic pupils and indoor environment quality parameters in the classroom and an unclear explanation of underlying mechanism. The evidence of indoor environment impacts on autistic pupils' outcomes is limited to support the design practices that need further investigation.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Multifaceted evaluation of the profitability of modernizing the heat supply system for multi-family residential buildings

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ID: 1356 Extended Abstract
Topics: 06. Heating, ventilation, air conditioning & cooling
Keywords: Energy efficiency, Modernization, Save energy, Heat losses, Pollutants emission

Improving the energy efficiency of the existing district heating systems is a current effort to save energy in the construction sector, to reduce consumption of the final energy and to decrease greenhouse gas emissions. Among other things, it is important to increase the efficiency of transmission and distribution of the heating medium and the use of the automatic regulation and control systems of the thermal stations operation.

The paper presents the efficiency assessment of the planned reconstruction of the heating system supplying nine multi-family buildings located in Biała Podlaska (Poland). The modernization of the system consisted in replacing two ineffective area thermal substations with ten individual bifunctional thermal stations for space heating and domestic hot water preparation, with the simultaneous replacement of the existing pipelines from the 1980s with modern pre-insulated pipes. The annual energy saving resulting from the proposed modernization was set at the level of 521 GJ/year. Heat losses of district heating pipes and heat losses caused by leaks before and after modernization were taken into account. Unit indices of gaseous and particulate pollutants emission, expressed in Mg/GJ, released into the atmosphere as a result of a fine coal combustion in a local heating plant, were determined. It was established that the reconstruction of the heating network supplying the analysed buildings will reduce the annual sulfur dioxide emissions by 0.083 Mg/year, carbon oxide emissions by 0.031 Mg/year, carbon dioxide emissions by 55.739 Mg/year, nitrogen oxides emissions by 0.072 Mg/year, particulate matter emissions by 0.040 Mg/year. The modernization profitability analysis was carried out, determining the cost of building the pre-insulated heating network in the amount of PLN 361,324 (€76,560). For this purpose, economic indicators were defined, such as: simple payback time and net present value.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Use of sensor systems to assess individual exposure to air pollution

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ID: 1381 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: sensor-system, air pollution, personal exposure

The development of sensor-systems for monitoring indoor and outdoor air quality has grown rapidly in recent years. These devices offer a variety of applications: public information / citizen science, air quality compliance/regulation, research in atmospheric sciences, exposure assessment...

The use of these technology raises several questions, including their metrological reliability, data management, use and interpretation, and ultimately their relevance to air quality issues.

In this context, ANSES has conducted an expertise to draw up an inventory of the use of air sensor-systems, focusing on the use of such systems to assess personal exposure to air pollutants, and on the prospective use of the generated data for assessing the health effects of air pollutant exposure. Profiles and motivations of users of sensor-systems were also discussed.

Results of this expertise have shown that sensor-systems offer many opportunities for field of personal exposure assessment: real time measurements, multiplication of measurement points, instrumentation of understudied microenvironments. Although these devices are easy to wear, the acceptability of wearing them for long periods can be problematic and their autonomy is still limited, which makes them preferable for studying short-term exposures. For long-term exposure assessment, data from sensor-systems are regularly supplemented by data from reference monitoring stations and/or modelling.

The sensor systems thus appear as complementary devices to the data sources or exposure assessment methods already used in exposure assessment studies. Moreover, sensor systems could allow the optimization of mapping (on spatial and temporal scales) and large-scale models, thus contributing to an improvement in the assessment of exposure to air pollution.

The analysis shows that beyond the metrological accuracy of the sensor-system, which is still the main condition for assessing individual exposure, many other points must be satisfied. Among these key points, those related to the contextualization and implementation of the sensor-system(s) (representativeness and spatio-temporal coverage, description of microenvironments, planned activities and unexpected events) are of primary importance. Protection of personal data is also a key issue.

Finally, Anses has proposed a series of recommendations to manufacturers and distributors of sensor-systems, private users, research actors, and public administrations in order to improve the use of sensor system for air pollution exposure assessment. To this purpose, Anses encourages the deployment of multidisciplinary projects bringing together skills in metrology, data sciences, exposure assessment, epidemiology and human and social sciences, given the multitude of disciplines involved in this type of project.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Viral aerosol removal efficiency of upper-room ultraviolet germicidal irradiation (UVGI) system compared to increasing ventilation rate

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ID: 1384 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Computational fluid dynamics (CFD), ultraviolet germicidal irradiation (UVGI), coronavirus, airborne infection, indoor air quality

Several studies have investigated the role of ventilation in mitigating the risk of airborne virus infection. However, some buildings are often not equipped with mechanical ventilation systems, and increasing the ventilation rate is not readily available. Accordingly, upper-room ultraviolet germicidal irradiation (UVGI) system is getting attention as a reliable approach to control indoor viruses. This system inactivates airborne viruses using ultraviolet light from UV lamps near the ceiling. Since the time scale of the virus disinfection is critical for the disinfection performance, this study investigates how fast upper-room UVGI system reduces the airborne virus concentrations compared to increasing the ventilation rate.

Computational fluid dynamics (CFD) simulation was performed for a small office (4.0m x 4.0 m x 3.6 m) in which two occupants were facing each other. The ventilation rate was set to 0.6 h^{-1} with 100 % outdoor air and a temperature of 17 C under two ventilation strategies: mixing and displacement ventilation. In the model, one person continuously released viral aerosols from the mouth with an air speed of 4 m/s and temperature of 34 °C. The UVGI zone was modeled with a UV fluence rate of 30 μW/cm², and the susceptibility constant of 3.77 x 10-3 cm²/μW-s was set for SARS-CoV-2.

To compare the effects of ventilation rate and UVGI system, we increased ventilation rate from 0.6 h^{-1} to 6 h^{-1} for the increasing ventilation rate case (without UVGI), and we turned on the UVGI system for the UVGI case (with the minimum required ventilation rate of 0.6 h^{-1}).

The result shows that under mixing ventilation, upper-room UVGI system takes 30 minutes to reduce the virus concentration by 90% while increasing ventilation rate takes 180 minutes. And due to the enhanced air mixing effect of mixing ventilation the human breathing zone concentration and the ASHRAE breathing zone concentration have no difference for both cases. Under displacement ventilation, upper-room UVGI system case and increasing ventilation case take 60 minutes to reduce the virus concentration by 90%. In contrast to mixing ventilation, the human breathing zone concentration is four times higher than the ASHRAE breathing zone concentration for the UVGI case. Meanwhile, the increasing ventilation case generates no difference between the concentrations from the two zones because of the mixing effect from the higher ventilation rate. These results suggest that upper-room UVGI system could be an alternative to increasing ventilation rate for virus control, however, the air mixing should be considered.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Indoor climate conditions with HVAC room unit integrated into the suspended ceiling or island ceiling

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ID: 1391 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Office, Radiant panel, Ceiling diffuser, Mixing ventilation

The target of the operation of the HVAC room units is to maintain good indoor climate conditions for occupants and stable supply air distribution in varying occupancy/heat load levels. In this study, meeting room cases were simulated with HVAC room units integrated into the suspended ceiling or island ceiling for analysing challenging, non-uniform heat load situations. Office room and meeting room cases with the suspended ceiling were earlier measured in full-scale test setups and modelled with CFD simulations. The simulated meeting room setup included heat loads from 10 occupants, computers, ceiling lighting and window solar heat gain. Active diffusers with radiant panels provided cool ventilation supply airflow and additional water based cooling to compensate heat gains. CFD simulations were performed in steady state conditions with RANS simulation method and with SST turbulence model. Buoyancy and thermal radiation heat transfer were modelled. A fine computational grid was used with detailed modelling of supply airflow patterns. This study revealed new understanding of locating HVAC room units in office spaces. When integrating HVAC room units into the island ceiling vertical temperature stratification on top of island ceiling was obtained. Indoor climate conditions were otherwise similar in both situations with active diffusers.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Efficiency of a newly designed portable air purifier in reducing the SARS-CoV-2 airborne infection risk in close-proximity

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ID: 1392 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: SARS-CoV-2, air purifier, risk of infection, particles

The COVID-19 pandemic caused by the novel SARS-CoV-2 virus has highlighted that airborne transmission represents the main route of contagion as it led to several outbreaks worldwide. The scientific literature has recently proposed several studies confirming the key role of the HVAC systems in reducing the risk of infection in indoor environments by increasing the clean air exchange rate. Nonetheless, even if general ventilation systems allow reducing the infection risk of susceptible subjects sharing the same indoor environment with an infected subject, their effectiveness could be significantly reduced in case of close-proximity configurations (e.g. face-to-face conversation) since the susceptible person, due to the short distance, is exposed to high concentrations of virus-laden particles emitted by the infected subject.

In the present paper we proposed and designed a portable, battery-operated, air purifier (patent number 102022000010346) allowing to reduce the risk of infection in close-proximity scenarios (e.g. people sitting face-to-face at a restaurant table) by shielding the susceptible subject with properly designed clean air flow rates able to guarantee a pathogen-free area in the breathing zone of the exposed person.

The efficiency of the portable air purifier was tested through detailed CFD analyses. In particular, recently we developed an integrated thermo-fluid dynamic model to quantify the risk of SARS-CoV-2 transmission from an infected host to a susceptible person during face-to-face conversation. Such risk assessment was based on a three-dimensional transient numerical model for the description of exhaled droplet spread once emitted by a speaking person, coupled with a recently proposed SARS-CoV-2 emission approach.

Here the same approach was applied performing simulations with and without the portable air purifier to estimate the different risk received by the exposed subject. In particular, we considered a scenario characterized by two subjects (infected and susceptible) sitting face-to-face at a restaurant table. The results of the study were very promising since the device was able to reduce the risk of infection by >90%.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Adaptive thermal comfort behaviours in UK homes: results of a large survey

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ID: 1405 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Thermal comfort, Adaptive behaviour, Latent heat, Energy literacy, Personality traits

To better advise and protect residents from ever more extreme cold weather events and increased energy cost, there is a need to map out current adaptive thermal comfort behaviour. In 2021, a large online survey was undertaken across the UK (n= 5,486). In this paper, we reviewed the residents' reported adaptive thermal comfort behaviours; these ranged from turning on the heating or putting on additional/warmer clothes to closing windows. Using correspondence analysis relationships between these reported behaviours and occupants and environmental features are uncovered. Results show that participants identifying themselves as female are more likely to put on additional/warmer clothes, while participants identifying themselves as male are more likely to turn on the heating. Participants on lower income are more likely to wait for the scheduled heating or have a hot drink, while participants on higher income are more likely to turn the heating on. Finally, participants willing to accept reducing their household temperature at peak energy-use time are more likely to close windows and put on additional/warmer clothes. These insights reveal some interesting demographic and household features, also emphasizing the active role of the residents in shaping future residential environment and energy systems.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Effect of the time of bioaerosol emission on potential exposure to microorganisms in the class room with and without operating mechanical ventilation.

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ID: 1410 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: bioaerosol; indoor environment; microorganisms count

Exposure to bioaerosols, especially those containing pathogenic organisms, is of particular importance in the indoor environment. If a one-off event contributes to the emission of microorganisms, a large decrease in the number of microorganisms can be achieved relatively quickly with a properly operating ventilation system. A sneeze or cough will cause a sudden increase in the number of microorganisms, which will disperse relatively quickly. Nevertheless, they will pose a huge threat. It's even worse if the source of the dangerous bioaerosol works continuously.

The aim of the research was to analyze the change of bioaerosol concentration in air in a simulated school classroom with and without mechanical ventilation. The tests were carried out under controlled laboratory conditions in a test chamber simulating classroom environment. The emission of microorganisms in the previously sterilized room was carried out continuously by nebuliser with the ventilation system switched off. Bacteria belonging to the genus Bacillus and Micrococcus luteus (both Gram +) were used as model organisms used to prepare bioaerosol (mixture). After 3 minutes, 7, 10 and 13 minutes, respectively, the concentration of bacteria was measured using the AirIdeal 3P apparatus. An intensive increase in the number of microorganisms was observed with the increase in the emission time. After only 7 minutes, the value of 500 cfu/m³ was exceeded at all measuring points. The concentration of the total number of bacteria exceeded 1000 cfu / m³ after 13 minutes. Switching on the ventilation system resulted in an expected decrease of aerosol concentration in the classroom air.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

How adequate are the ventilation and thermal comfort levels of net-zero houses? A case study in the Pacific Northwest

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ID: 1414 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Ventilation assessment, net-zero house, fresh air, IEQ, CO2 levels

Maintaining adequate levels of ventilation and thermal comfort is one of the pillars of healthy and efficient buildings, especially nowadays in a post-COVID-19 world. Sufficient amounts of fresh air contribute to the mitigation of airborne diseases and promote indoor healthy levels. Prevailing passive and net-zero houses have often been associated with a lack of providing sufficient comfort levels to occupants as well as adequate fresh air supply. This is partly due to air-tight envelopes, strict energy demand requirements, and the adoption of cost-effective HVAC systems. In this paper, the ventilation effectiveness and thermal comfort levels of a prefabricated two-story net-zero house are assessed. An experimental field Indoor environmental quality study is designed to quantify and assess the ventilation adequacy, thermal comfort levels, as well as the building envelope's infiltration. Multiple IEQ sensor packages have been designed and built to measure the indoor environmental condition in key living spaces of the house. Standard tracer gas tests and ASTM E741-00 concentration decay method are adopted to evaluate the air change rates for the eight zones of the net-zero house. Findings from the ventilation flowrates, air tightness and thermal comfort assessments are evaluated in relation to prevailing standards. Recommendations for design improvements are provided accordingly.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Sensibility Analysis for Examining the Optimum Room Temperature for Nocturia based on a Multilevel Model

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ID: 1416 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Nocturia, Room Temperature, Multi-level Analysis, Sensitivity Analysis

The WHO has recommended a room temperature of at least 18°C for good health. However, few houses in Japan are able to maintain a temperature of at least 18°C in winter. Nocturia, which is defined as urinating more than once during the night, is adversely affected by cold indoor environments. Although the relationship between indoor thermal environment and nocturia is becoming clear, the optimum temperature to prevent nocturia has yet to be clarified. Against this background, this study aimed to determine the optimum room temperature for preventing nocturia by performing a sensitivity analysis. There have been various reports on the effect of living environment on nocturia. In this study, we developed a prediction model with the outcome of nocturia as the objective of the sensitivity analysis. The multilevel logistic regression model indicated that living room temperature was associated with nocturia. A 1°C increase in room temperature at bedtime was associated with a lower odds ratio for nocturia. To verify the accuracy of the prediction model, we conducted internal and external verifications. The results showed that the accuracy of the prediction model increased as the frequency of nocturnal urination increased, and the prediction model with three or more nocturnal urination cycles had the highest accuracy. However, because the frequency of occurrence of the raw value was less than 10%, the prediction model used in the sensitivity analysis was the one with two or more nocturnal urination cycles. In this verification, models were created for both the living room and the bedroom. The living room model was selected because it was more accurate than the bedroom model. In the sensitivity analysis, the probability that a subject would urinate more than two times during the night was calculated using a multilevel logistic regression model. The results showed that the probability of nocturia was suppressed as the room temperature increased, reaching 30% and 20% when the room temperature was increased to 18°C and 21°C, respectively.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Preliminary study of bioaerosol dispersion in classroom space

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ID: 1421 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: bioaerosol, bacteria number, indoor air, mixing ventylation system

Indoor air quality is a very important factor determining the life comfort and health of people. It is estimated that most people spent about 80% of their day in internal space. Particular threats are posed by bioaerosols, containing viruses, pathogenic bacteria, fungi and products of their metabolism. The classroom is a special case of internal space, in which students are exposed to bioaerosols generated by them during the lesson. Considering the amount of air flowing through the respiratory tract per hour it is easy to appreciate the suitable air quality.

The aim of the research was the preliminary estimation of bioaerosol dispersion and efficiency of the ventilation system and air sterilization (UV, O3). The studies were carried out under controlled conditions in a chamber, simulating the classroom with the volume of 163.m^3 (6mx9mx3m). Mixing ventilation system with supply airflow of 650 m^3/h was operating during 45 min. lesson. For bioaerosol generation, the suspension of two bacteria strains were used as the mixture (Bacillus sp., Micrococcus luteus - both (G(+), in concentration 150x106 cfu/ml by McFarland scale). The bioaerosol was generated by a nebulizer working continuously during the whole lessons (1ml of suspension dispersed per 45 min.) which was the only single source of bioaerosol. The microbiological analyzes were performed in repetition (series), before bioaerosol dispersion in a clean room (previously sterilized) and then after 45 min. of bioaerosol dispersion. Between each series the classroom was sterilized. The samples were taken on from one point located next to the nebulizer and two points located at the same distance from the source of bioaerosol. The microbiological samples were taken by impact method with the usage sampler Air Ideal 3P (Biomerieux).

Obtained results showed that after 45 min. of bioaerosol emission the number of bacteria in chamber air increased about a thousandfold. Operation of the ventilation system during bioaerosol spreading caused well mixing and equal spreading of bacteria in the chamber space. There weren't significant differences in the number of bacteria between sampling points located in different distances from the bioaerosol source. Usage together of two sterilization methods (UV for 60 min. and O3 for 30 min.) allowed to obtain microbiologically clean air in the chamber.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Design, development and performance evaluation of an electrostatic precipitator for indoor environment.

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ID: 1430 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Standard aerosols, real scenario, particle sources, byproduct, energy consumed/CADR

Indoor air quality is a major concern in the modern environment since people spend 80-90% indoors. Even though several indoor air cleaning technologies are available they have a lot of drawbacks during practical application. Therefore current study is on the applicability of electrostatic precipitator (ESP), a preferred cleaning technology in industries to an indoor environment thereby providing additional benefits like high capture efficiency for particulate matter, flexibility of keeping as standalone/induct unit, lesser energy consumption and low maintenance requirements. Designed ESP is operated at voltage of 9 kV considering voltage-current characteristics, different theoretical formulas and based on number of ions generated. Similar way, operating flow rate was fixed at 8 LPM considering migration-residence time relationship and based on velocity distribution as determined by computational fluid dynamics modelling. Designed ESP effectively captured standard aerosols, major indoor particle sources and ambient indoor infiltrated particles. As ionisation in ESP, deactivated standard bioaerosols and degraded total VOC effectively, method is found to be also efficient for multipollutant removal. Additionally, energy consumption and by-products emission were found to be comparatively lesser compared to commercial purifiers suggesting its possibility of scaling up as a product.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Risk Assessment of Hazardous Chemicals in beauty clinics in Korea

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ID: 1451 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Beauty salon, risk assessment, aldehydes, VOCs, indoor air quality

Beauty salons are environments which high level of airborne chemical pollutants are exposed to the staff, but current regulation about air quality and hazardous chemicals in these industries have not been specified. According to 'product safety and health index(PSHI)', chemical's hazardousness were quantified, and came up with a list of chemicals that needed to be controlled and monitored in the industry. Next, aldehydes and VOCs in air were monitored by passive sampling method in beauty salons located in Seoul, Korea. For the result, formaldehyde, acetaldehyde, acetones, benzaldehyde were detected the most in aldehydes, and toluene was detected the most in VOCs. From the substances that were detected in the beauty salon, risk assessment was conducted to 4 chemicals with high hazardousness: Formaldehyde, acetaldehyde, acetone, and propinaldehyde. ECR(excess cancer risk) were shown of 1.46E-06 to 1.10E-03 for formaldehyde, and 8.47E-08 to 8.97E-05 for acetaldehyde. And for HQ(hazard quotient) were shown of 8.74E+0 to 1.19E+03 for acetone, and 1.13E+0 to 1.31E+01 for propionaldehyde. By this result, it can be concluded that indoor air of beauty salons have a high risk of hazarodus effect on the occupants, so the need of management system for indoor air quality were emphasized, and guideline for protection of the occupants are needed. Especially, Korea's current regulation for indoor air quality targets the concentration of TVOCs, but this should be changed to monitoring specific substances according to the facility. In order to track and control the risk for different environments, it is required to track substance that are most frequently detected for each environment, and risk control should be made from it's result. For this, further study for indoor air quality of individual industries and its risk by hazardous chemicals are needed.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Children exposure to endocrine disruptors chemicals: what do we know until now and what can be done about it?

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ID: 1456 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: endocrine disruptors; indoor air quality; schools; children; neurocognitive development

The current evidence has been showing that many of the endocrine-related diseases and disorders (are on the rise. Exposure to most endocrine disrupting chemicals (EDCs) is complex. Previous studies have addressed EDCs ingestion and dermal pathways whereas inhalation exposure has been addressed far less. Depending on their physical properties, in air EDCs are found either in gas phase (volatile or semi volatile organic compounds) or bound to particulate matter (PM); however, EDCs analysis associated with particles has been scarce. In western society people spend 80–90% of their time indoors, and the respective sources (furniture, materials, electronics, use of personal care products, cosmetic, pesticides) as well as increasing urbanization, changing behaviours can result in indoor exposures several orders of magnitudes higher than outdoors. This is especially relevant for children whose exposure to EDCs (known or suspected) is higher in comparison with adults (through their hand-to-mouth activity, higher metabolic rate) and at the same time their developing tissues are exquisitely sensitive to endocrine signals. Inevitability of exposure to EDCs (known or suspected) in daily lives of modern society is increasing interests in developing and implementing interventions to prevent or reduce harmful health effects of EDCs in various educatory environment. A comprehensive search will be performed for previous studies published in the last decade with detailed information on the respective exposure levels of: parabens, phthalates, flame retardants, disinfectants, metals – (As, Cd, Pb), and polycyclic aromatic hydrocarbons in a child specific environment which can meanwhile help to understand the major exposure sources and pathways and thus, handle EDCs according to the risk they pose, as single chemicals or in mixtures.

The aforementioned EDC exposure levels can influence cognitive conditions and behaviour among schoolchildren; however, there exists no research study namely in Portugal. To address this gap EDC(Mind)2 a multidisciplinary project aims to assess child exposure to EDCs (air, dermal, diet) among a population of 1800 Portuguese schoolchildren (20 schools), emphasizing its impacts on neurodevelopment

Through this project, we aim to increase awareness of the importance of EDC exposure prevention, while reinforcing their commitment to environmental health as a set of guidelines will elaborate a guidance with a focus on “what can be done about it?”

The work is financed by PTDC/CTA-AMB/3040/2021 from Fundação para a Ciência e a Tecnologia (FCT) through national funds. Additional financial support was received from LA/P/0045/2020 (ALiCE) and UIDB/00511/2020 - UIDP/00511/2020 (LEPABE). Joana Madureira acknowledges her FCT fellowship SFRH/BPD/115/112/2016.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Performance of artificial neural network-based predictive controllers for thermal comfort in typical prefabricated movable buildings.

Ciervo, Antonio; Rosato, Antonio; Maffei, Luigi

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ID: 1462 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Prefabricated movable buildings, Overheating, Predictive controller, Artificial neural networks, Building energy efficiency

Prefabricated Movable Buildings (PMBs) are gaining great attention in several applications, such as accommodations, offices in construction sites, disaster-reliefs, etc. A simple on-off strategy is often used for controlling air-to-air Electric Heat Pumps (EHPs) usually serving PMBs, leading to significant ‘‘overheating” (indoor air temperature exceeding desirable thermal comfort level) and energy waste. In this study, a reference PMB, intended for 3-person office use in construction sites, has been identified as representative of the PMBs available on the Italian market. The performance of the reference PMB served by an EHP have been dynamically simulated via the software TRNSYS 18 while operating under 4 different EHP control logics during heating season of Naples (Italy). In particular, a traditional on-off logic has been compared with 3 different strategies based on the prediction (over a period of 30 minutes) of indoor air temperature via Artificial Neural Networks (ANNs). The analyses have been performed with the main aims of assessing the capability of the proposed ANN-based predictive controls in improving thermal comfort by limiting overheating phenomena and reducing EHP electric consumption. The simulation results highlighted that the ANN-based strategies can reduce both overheating period up to 10.5% and EHP electric demand up to 5.3%.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Preliminary investigations on the use of Net Promoter Score to measure occupant satisfaction in office spaces

Davalos Quevedo, Maria Victoria (1); Luna-Navarro, Alessandra (1); Pottgiesser, Uta (1); Blum, Ulrich (2)

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ID: 1474 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia
Keywords: occupant satisfaction, workspace design, Net Promoter Score, Human-Centric Design

Until now, research shows that the most common method to measure occupant satisfaction with the office space is through POE (Post-occupancy evaluations), which is performed once in time, for instance after a change or relocation has been made.

Real-time feedback from occupants could lead to a better and more exact understanding of the workspace and its occupants and help architects and designers to achieve better solutions.

A new methodology was developed by integrating the Net Promotor Score (NPS), a widely used market research metric for measuring customer satisfaction with products, in established frameworks for measuring occupant satisfaction in the indoor environment.

A demonstration of the new integrated method was conducted in a field study in an office building in Germany with 50 employees, who were asked to give daily feedback on six categories and a total of 20 survey items regarding occupant satisfaction with indoor workspace design, based on literature review.

The aim of the experiment was to preliminary: (i) understand which aspects of workspace design can lead to a higher occupant satisfaction; (ii) evaluate which frequency (weekly vs. once in time) of retrieving occupant feedback leads to a more effective understanding of space.

The six categories were asked weekly, for three months during the summer months, and once in time.

The results are bifold, showing that there are certain aspects of the workspace that lead to higher occupant satisfaction than others and where more attention is needed when designing a sustainable office space, and, that occupants are willing to give constant feedback on space if the items asked are of a wide variety and not always repetitive.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Field Survey of Microplastic in Different Indoor Environments of Japan

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ID: 1482 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Microplastic, Indoor Environment, Field Intervention Survey, Semi-Volatile Organic Compounds

The issue of marine pollution caused by micro-plastics has emerged and has attracted worldwide attention. If the source of micro-plastic is routine plastic waste and products, they will be located very close to the living environment, and there is a concern about the risk of micro plastic contamination even in the residential environment. Meanwhile, its influence on the indoor air quality has not been studied enough not yet. Our previous exploratory studies have confirmed the possibility of the presence of microplastics in indoor environments of Japanese residential houses. On this basis, we additionally investigate the concentration of indoor microplastics in residential buildings, kindergartens and elderly care facilities of Japan. Settled house dust is sampled by vacuum cleaner and human-derived hair, pet hair, etc. are removed and then qualitative analysis of microplastic components is conducted, and finally the sample is classified by size for each analysis. Micro-Fourier Transform Infrared (μ-FT-IR) spectrophotometry are used for qualitative analysis of microplastic components. Cellulose and many resin-based substances such as polyethylene terephthalate, polyethylene, polyester, and polyamide were detected in almost indoor environments.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Occupancy and personal exposure detection by using smart sensors in two office buildings

Yun, Seoyeon; Licina, Dusan

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ID: 1483 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: Low-cost IAQ sensor, Indoor air quality, Building occupancy, Human exposure, Spatio-temporal variation

Occupants and their activities have been prominent sources of indoor air pollution, which may affect exposure levels and comfort for building occupants. Despite the recent advent of low-cost sensors, there have been few real-time analyses of air pollutant exposures linked to occupancy dynamics. This study aimed to capture dynamic personal exposure or occupancy in offices through IAQ parameters and occupant activity profiles by using smart sensors. Continuous field measurements of air temperature, relative humidity, CO2, and size-resolved particles at three stationary locations (two sidewalls and a workstation) were conducted for 2-week in each of the two Swiss office buildings. Four recruited office workers per building carried a personal vest with CO2/PM monitor and completed activity surveys with smartwatches. The number of occupants in room and building was tracked via location platform and staff visual inspection. The stationary wall- and desk-mounted CO2 monitor near occupant was a good indicator for both personal exposures and occupancy. The PM level at the occupant desk was the best proxy for personal PM exposures. Consideration of activity profiles was required to better characterize personal PM exposures during vigorous activity. The findings will help understand personal air pollution exposures under dynamic occupancies for efficient HVAC control.

Monday, 12.06.2023 13:30-14:00 Room C Carbon

Effects of solar control systems on human daylight-driven health potentials

Khanie, Mandana Sarey (1); Nielsen, Rasmus (1,2); Brembilla, Eleonora (3); Foldbjerg Rasmussen, Helle (2); Korsholm Andersen, Rune (1)

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ID: 2512 Extended Abstract
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: Spectral lighting simulation, non-visual effects, non-image forming, BSDF

Individuals spend over 90% of their time indoors and have limited exposure to the outdoors. This shortage of outdoor stimulation has heightened the significance of designing buildings that enhance indoor health. The occupants' health is affected by the spectrum and intensity of light that penetrates the solar control systems. Hence, the effect of combined solar control systems and façade, i.e., complex fenestration systems (CFS), on human health needs to be thoroughly understood. Yet, most tools used to design and control solar shading systems do not take spectral effects into consideration. In this study, we developed a tool to compute spectral lighting on CFS using Bidirectional Scattering Distribution Function (BSDF) together with multi-phase and N-step simulation techniques with Radiance as the rendering engine. The novel developed routine predicts the spectral distribution of solar control systems, allowing for the assessment of their effect on well-being and health.

Parallel sessions

Monday

Session 1 Monday Carbon - Sensor technology

Time:
Monday, 12.06.2023 11:00-12:30

Room: C Carbon

Chair:
van Treeck, Christoph
RWTH Aachen University

Co-Chair:
Laverge, Jelle
Ghent University

Monday, 12.06.2023 11:00-11:15 Room C Carbon

Non-invasive physiological parameters sensing for personalized human thermal comfort prediction

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ID: 1417 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Human thermal comfort, non-invasive sensing, infrared images, feature extraction

Sensing and projecting an individual's human thermal comfort in buildings is a complex but crucial task for the transition toward human-centered indoor climate control. Non-invasive collection of physiological and personal information from the human body, such as skin temperature, activity rate, and clothing insulation, is possible when applying computer vision algorithms to infrared (IR) and RGB images. In this study, we applied multi-modal non-invasive computer vision algorithms to extract personal features such as the clothing ensemble, activity level, posture, gender, age, and skin temperature as human's thermal comfort defining parameters. Moreover, we evaluated the capability of an IR camera to detect the skin temperature of the face and hands by comparing them with the contact measurement using iButton skin temperature sensors in controlled experiments performed on males and females in a climatic chamber. Finally, we highlighted the remaining research directions that would pave the way for non-invasive personalized human thermal comfort.

Monday, 12.06.2023 11:15-11:30 Room C Carbon

Using machine learning methods for the development of an electronic nose (E-Nose) for detection of air quality in shopping centers

El-Mokadem, Mahmoud; Louca, Samy; Abdelrahman, Ali; Rewitz, Kai; Müller, Dirk

RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

ID: 1166 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: indoor air quality, total volatile organic compounds, machine learning

With the increasing awareness concerning indoor air quality (IAQ) and energy efficiency, the development of IAQ sensor systems is becoming more relevant, for example to enable demand-controlled ventilation (DCV). Currently, DCV in most indoor environments is based on CO2 concentration, which is a good indicator for human emissions. For shopping centres (SC), DCV rarely considers volatile organic compound (VOC) emissions from materials, which could significantly affect customer health and consumer experience. E-Noses can help to detect and interpret these gases. This requires an adequate calibration of the E-Nose. Due to the high number of sensors and influencing factors such as temperature, relative humidity or type of odour, choosing the best model approach is not trivial. Therefore, we compare linear regression with support vector regression, artificial neural networks and random forest models for the calibration of an E-Nose to predict perceived intensity (PI) for six different SC products. Subjective test data from a trained subject panel and objective test data from the E-Nose are used to train the different model types for the whole dataset and product-specific datasets. Testing showed that random forest regression leads to the lowest root mean square error of 0.07 PI.

Monday, 12.06.2023 11:30-11:45 Room C Carbon

Development of a semi-wireless measurement system for monitoring skin temperatures

Derwein, Dennis (1); Burgholz, Tobias Maria (2); Mhisen, Tareq (2); Rewitz, Kai (1); Müller, Dirk (1)

1: RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Germany; 2: Heinz Trox Wissenschafts gGmbH, Germany

ID: 1390 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 08. Psychology, psychophysics, performance & productivity
Keywords: thermal comfort, skin temperature measurement, proband studies, monitoring, thermophysiology

The calibration of thermo-physiological comfort models requires the measurement of the skin temperatures of individual body parts in subject trials. Especially when a high number of measurement points on the human body is required, established sensors such as platinum resistance thermometers and coin-sized wireless temperature loggers (e.g. iButtons) have significant disadvantages. In this study, we developed the prototype of a semi-wireless skin temperature measurement system in which individual microcontroller modules, each hosting up to 8 daisy-chainable and wired sensor modules measuring skin temperatures, send the data wirelessly via a ZigBee network to a coordinator module. Data can then be collected and stored locally or stored online in time series databases. We demonstrate the functionality of the prototypes in a test setup by comparing measured surface temperatures with those of platinum resistance thermometers and iButtons. Tests show that the prototype functions reliably and has a measuring deviation of 0.0342 K, which is comparable to the measuring deviation of the platinum resistance thermometers and iButtons. Our system thus combines the advantages of those systems in terms of measuring accuracy and a live view during experiments with convenient and quick attachment of the sensors without restricting the subjects in their movements.

Monday, 12.06.2023 11:45-12:00 Room C Carbon

Spatial Mapping of Ultrafine Particle Concentrations in an Office HVAC System Using a Diffusion Charger Sensor Array

Wagner, Danielle N.; Jung, Nusrat; Boor, Brandon E.

Purdue University, United States of America

ID: 1337 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: ultrafine particles, building ventilation, HVAC filtration, building automation systems, indoor air sensors

Indoor aerosol concentrations can be highly dynamic relative to occupant activities and methods of ventilating indoor spaces. A multi-semester measurement campaign was conducted in one of the four living laboratory offices at the Purdue University Ray W. Herrick Laboratories to investigate spatiotemporal variations in ultrafine and fine particle number concentrations under variable occupancy and ventilation modes. Ultrafine and fine particles from 10 to 2,500 nm were measured in real-time (1 Hz) with four portable diffusion charger sensors that were simultaneously placed at separate locations throughout the living laboratory office and its HVAC system: room/return air, outdoor air, pre-filter supply air, and post-filter supply air. An integrated building automation system was used to achieve real-time monitoring and precise control of the HVAC system. Supply, return, and outdoor airflow rates were adjusted under different ventilation modes to achieve different air exchange rates and pressurization conditions. Occupancy was tracked via chair-embedded thermocouples. Data from the diffusion charger sensor array and building automation system were integrated with a material balance model to determine ultrafine particle number source (#/h) and loss (1/h) rates for various processes throughout the HVAC system.

Ultrafine and fine particle number concentrations exhibited spatiotemporal variations throughout the HVAC system and generally ranged from 10^2 to 10^4 #/cc among the four monitoring locations. Outdoor air concentrations were generally greater than those measured in the room/return air, aside from indoor aerosol generation events, such as floor burnishing and ozonolysis of monoterpenes released from eating citrus fruit. Source and loss rates scaled with volumetric airflow rates at each location. Ultrafine and fine particle source rates at the post-filter supply air were on the order of 10^11 to 10^12 #/h and exceeded 10^13 #/h at the outdoor air. Loss rates across the HVAC filter bank showed high variability during the campaign. As aerosol sensing becomes more widely available and accurate for smaller ultrafine particles, it is important to consider routine monitoring of indoor aerosols and to potentially utilize real-time particle number concentrations for mechanical ventilation control.

Monday, 12.06.2023 12:00-12:03 Room C Carbon

Performance assessment of low-cost indoor environmental monitors for comfort control systems in office environments

Zimianitis, Petros; Zheng, Hailin; Walker, Shalika; Kramer, Rick; Zeiler, Wim

Eindhoven University of Technology, Netherlands, The

ID: 1124 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: comfort control systems, air quality measurements, thermal comfort, sensor comparisons

To meet regulations and user satisfaction, the built environment implements building management systems and conditioning strategies through smart controls. Particularly office buildings, are leading this transition toward smart controls. However, occupant satisfaction of office buildings under indoor conditions is found to be less than 50%, while the indoor temperature is often controlled within tight temperature limits. This dissatisfaction is mainly due to the large inter-individual differences in thermal perception of the environment. To address this issue and to provide potential solutions, Comfort Control Systems (CCS) are being explored. These systems assess and optimize the indoor conditions through monitoring the conditions while obtaining occupant feedback. The devices used for monitoring are predominately low-cost indoor environmental monitors (LCMs). Although the performance of LCMs against high-quality monitoring instruments have tested before, studies on the applicability of LCMs under the context of CCS are still scarce. Therefore, this research investigates the performance of 14 LCMs and single sensors and discuss whether these devices can be used to provide input to CCS. Results showed that LCMs had limitations in achieving absolute accuracy. Despite that, their relative accuracy and ability to detect environmental changes is sufficient for use as part of a CCS in office buildings.

Monday, 12.06.2023 12:03-12:06 Room C Carbon

Developing of an infrared sensor based indoor occupant detection system using machine-learning algorithms

Rewitz, Kai; Seiwert, Paul; Kammerer, Vincent; Müller, Dirk

RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Germany

ID: 1286 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 07. Occupant behavior & controls
Keywords: occupant detection, infrared sensor, machine-learning, Convolutional Neural Network

This paper presents the development of hardware and software for real-time occupant detection in indoor environments. The hardware consists of a Raspberry Pi microcomputer and a FLIR Lepton 3.5 thermal sensor with a resolution of 120x160 pixel. A recording logic is developed, in which thermal data are pre-processed and stored in a cloud storage and locally on the computer. For occupant detection, we trained a Convolutional Neural Network (CNN) with a custom data set of 522 images, which consists of thermal images collected in an office environment. For the network architecture, an Inception V2 network is used and the principle of transfer learning is applied. The trained network yields information on room occupancy that can be used to improve control of the room climate system. The performance of the CNN is evaluated by Recall and Precision and Average Precision metrics. The CNN achieves an Average Precision of 97 % for a test dataset and 60 % for a more challenging validation dataset. The functionality and robustness are demonstrated in a field test for an open-plan office. The evaluation of the thermal data is conducted locally on the sensor system, so that no central computing unit is required to evaluate the sensor data.

Monday, 12.06.2023 12:06-12:09 Room C Carbon

Do Alcohols dominate the VOC measurement of low-cost sensors?

Schultealbert, Caroline (1); Baur, Tobias (1); Leidinger, Martin (1); Conrad, Thorsten (1); Amann, Johannes (2); Bur, Christian (2); Schütze, Andreas (2)

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ID: 1357 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: low-cost sensors, VOC, TVOC, monitoring, ventilation

In two different field studies in office and residential spaces low-cost VOC (volatile organic compounds) sensors based on metal oxide semiconductor sensors (MOS) are deployed and the impact of alcohols on their VOC signal is evaluated. This is done by analytical reference measurements showing that alcohols make up more than 75 % of the VOC concentration. Therefore, comparing low-cost sensor signals to classical TVOC analysis according to ISO16000-6 is not sufficient to validate the sensor performance. In the second field study a selectively trained sensor system in temperature cycled operation is used, yielding a Pearson correlation of 0.92 between measured ethanol and the sum of VOCs, showing that this gas explains most of the observed dynamics. Within this residential space cooking is found to be the dominant source. Both results help to understand the often-experienced high deviations between low-cost sensors and analytical reference methods. Apart from that the impact on existing recommendations for acceptable TVOC (total VOC) concentrations and their use in demand-controlled ventilation are discussed.

Monday, 12.06.2023 12:09-12:12 Room C Carbon

Blurred-eyed sensor, show me my exposure to indoor air pollutants.

REDON, Nathalie (1); UMBA KALALA, David (1); PINTO, Thibault (2); CRUNAIRE, Sabine (1); VERRIELE, Marie (1); FRERE, Séverine (2); HELLEQUIN, Anne-Peggy (3); LOCOGE, Nadine (1)

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ID: 1303 Extended Abstract
Topics: 07. Occupant behavior & controls, 09. Public health, occupational & environmental health
Keywords: air quality sensor systems; individual exposure; pedagogic indicators

Can multi-sensors help people to reveal their individual exposure to air pollutants? How to shape their individual data in a way they will better understand the sources and thus inspire them new good behaviours? The CERBAIR project aims to answer these questions through a field campaign carried out during 15 days in a highly urbanized district, with 30 participants little aware of air quality. They benefited from social interviews before, halfway, and after the experiment. They had to wear 24/7 a portable geolocated multi-sensor system able to monitor every 6 min temperature, relative humidity, and five air pollutants: CO_2, $PM^2.5$, VOC, NO_2 and O_3. These multi-sensor systems were previously metrologically qualified in laboratory in order to ensure the quality of the data. The system itself is completely indicator-free, whether digital or coloured. The only way for participants to consult their raw data was via a personalized access to a secure online platform. At the end of the campaign, the results were specially formatted in a pedagogic way, and delivered individually. The first shaping is usual: it is a three-level colour scale from green when all concentrations are below the first limit, to yellow and red, when at least one concentration exceeds the second or third limit. The second one is more original, rarely offered by usual air quality sensors: it quantifies the percentage of time passed under bad, medium et good air quality. Both designs allow participants to quickly and clearly understand which pollutants are the main sources of exposure, and above all, to quantify their part in their schedule. Profiles are very contrasted: from 57% of time under bad air for the worst case, to 83% of time under good air for the best one. For a same profile between two participants, the emitting activities can be very different: VOC emissions due to the furniture in the bedroom during the sleeping phase vs those due to diy. Without an individual logbook, it would not be possible to tell the difference. This is a limit of the current indicators.

Furthermore, these data are calculated a posteriori, which do not allow to act in real time. To conclude, this study shows that multi-sensors systems help to awaken the participants to the strong, often unsuspected part of indoor air quality in their exposure, but that the construction of effective indicators from the data they provide is still a work in progress.

Session 2 Monday Silver - Occupant behaviour

Time:
Monday, 12.06.2023 11:00-12:30

Room: Ag Silver

Chair:
Mahdavi, Ardeshir
TU Graz

Co-Chair:
Luna Navarro, Alessandra
TU Delft

Monday, 12.06.2023 11:00-11:15 Room Ag Silver

Investigation of window operation behaviour in naturally ventilated classrooms during the COVID-19 pandemic

Brumer Franceschini, Paula (1); Schweiker, Marcel (2); Oliveira Neves, Leticia (1)

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ID: 1223 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: Window operation, Occupant behaviour, Indoor air quality, Thermal comfort, COVID-19 pandemic

The COVID-19 pandemic has once again emphasized indoor air quality (IAQ) as a fundamental path for preventing airborne virus transmission, especially in indoor environments with increased ventilation needs due to high occupancy and long exposure time, such as school classrooms. In naturally ventilated classrooms, thermal and IAQ conditions are mainly affected by window operation. Therefore, this study addresses the window operation behaviour, the thermal conditions and the perceived IAQ in naturally ventilated classrooms in a humid subtropical climate during the COVID-19 pandemic. Window operation and environmental variables of classrooms were monitored in three school buildings. Generalized linear models were developed to establish correlations between window status, indoor conditions and COVID-19 restrictive measures. Thermal conditions and IAQ were adequate most of the time in all classrooms. Indoor operative temperature, relative humidity, CO2 concentration and COVID-19 restrictions were identified as drivers for window status in all schools. Yet, the results suggest that occupant behaviour is context dependent. Indeed, the school with the highest number of ‘closed’ status presented higher CO2 concentrations and more differences in seasonal behaviour. The other two schools presented a behaviour pattern more correlated with the COVID-19 restrictions, a higher number of ‘open’ status and more cold discomfort hours.

Monday, 12.06.2023 11:15-11:30 Room Ag Silver

Indoor environment in Danish apartments during the Covid-19 lockdowns

Andersen, Rune Korsholm; Rupp, Ricardo Forgiarini

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ID: 1354 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Temperature, Dwellings, heating

A large part of the population was forced to work from home due to the COVID-19 pandemic and the measures taken to reduce its' spread. To investigate the effects of the lockdowns, on the indoor environment, data from 1068 apartments in four departments was analysed using linear mixed-effects.

The measurements included indoor temperature, relative humidity and CO2 concentration measured in 5-minute intervals from January 2018 to January 2022. Hourly outdoor temperature and wind speed was acquired based on the closest weather stations.

The indoor environmental parameters were modelled based on both indoor and outdoor conditions. Models of temperature, relative humidity and CO2 concentration were developed separately based on data from each department. Forward selection was used to select variables based on BIC. The severity of the lockdown periods was defined using the "COVID-19: government Stringency Index" from the Oxford COVID-19 Government Response Tracker.

The indoor temperature was positively correlated with the stringency index.

In the department without mechanical ventilation, the CO2 concentration was positively correlated with stringency. The correlation was negative in departments with mechanical ventilation.

The relative humidity was lower in periods with high stringency than with low stringency. This could be a result of other seasonal effects.

Monday, 12.06.2023 11:30-11:45 Room Ag Silver

Optimizing Automated Shading System by Exploring Occupant Behaviour and Comfort in Office Environment: An Experimental Study

Derbas, Ghadeer Abdallah (1,2,3); Voss, Karsten (2)

1: Palestine Technical University – Kadoorie, Palestine; 2: Wuppertal University, Germany; 3: Forschungszentrum Jülich, Germany

ID: 1137 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Automated shading system, Occupant behaviour, Thermal performance, Visual performance, User satisfaction, User preferences

This paper presents an experimental study conducted in a full-scale test cell "btga-box" from July until September 2020 at Haspel Campus in Wuppertal, Germany. This study aims to explore and evaluate the consistency of occupant interaction with automated shading systems, occupants' satisfaction with shading performance in office environments, and the underlying thermal and visual conditions under different scenarios (e.g., shading control strategies, window size, cooling system, time of the day, and sky conditions) for optimal shading design solutions (i.e., less override actions). Six different scenarios with repeated measures are evaluated using several performance metrics, then compared in paired groups using sample t-test statistical analysis. Twenty-eight participants of varying ages, gender, and ethnicity took part in the experiments. After each scenario, the participants were asked to complete a web-based questionnaire, reporting their behaviour, thermal and visual comfort perception, satisfaction, and preferences concerning the automated shading system. Concurrently, indoor environmental parameters, weather data, system, and user-triggered actions were recorded. The key findings of this study suggest that a robust shading system (i.e., few override actions) can be achieved by: a multi-objective control strategy with an intermediate position, an acceptable range of irradiance thresholds, and a decent level of adaptive control options over the workplace. Providing good cooling and ventilation systems (i.e., window opening and ceiling fan usage) can improve user satisfaction with the indoor environment, including shade operation. Using a window-to-wall ratio (WWR) of 40% increase the frequency of shade-raising actions by 24% compared to WWR=75%. However, a small window size combined with a high irradiance shade lowering threshold (450 W/m²) decreases the shade raising actions by 49% compared to the low irradiance threshold (300 W/m²).

Monday, 12.06.2023 11:45-12:00 Room Ag Silver

A cross country survey on occupants' use of natural ventilation in Brazilian homes

Buonocore, Carolina; André, Maíra; Castro, Luiza; De Vecchi, Renata; Lamberts, Roberto

Federal University of Santa Catarina, Brazil

ID: 1433 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 07. Occupant behavior & controls
Keywords: Natural ventilation, Brazilian homes, Thermal comfort

Natural ventilation (NV) is a default conditioning strategy in Brazilian residences, despite diverse weather conditions across the country. However, this sector's air conditioning (AC) energy consumption increased three times in the last 12 years and continues to grow. To better understand usage patterns and their motivations, a National Survey was carried out in late 2021—the survey aimed at identifying the most common conditioning strategies in homes and usage drivers. The survey reached 1,348 responses, and the sample is presented along with the latest National Electrical Appliances Possession and Usage Habits Research for the Residential Sector (PPH) sample. Results show that NV, AC and fan usage patterns vary across Brazilian regions, although NV is predominant in all regions. Constant NV use is less common, and frequent fan use is recurrent in Northern (hottest) regions. Higher-income leads to more frequent use of AC and less frequent use of fans. The main motivations to adopt NV are similar in all regions: personal preference, energy savings, and air renewal. Results reinforce that the multiple benefits of NV are perceived by participants and favour its adoption in Brazilian residences, although AC or fans are eventually required to maintain thermal comfort.

Monday, 12.06.2023 12:00-12:03 Room Ag Silver

Agent-based modeling for occupant behavior representation in building performance

Malik, Jeetika (1); Hong, Tianzhen (1); Mahdavi, Ardeshir (2); Berger, Christiane (3); Ouf, Mohamed (4)

1: Building Technology and Urban Systems, Lawrence Berkeley National Laboratory, USA; 2: Institute of Building Physics, Services, and Construction, Faculty of Civil Engineering Sciences, TU Graz, Austria; 3: Department of Architecture, Design and Media Technology at Aalborg University, Denmark; 4: Department of Building, Civil and Environmental Engineering, Concordia University, Canada

ID: 2484 Extended Abstract
Topics: 07. Occupant behavior & controls
Keywords: occupant behavior, agent-based modeling, building performance simulation, occupant representation

Agent-based modeling (ABM) is an advanced computational technique that offers considerable potential to support occupant-centric building design and controls through realistic emulation of human processes and behaviors. Given reliable empirically-based data, ABM can capture human behavior and behavior feedback, thereby representing the reasoning and decision making processes underlying human–building interactions. Moreover, this bottom-up modeling approach can produce the effects of collective behavior that emerges from individual-level occupant interactions. The proposed workshop is targeted at architects, engineers, energy modelers, facility managers, and building science researchers to develop an understanding of agent-based occupant models for improving the predictive performance of building simulation thereby supporting energy efficient, demand flexible, and climate resilient buildings. The participants will be informed about the applicability of ABM among different building lifecycle phases or spatial scales, methodological insights on the simulation approaches or data requirements, as well as guidance on choosing the optimal resolution of the occupants' representation for different use cases. Moreover, a case study demonstrating the programming of occupant agents, developing ABM, and co-simulation with a building energy model will be also presented.

Monday, 12.06.2023 12:03-12:06 Room Ag Silver

Influence of personal comfort systems operability on thermal comfort and workplace productivity

Aono, Kazuki (1); Ukai, Masanari (1); Takehara, Daiki (1); Tanabe, Shin-ichi (1); Kimura, Kentaro (2); Shimizu, Akihiro (2); Aizawa, Naoki (2); Muto, Yuka (3); Hatori, Daisuke (3)

1: Waseda University, Japan; 2: Takasago Thermal Engineering Co.,Ltd, Japan; 3: Mitsubishi Jisho Design Inc., Japan

ID: 1176 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 07. Occupant behavior & controls
Keywords: Personal Comfort Systems, Operability, Thermal Comfort, Workplace productivity

In recent years, the number of offices introducing personal comfort systems (PCS) has increased to improve workers' comfort, workplace productivity, and energy conservation. However, in some offices, the complexity of the PCS operation, caused by sophistication, discourages workers from using the PCS. Considering this background, this study aims to investigate the influence of the PCS operability on their usage rate, evaluation of the thermal environment and workplace productivity. A measurement survey was conducted with three types of PCSs with the same performance but different operational types. The results of the PCS usage rate show that the PCS is more likely used at high ambient operative temperatures. It was also found that as PCS operability evaluation improves, the usage rate also increases significantly. As a result of the correlation analysis, the PCS operability evaluation was significantly correlated with thermal environment satisfaction, influence on working efficiency, and subjective-work ability. Based on the above observations, it was confirmed that improving the operability of PCS enhances the evaluation of thermal environment and workplace productivity, as it allows office workers who feel thermal discomfort to freely use PCS.

Monday, 12.06.2023 12:06-12:09 Room Ag Silver

Developing a Framework to Assess the IEQ and Occupants' Comfort and Behaviour in Residential Buildings: A Pilot Study

Cao, Yuan; Touchie, Marianne; Lee, Seungjae

University of Toronto, Canada

ID: 1272 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Occupant Comfort, Occupant Behaviours, Indoor Environmental Quality (IEQ), Residential Buildings

Occupant comfort in buildings has been widely studied in academic research. Prior studies have established that commercial buildings can significantly impact occupant comfort and behaviours. However, similar investigations of the impact on occupants in residential buildings, where people spend over 65% of their time, are less common in the literature. The reasons behind the lack of comprehensive residential studies could be the wider range of potential influencing factors on residential occupants, the higher degree of interaction between occupants and building controls compared to other building types, and the challenges related to long-term monitoring in occupants' homes, particularly in a way that is unobtrusive. Therefore, this study proposes a new, comprehensive framework to both subjectively and objectively assess the impact of residential buildings on occupants' comfort and behaviours by deploying a combination of seasonal long-form surveys, real-time residents' feedback collection via smartwatches, as well as continuous indoor environmental quality (IEQ) and behaviour monitoring using sensors. Findings and lessons learned from a pilot study are discussed, which provides valuable insight for future studies.

Monday, 12.06.2023 12:09-12:12 Room Ag Silver

Sensitivity Analysis of Occupant Behavior in energy models for data driven design decisions

Verghese, Sharon Susan; Hartmann, Timo

Technische Universität Berlin, Germany

ID: 1316 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Occupant behavior, sensitivity analysis, data driven decisions

Occupant behavior is a complex aspect to capture in energy modeling. Performance prediction gap is a major hurdle for energy efficient design of buildings and a part of it could possibly be attributed to inefficient modeling of occupants. Current practices involve occupant behavior analysis in post construction stages, however incorporating occupant behavior onto early design stages are based on assumptions and pre-defined. The framework developed within this paper aims to incorporate a deterministic model of occupant behavior in energy models, simulate varying occupancy and occupancy related operational parameters, assess space based sensitive occupant centric parameters to derive occupant based, energy efficient design decisions in early design stages. This framework has been developed to aid targeted users like energy modelers, consultants and designers to use this automated, data driven, adaptable and scalable framework to capture occupant centric decisions. The results derived from the implementation of the framework has been demonstrated on a residential project undergoing renovation, during the design phase of the project. Despite the complex nature of occupant behavior, this framework demonstrated aims to provide a comparatively less computationally expensive strategy to implement sensitivity analysis and decisions based on occupant presence onto early stages of design in buildings.

Session 3 Monday Oxygen - Mould & humidity

Time:
Monday, 12.06.2023 11:00-12:30

Room: O2 Oxygen

Chair:
Wiesmueller, Gerhard A.
Zentrum für Umwelt, Hygiene und Mykologie Köln

Co-Chair:
Luo, Wei
Maastricht University

Monday, 12.06.2023 11:00-11:15 Room O2 Oxygen

Assessing the hygrothermal performance of dormer attics for energy retrofit risk

Liu, Ying; Considine, Brian; McNabola, Aonghus

Trinity College Dublin, Ireland

ID: 1178 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Dormer attics, Hygrothermal performance, energy retrofit, insulation, ventilation

To cope with challenges caused by fuel poverty and provide a healthier indoor environment, the national agencies have launched several building retrofit schemes for energy efficiency improvement in different categories. However, dormer-type dwellings currently do not qualify for such schemes due to a conflict between the required insulation and the need to maintain attic ventilation. This research analyses the hygrothermal performance of a case study Irish dormer bungalow using WUFI software. Firstly, this research simulated the hygrothermal performance of the original house with no dormer attics and compared it with the data recorded by sensors in the place for model calibration. Then proposed retrofit scenarios were assessed, adding one occupied dormer room in the attic. The hygrothermal performance of the room and roof materials of three different roof insulation scenarios was analysed. The simulation results show that adding a roof ventilation cavity lowly influences the dormer room hygrothermal conditions. However, the ventilation rate in the roof cavity can reduce the temperature and increase the RH% of the insulation material. This research also shows that a reduction in the cavity from 50 to 25 mm makes only a 2% change in temperature and RH% of the insulation material, approximately.

Monday, 12.06.2023 11:15-11:30 Room O2 Oxygen

Modeling the full cycle of air-born spores in buildings

Ajib, Hiba (1,2,3); Wall-Ribot, Bénédicte (1,3); Labbé, Sébastien (1,3); Abadie, Marc (2,3); Limam, Karim (2,3); Duforestel, Thierry (1,3)

1: EDF R&D, Moret-sur-Loing, France; 2: Laboratory of Engineering Sciences for the Environment LaSIE (UMR CNRS 7356), La Rochelle University, France.; 3: 4evLab, CNRS, La Rochelle University, Electricité de France EDF, Avenue Michel Crépeau, 17042 La Rochelle Cedex 1, France

ID: 1375 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: air-born spores, mold growth, indoor air, modeling, office and residential buildings

Predicting mould growth in buildings is essential to avoid environmental, financial and health damage. It is an important factor in evaluating indoor air quality through the quantification of spores emitted by the fungal colonies. Most of the spores that are found indoors are transported from outside either by ventilation or by the occupants and in favourable conditions these spores germinate, grow and emit spores indoors. The aim of this paper is to model the full cycle of air-born spores from their exchange between indoor and outdoor environments to their deposition on indoor surfaces, germination, growth, and multiplication. Two mould growth models, i.e., the VTT and the isopleth models, are implemented in 0D/1D components in the BuildSysPro QAI library to evaluate the mould contamination on surfaces. Three different air change rates (ACR) are considered to study their effect on mould formation (0.5 h^{-1}, 0.3 h^{-1} and 0.2 h^{-1}). The mould index and the mycelium length are compared in these three scenarios. The results show that even at a very low air change rate (0.1 h^{-1}), resuspension of spores from the floor does not have a significant impact on the concentration of spores in the air.

Monday, 12.06.2023 11:30-11:45 Room O2 Oxygen

Exploring Effects of Environmental Factors on Pollutant Exposures via PM Monitoring and Microbial Analysis of Home Dust

Jarma, David A; Maestre, Juan Pedro; Kinney, Kerry

University of Texas, United States of America

ID: 1438 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Dust, Microbiome, PM Monitoring, Pollutant Exposure

Particulate matter (PM) measurements are often used as an indicator of indoor air quality. A more thorough understanding of air quality, specifically pollutant exposure, can be found when PM2.5 measurements are used in tandem with microbial analysis of collected dust.

Inhalation of airborne particles is a route of exposure for many microbial, chemical, and other pollutants. Within the home, these particles are removed from the air by the filter in the HVAC system and settle out of the air in the form of dust that accumulates on surfaces. Reservoirs such as these provide a unique insight into the composition of pollutants present in the home over an extended period of time. In any given home, environmental factors such as pets, flooring types, furniture materials, cleaning practices, and many others can influence the composition of the air. While these long-term samples cannot indicate if concentrations are immediately harmful to occupants, they provide insight into the long-term pollutant exposures present in the home. Many respiratory diseases have been associated with extended exposures to pollutants, so the mitigation of these exposures within the home is crucial for sustained occupant wellbeing.

In this study, dust samples, environmental swab samples, and survey data were collected from 45 homes in the Austin area. Additionally, a Bevo Beacon in the home collects PM2.5 concentrations continuously for about a month before these samples are collected. Environmental swabs were collected from locations strategically located to provide information about the microbial exchange between indoors and outdoors. The survey collects information about cleaning practices, materials in the home, occupants and pets, and cooking practices, among others.

This ongoing study aims to investigate the links between environmental factors in the household, airborne PM concentrations, and the microbiome associated with them. Combining physical dust samples, environmental monitoring, and surveying will aid in identifying factors that may influence the indoor microbiome and the concentration of

PM within the home. Sample analysis, including DNA extraction and sequencing, will allow us to explore relationships between household factors and specific microbiota. This work aims to expose factors that influence indoor exposures to household pollutants, airborne PM concentration, and indoor microbiome with the ultimate goal of mitigating harmful long-term exposures directly at their sources within the home environment.

Monday, 12.06.2023 11:45-12:00 Room O2 Oxygen

Potential microbial growth on bio-based insulation materials and their ability to emit microbial volatile organic compounds

ZINE-FILALI, Nouha (1); BRAISH, Tamara (2); LOCOGE, Nadine (2); ANDRES, Yves (1)

1: IMT Atlantique, France; 2: IMT Nord Europe, France

ID: 1404 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Fungi, mVOC emissions, aging process, bio-based insulation materials, antifungal treatments

Nowadays, bio-based insulation materials are increasingly used in building renovation and new construction due to their ecological and hydrothermal performance. However, in the presence of a humid and hot climate (T= 25°C and RH = 95%), these materials can be subject to microbial growth. This can lead to their physico-chemical aging and thus affect their insulation performance. Moreover, microbial growth can also affect indoor air quality (IAQ) through the emission of microbial Volatile Organic Compounds (mVOCs) and fungal spores.

The aim of this study is to evaluate the ability of bio-based materials to promote fungal growth before and after the aging process and to investigate the potential mVOC emissions. To this end, a hemp-flax-cotton insulation material was subjected to a 3-month accelerated aging process. This process consists of repetitively exposing the material to one week of dry conditions (T= 25± 0.8°C, RH=11± 4%) followed by another week of wet conditions (T= 25± 0.8°C, RH= 60± 2%) for 3 months. The native and aged materials were inoculated by fungal spores using a dry aerosolization system prior to incubation (T= 27± 2°C, RH= 95± 1% for 30 days). Developed fungi were then quantified using the cultured cell method.

VOC/mVOC emissions from the inoculated incubated material were characterized in a glass scrubber bottle. Sampling occurred after 24 hours of incubation (before inoculation) and then after 3, 7, 9, 15, and 30 days of inoculation and incubation. The identification and quantification of the emitted compounds were carried out using gas (TD-GC-MS/FID) and liquid (HPLC) chromatography.

At the microbial level, the results showed a proliferation of inoculated mold on the surface of the native and aged material, where the concentration of the developed spores was 5± 2 x 102 times higher than the initially deposited spore concentration.

Regarding VOC/mVOC emissions, the hemp-flax-cotton material was noted as a very low VOC emitter with emission rates (ER) ranging from 1 to 7 µg m^{-2} h^{-1} on the 1st day of incubation. Thereafter, the ER of the 58 detected VOCs decreased with the incubation process while 7 other compounds newly appeared (ER = 0.1-5 µg m^{-2} h^{-1}) after 7 days of inoculation and incubation. The ER of the 7 new compounds was noted to be the most intense on day 9 and then this rate continued to decrease until the depletion of some compounds after 30 days of incubation.

Monday, 12.06.2023 12:00-12:03 Room O2 Oxygen

HUMIDITY IS AN INDISPENSIBLE PARAMETER OF INDOOR AIR QUALITY

Hugentobler, Walter

École Polytechnique Fédérale de Lausanne, Switzerland

ID: 1413 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: IAQ parameters, humidity impacts, moisture needs of occupants, indoor dryness

Buildings should meet our individual and societal needs such as protection from the elements, security, privacy, comfort, productive work and - undoubtedly most important - promote health. "Healthy Buildings" should address and include the needs of vulnerable individuals with common respiratory diseases and risk factors. These requirements cannot be met without maintaining moderate humidity as a characteristic of good indoor air quality. The notion that very dry indoor air does not harm the health of building occupants must be adjusted based on recent study results.

This article addresses the situation in temperate climate and the humidity effects on the human respiratory tract. It does not refer to the effects of humidity on the transmission dynamic and on the infectivity of expectorated aerosols with airborne transmissible respiratory viruses and bacteria.

Monday, 12.06.2023 12:03-12:06 Room O2 Oxygen

Bio-based insulating materials and their influence on Indoor Air Quality

TINEL, Liselotte (1); Braish, Tamara (1); Delpechin, Laurence (1); Caudron, Cécile (2); Nadine, Locoge (1)

1: IMT Nord Europe, France; 2: Cerema, France

ID: 1151 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: VOC, bio-based materials, construction material, emission

In the current context of climate change, and as a highly emissive sector, the construction sector has set in profound changes. One of these changes implies the development and use of bio-based materials, and particularly for insulation materials, bio-based products already represent a large part of the market. Bio-based insulation materials reduce their carbon footprint by incorporating biological fibres, such a hemp, wool or wood, hence reducing the use of high energy demanding mineral counterparts.

Due to their high organic content, bio-based materials can form a considerable source of Volatile Organic Compounds (VOCs) and may offer a favourable environment for the development of micro-organisms. The project Emibio was undertaken to evaluate the contribution of these new insulation materials to IAQ, and more specifically, which and how much VOCs they emit and if they offer a favourable environment for microbial development. Here we focus only on VOC emission.

To verify the influence of these materials on the IAQ, a recent public building was selected, constructed using bio-based materials. The experimental room in the school, located in the North of France, had 3 exterior walls made of wooden modules, containing 36 cm blown-in cellulose insulation and covered with plasterboard. The emissions of these materials were monitored in-situ but also measured from each of the materials individually in a test chamber.

In-situ sampling was done on adsorbent tubes and cartridges using a Field and Laboratory Emission Cell. VOC emissions from new materials were monitored in a Climpaq test chamber under controlled conditions of temperature, humidity and air exchange rate, following the ISO 16000 standards. The analyses for both sample types was done by chromatography techniques.

The measurements in the test chamber showed that the most emissive element in the wall was the OSB wood panel, followed by the wood used for the frame ([TVOC] = 239 and 184 µg m^{-2} h^{-1} eq. toluene resp.). Slightly lower TVOC concentrations were obtained for the cellulose insulation (109 µg m^{-2} h^{-1} eq. toluene). The emissions from glass wool, a conventional insulation material, were also measured as a reference ([TVOC] = 3.5 µg m^{-2} h^{-1} eq. toluene). VOCs measured in the test chamber were however not necessarily found in the samples taken in-situ nor were they major contributors to the VOCs measured in the ambient air of the room. This study puts the contribution of individual material emissions in perspective and underlines the importance of the history of use of the materials.

Monday, 12.06.2023 12:06-12:09 Room O2 Oxygen

The effect of energy retrofits on indoor microbiota

Kempe, Minna (1); Haverinen-Shaughnessy, Ulla (1); Täubel, Martin (2)

1: University of Oulu, Finland; 2: Finnish Institute for Health and Welfare, Finland

ID: 1342 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: microbiota, energy retrofit, settled dust, amplicon sequencing, exposure

Evidence suggests that the microbial content of the indoor environment has importance to human health. It is already well known that moisture damage causing microbial growth in buildings may have harmful health effects. More recent lines of evidence suggest that indoor microbes can also be beneficial to human health, especially considering early childhood exposures and asthma and allergy outcomes later in life. The urgent need for energy saving is more obvious today than ever before, and is a particularly pressing issue for buildings, triggering the construction of highly energy-efficient buildings and energy retrofits of the existing building stock. There are large gaps in our understanding of how such energy efficiency measures impact indoor exposures and ultimately human health.

We would like to present results on how energy retrofits in apartment buildings affect the indoor microbiota. We will utilize data collected in the project INSULATE (2010-2015), which studied the effects of energy retrofits on IAQ and occupant satisfaction in 240 apartments located in Finland and Lithuania. Case and control buildings were selected from volunteering multi-family buildings. Alongside monitoring of a multitude of other exposure factors, settled dust samples were collected in the main living areas before and after retrofits and analyzed for selected groups of fungi and bacteria using quantitative PCR, as well as with bacterial and fungal amplicon sequencing. Earlier analyses of the quantitative PCR data have revealed that both fungal and bacterial concentrations were significantly decreased in Finnish buildings after, as compared to the situation before the retrofits.

Currently, the bacterial and fungal sequencing data derived from the INSULATE dust samples are being analyzed. With this new dataset, we will be able to answer questions on how energy retrofits may affect the indoor microbiota compositionally and structurally. The removal of old building materials, cleaning activities, improved ventilation, and decreased infiltration of outdoor air after the retrofits could contribute to changes in microbial content. The size of such possible effects will determine whether energy retrofit associated changes in indoor microbiota are visible against the strong background of other sources and determinants of indoor microbiota. Due to the extensive data collected, INSULATE study is perfectly positioned to explore other factors, such as occupant behavior, building properties, various indoor particle and chemical exposures, and outdoor climate, in relation to the microbiota of apartments. Such analyses will be presented at the Healthy Buildings 2023 conference.

Monday, 12.06.2023 12:09-12:12 Room O2 Oxygen

In Vitro Test System for Assessing the Health Effects of Indoor Mould

Wolff, Anja (1); Klar, Stefanie (1); Reinert, Jessica (1); Valtanen, Kerttu (2); Jäckel, Udo (1)

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ID: 1198 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: Indoor mold, extracts, cell viability, cytokine release

Indoor mould is a common problem worldwide, affecting on average 16 % of European housing (Haverinen-Shaughnessy, 2012; Norbäck et al., 2017). In this context, respiratory health problems are repeatedly reported (Mendell et al., 2011) suggesting that continuous inhalative exposure to mould increases the risk of respiratory diseases like asthma (Heseltine et al., 2009; Sahakian et al., 2008). There are currently no limit values for assessing the health risk of indoor mould exposure, to address the problem a potential in vitro test system was developed in this study.

Conventional building materials, gypsum boards and wallpaper, as well as malt extract agar were inoculated with four different indoor mould species: Alternaria botrytis, Aspergillus versicolor, Penicillium chrysogenum, Stachybotrys chartarum. Extracts were prepared from overgrown material pieces (material extract) or from material surface (spore extract). Cytotoxic and immunological effects were investigated using lung epithelial cell line NuLi-1 and differentiated monocyte cell line THP-1. Cell viability was assessed after 24 h and over 48 h. Immunologically, the cytokines granulocyte-macrophage colony-stimulating factor (GM-CSF) and interleukin-1ß (IL-1ß) were examined in NuLi-1 and in THP-1 macrophages, respectively.

A. botrytis and A. versicolor showed no significant effects on cell viability and cytokine release when extracted from all three material types compared to the control. Gypsum boards and wallpaper extracts of P. chrysogenum also showed no effects. In contrast, material and spore extracts of agar showed toxic effects, resulting in toxicity over 66 % on average for NuLi-1 and THP-1 after 24 h as well as reduction in GM-CSF concentration and increase in IL-1ß concentration compared to the control. The extracts of S. chartarum showed the highest effects with a toxicity of 80 % or higher for gypsum boards and wallpaper. However, the spore extracts of agar showed a lower toxicity to the other material types, possibly due to lower measured spore density. To further investigate the cell effects of aerosolised mould components an experimental set-up was established. Here, the inoculated materials were placed in an exposure chamber and surface components released by an air stream, collected on quartz fibre filter followed by extraction as well as cytotoxic and immunological investigations.

In summary, the results of GM-CSF and IL-1ß concentration match the results of cell viability. The test system could detected differences between different mold species, material types and extracts and showed that indoor contaminated with S. chartarum could present a potential health risk to humans if inhalatively exposed.

Monday, 12.06.2023 12:12-12:15 Room O2 Oxygen

Supporting occupants in homes with mold growth - Findings from a Danish advisory service

Aalling, Lenette; Gunnarsen, Lars

Aalborg University, Denmark

ID: 1310 Extended Abstract
Topics: 07. Occupant behavior & controls
Keywords: Mold, fungi, indoor environment behavior, advisory service, occupants

Problems with moldy homes have always existed. Research in building physics and mycology constantly makes us wiser on how to avoid fungi in constructions and the indoor environment – as well as the potential dangers of exposure. Yet we still encounter Aspergillus versicolor and Tricoderma viride, just to mention a few of the indicators of moisty buildings.

So how do we improve the dissemination of knowledge and raise awareness, and bridge the gap between science and practice?

Molds only live in buildings where the construction or surfaces are or have been humid. This can either be caused by construction faults or poor maintenance, and/or from the way occupants use the building.

At the research group on Indoor Health Impacts at Aalborg University, we therefore focus on advising those closest to the problem: occupants and operating staff of multifamily buildings.

Since 2008, we provide a science-based, inter-disciplinary mold advisory service. Answering questions by phone and email gives us a unique and detailed knowledge of people’s everyday challenges in maintaining a healthy and mold-free indoor environment.

Occupants contact the service when they have a concrete issue with mold in their home and are therefore motived to take action. And they appreciate receiving advice related to their specific situation – whether they seek information on removing mold, preventing it from reappearing, or advice on how to escalate issues with lacking maintenance.

This coincides with findings in a study on influencing occupants’ indoor climate behavior. The research was carried out as an offshoot from the advisory service and published as BUILD Rapport No. 2020:18. Key take-aways are that changes in indoor behavior do not take place ‘just’ by presenting written knowledge and making information campaigns. Instead, it is a matter of meaningfulness, timing, in-person communication and ‘praxis campaigns’.

In 2021, 20% of our enquiries were related to avoiding mold. Advice on changing indoor behavior was however part of our advice in almost 26% of all enquiries.

Our advice always takes into account the physical conditions of the actual building. In some buildings however, practicing what - from a building physics perspective - is considered appropriate indoor environment behavior is not enough. In 2021, we referred occupants to the operating staff or building owner in almost 13% of all enquiries. An important learning on how to support occupants in moldy homes is therefore that the responsibility for the indoor environment quality is not solely on the occupants!

Session 4 Monday Carbon - IAQ

Time:
Monday, 12.06.2023 14:00-15:30

Room: C Carbon

Chair:
Adlington, Martin Donald S
University of Derby

Co-Chair:
Bardey, Janine
Heinz Trox Wissenschafts gGmbH

Monday, 12.06.2023 14:00-14:15 Room C Carbon

Evaluation of indoor environmental quality and pupils' satisfaction in Flemish primary schools

Carton, Quinten (1); Mennes, Filip (2); Vanden Broeck, Sander (1); Van Roy, Vincent (1); Kolarik, Jakub (3); Breesch, Hilde (1)

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ID: 1464 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Indoor environmental quality, Occupant satisfaction, Classrooms, Nature of Science

Children spend much of their time in classrooms, which often have an unsatisfactory indoor environmental quality (IEQ). Unsatisfactory IEQ conditions could hamper pupils' learning performance. Therefore, it is important to provide IEQ conditions which meet the pupils' needs. This study evaluates the IEQ and pupils' satisfaction in 7 primary school classrooms. 6-week long data collection campaigns were performed during heating season and within the frame of a citizens' science project. Data collection consisted of both IEQ monitoring and satisfaction assessments. The following IEQ parameters were monitored: CO2-concentration, air temperature, relative humidity, sound pressure level and lighting level. Pupils' satisfaction and knowledge on nature of science (NoS) was assessed using both right-here-right-now and retrospective surveys. The collected data was used to (1) evaluate the classrooms' IEQ, (2) asses pupils' satisfaction with IEQ, and (3) validate a recent developed questionnaire to determine pupils' NoS. Results show that the classrooms' IEQ often violates guideline values, especially too low room temperatures were found. Furthermore, the satisfaction assessments indicate frequent dissatisfaction with the acoustic (18.4%), IAQ (16.5%) and thermal (11.7%) conditions in the classroom. Lastly, the validation of the NoS questionnaire showed insufficient internal consistency in the subscales of the questionnaire.

Monday, 12.06.2023 14:15-14:30 Room C Carbon

Comparison of the resilient performance of different ventilation strategies in Belgian elderly care homes

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ID: 1116 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Ventilation resilience, elderly care homes, natural ventilation, mechanical ventilation, indoor air quality

Elderly people in nursing homes spend most of their times in common areas, to allow for socialization and interaction. During shocks (e.g., power outages), contaminants' concentrations peak to unacceptable levels leading to acute exposure. Given the vulnerability of elderly residents, this may adversely affect their quality of life and increase medical expenditures. Ventilation systems are installed to absorb shocks. The aim of this work is to compare the ventilation resilience of 5 typical ventilation strategies (natural ventilation, extract, and balanced mechanical ventilation) in common rooms in Belgian elderly care homes against three types of shocks: (i) mechanical (MS) (ii) internal (IS) and (iii) outdoor shocks (OS). The resilience performance was assessed using three different indicators: ppm.hours, shock absorptivity and restoration times. A new indicator, the Resil. Score metric was also defined. The higher the score the worse the resilience. Results showed that for any MS, balanced mechanical ventilation had the best resilience (Resil. Score = 0.035-0.13). For IS, smart extract ventilation had the best resilient (Resil. Score = 0.071-0.082). For severe IS and OS, balanced mechanical ventilation had the best resilience (Resil. Score = 0.052-0.188). However, for severe OS, smart extract ventilation has the best resilience (Resil. Score = 0.242).

Monday, 12.06.2023 14:30-14:45 Room C Carbon

Algorithms for online CO2 baseline correction in intermittently occupied rooms

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ID: 1355 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Sensor auto-calibration, indoor air quality, data quality, CO2 sensors, CO2 monitoring

CO2 sensor data is often applied for Demand Controlled Ventilation (DCV), Indoor Air Quality (IAQ) assessment, and occupancy detection. In room controllers, the auto-calibration function shifts the zero level so that the measurements would not drift off. However, this creates jumps in data and sometimes values below outdoor CO2 level. If the data is further used, occupancy is detected differently, the ventilation would not function as designed, and the assessment would result in different IAQ class certificates. Therefore, in this work, a statistical method to correct the CO2 baseline automatically in real time was developed based on measurements from a school building in Estonia in 56 different rooms. The school had balanced heat recovery ventilation that assured adequate ventilation. During the process, the performance of different algorithms and parameters for the correction were compared. The CO2 concentration baseline correction algorithm was realised using the 1% percentile and 10-hour sliding time window as an optimal compromise to correct the base level to 400 ppm and the algorithm performed well based on qualitative assessment. The impact of the algorithm was significant when comparing the initially logged and corrected values against CO2 concentration thresholds 550, 800, and 1000 ppm.

Monday, 12.06.2023 14:45-14:48 Room C Carbon

Evaluation of a nursing home by a mobile measurement pillar to record indoor ergonomics via sensors and questionnaire

Bardey, Janine (1,2,4); Burgholz, Tobias (1,2,3); Rewitz, Kai (3); Müller, Dirk (2,3)

1: shared first authorship, authors contributed equally to the presented work; 2: Heinz Trox Wissenschafts gGmbH, Aachen, Germany; 3: RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate, Aachen, Germany; 4: Research and teaching area Healthy Living Spaces, Institute for Occupational, Social and Environmental Medicine, Medical Faculty, RWTH Aachen University, Germany

ID: 1144 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: indoor ergonomics, participant studies, field study, indoor comfort, nursing home

Physical indoor conditions are important for user satisfaction, well-being, health, and performance. To ensure good indoor conditions as well as consider energy efficiency, methods for collecting field data are needed. Accounting for the climate crisis including more frequent heat waves, vulnerable groups like sick or elderly people, and groups performing physical work such as caregivers require special attention.

Aim of this long-term study is to facilitate the collection of field data including both objective sensor data and subjective user feedback. It introduces the HTxCube, a mobile measurement pillar for evaluating occupant comfort regarding air quality, thermal, visual, and acoustical effects by using a questionnaire and sensors. The questionnaire covers perception, evaluation, and preference for the aforementioned aspects of indoor ergonomics, demographic data, activity, clothing, and whereabouts. Sensors record air and radiation temperature, relative humidity, illuminance, sound pressure level, and concentrations of CO_2, particles, and volatile organic compounds.

Preliminary results collected in two nursing homes among participants between 16 and 100 years are shown. Temperatures ranged from 13.4 °C to 30.4 °C (mean: 22.9 ± 2.8 °C), leading to thermal perception, evaluation, and preference reaching both extremes of the questionnaire scales. At higher temperatures, employees prefer lower temperatures compared to residents.

Monday, 12.06.2023 14:48-14:51 Room C Carbon

Development of a CO2-based indoor air quality measurement box for classrooms

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RWTH Aachen University, Germany

ID: 1155 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: CO2, Air quality, Covid-19, Sensor calibration, Relay control

Since the spread of the Covid-19 pandemic, CO2 as an indicator of indoor air quality has gained attention and serves as a proxy for the air exchange rate. Based on CO2 measurements, calculations to estimate and predict potential infection risks have been developed. This paper describes the development, construction, and calibration procedure of an indoor air quality measurement device for schools as well as residential settings based on the ESP32 microcontroller ecosystem and corresponding sensor technology. Based on real-time CO2 levels, the device can also control ventilation systems via an external relay. It does not require any network- or gateway connections, and runs self-sufficient with a lithium polymer (LiPo) battery for up to four weeks, ensuring flexible installation and data security. Data is stored locally in non-volatile memory (FLASH). Each device has two CO2 sensors, which may be placed inside the sensor box housing or at extend positions spread one meter apart. The use of Auto Self Calibration (ASC) lead to mismatching results. So, Forced Re-Calibration (FRC) was used to minimize relative device deviation, combined with calibrations to DWD/ICOS measurement station Hohenpeißenberg, Germany (HPB). This allows sufficient calibration on the one hand and minimizes differences between sensor outputs on the other.

Monday, 12.06.2023 14:51-14:54 Room C Carbon

A Digital Twin of an Operating Theater

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ID: 1311 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: Operating Theater, CFD, ROM, Digital Twin

This study is an example of the possible use of the Reduced Order Model (ROM) in air quality management in an operating theatre. We present a steady-state CFD simulation to obtain, in real-time, the variables of interest associated with any change in the room conditions. This is possible by means of a Digital Twin (DT) obtained by a ROM using a Singular Value Decomposition (SVD) compression algorithm. The workflow adopted to build the DT of the operating theatre is defined considering its importance not only for design and maintenance but also for reactive and in future prescriptive, environmental management.

Monday, 12.06.2023 14:54-15:09 Room C Carbon

An appropriate environment for people with mental disabilities and challenging behaviour

Huisman, Emelieke (1); Mueller-Schotte, Sigrid (1); Huisman, Chantal (1,2); Kort, Helianthe (1,2)

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ID: 2503 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia, 07. Occupant behavior & controls
Keywords: indoor environment, indoor climate, quality of life, mental disabilities

There is growing attention to the contribution of the (built) environment to people's wellbeing. The sector of Disability Care considers the physical environment relevant for the quality of life of people with mental disabilities exhibiting challenging behaviour. The expression of challeging behaviour varies, but self-jurious as well as aggressive or destructive behaviour have been reported in people with intellectual disabilities and multible disabilities.

Currently, increasing evidence exist about the influence of the environment in hospital and long-term care facilities while results of three scoping reviews show that the scientific evidence for disability care is limited. However, practical experience shows that people with challenging behaviour can be benefit from the built environment. For example, ambient noise can have a relaxing effect, it can also be perceived as an annoying factor working as a trigger for the occurrence of challenging behaviour.

The aim of this contribution is building knowledge about the influence of environmental factors on people with mental disabilities and displaying challeging behaviour. The following research challenges encountered 1) Examples of scientific evidence related to other relevant target groups and 2) Examples from practical experiences of the people working with the target group.

It is expected that addressing these evidence raises awareness of the importance of the built environment for people with mental disabilities and displaying challenging behaviour for future research.

Session 5 Monday Silver - Particles, IAQ & odour perception

Time:
Monday, 12.06.2023 14:00-15:30

Room: Ag Silver

Chair:
Ilacqua, Vito
US EPA

Co-Chair:
Maier, Laura
RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

Monday, 12.06.2023 14:00-14:15 Room Ag Silver

INDAIRPOLLNET: Driving indoor air pollution research in Europe

Carslaw, Nicola (1); Beko, Gabriel (2); Langer, Sarka (3); Schoemaecker, Coralie (4); Mihucz, Victor (5); Dudzinka, Marzenna (6); Wiesen, Peter (7); Nehr, Sascha (8); Huttunen, Kati (9); Querol, Xavier (10)

1: University of York, United Kingdom; 2: Technical University Denamrk; 3: IVL, Sweden; 4: University of Lille; 5: Eotvos Lorand University; 6: University of Lublin; 7: Wuppertal University; 8: CBS International Business School, Brühl, Germany; 9: Finnish Institute for health and welfare; 10: Institute of Environmental Assessment and Water Research (IDÆA), Consejo Superior de Investigaciones Científicas (CSIC)

ID: 1363 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: indoor air quality, indoor air chemistry, VOCs, surfaces, buildings

INDAIRPOLLNET (INDoor AIR POLLution NETwork https://indairpollnet.eu/) was A European COST Action programme, running from September 2018 until March 2023. It has more than 200 indoor and outdoor air quality scientists from universities, large and small companies and research institutes around Europe and beyond. Their expertise covers chemistry, biology, standardisation, household energy, particulate matter characterisation, toxicology, exposure assessment, air cleaning, building materials, building physics and engineering (including ventilation and energy) and building design. The aim of our network is to better understand indoor air chemistry to provide healthier buildings for the future, through designing a blueprint for future indoor air chemistry field campaigns.

This presentation will provide an overview of the highlights from our network. Our network was split into six working groups (WGs). These cover what we already know about indoor air chemistry from measurement and modelling studies (WG1), what the indoor and outdoor air quality communities can learn from each other (WG2), which pollutant species we should measure indoors based on different ranking criteria (WG3), how we best measure these species (WG4) and in what sort of buildings we should make measurements (WG5), to make our results as representative as possible. Finally, WG6 aimed to define a framework for future indoor air chemistry field campaigns. We will present the main findings and suggest future research priorities.

Monday, 12.06.2023 14:15-14:30 Room Ag Silver

New Insights on Indoor New Particle Formation in Residential Buildings

Patra, Satya S. (1); Jiang, Jinglin (1); Huang, Chunxu (1); Ding, Xiaosu (1); Price, Paige (2); Kumar, Vinay (2); Keech, Connor (3); Steiner, Gerhard (4); Tasoglou, Antonios (5); Stevens, Philip S. (2); Jung, Nusrat (1); Boor, Brandon E. (1)

1: Purdue University, United States of America; 2: Indiana University, United States of America; 3: DURAG Inc., United States of America; 4: GRIMM Aerosol Technik Ainring GmbH & Co. KG, Germany; 5: RJ Lee Group Inc., United States of America

ID: 1335 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: ultrafine particles, volatile organic compounds, ozone, indoor chemistry, nanocluster aerosol

New particle formation (NPF) is a significant source of secondary atmospheric aerosol. It is a two-step process that involves the formation of stable nanometer-sized molecular clusters, followed by their growth to larger sizes. Recent research has demonstrated the occurrence of NPF events in indoor environments due to the ozonolysis of monoterpenes and monoterpenoids released from cleaning products. Direct measurements of sub-3 nm nanocluster aerosol (NCA) are needed to understand the ubiquity and characteristics of ozone-initiated NPF events due to the use of terpene-based household and personal care products in indoor environments.

Field measurements of indoor terpene ozonolysis under variable air exchange rates (AERs) and coagulation/condensation sinks were performed as part of the 2021 zEDGE-iRACE measurement campaign at Purdue University. Sub-3 nm NCA was measured using a novel nano-mobility particle size spectrometer – the Particle Size Magnifier – Scanning Mobility Particle Sizer (PSMPS). The PSMPS combines a short differential mobility analyzer (S-DMA), a diethylene glycol-based particle size magnifier, and a butanol-based condensation particle counter (CPC). Larger particles were monitored using a Scanning Mobility Particle Sizer (SMPS) with a long DMA and a Wideband Integrated Bioaerosol Sensor (WIBS). VOC concentrations were measured using a proton transfer reaction time-of-flight mass spectrometer (PTR-TOF-MS) and O3 concentrations were measured using a non-dispersive ultraviolet absorption O3 analyzer. Various terpene-based cleaning, aromatherapy, and personal care products were used during controlled experiments in a real net-zero energy building, the zEDGE Tiny House.

Frequent particle nucleation (42/45 experiments) and growth (33/45 experiments) events were observed across all experiments. Notably, indoor NPF events occurred at lower O3 concentrations compared to that outdoors. Higher indoor monoterpene and monoterpenoid concentrations, emitted directly from the products, compensate for the lower O3 concentrations, thereby driving the ozonolysis reaction forward. Not all nucleation and growth processes occurred in the same manner among the tested terpene-based products. Pulsed terpene injection experiments, such as spraying an air freshener, resulted in instantaneous, rapid particle growth, but experiments using aromatherapy products exhibited a more gradual growth of particles. NPF intensity was strongly related to the AER and monoterpene/monoterpenoid concentrations. The observed indoor particle growth rates were significantly higher than those reported for outdoor NPF events. Coagulation and condensation scavenging by larger pre-existing particles can be a significant loss process for freshly nucleated NCA and its low-volatility gas-phase precursors. This aspect was evaluated by atomizing ammonium sulfate to create artificial indoor sinks. The presence of such sinks inhibited NPF indoors.

Monday, 12.06.2023 14:30-14:45 Room Ag Silver

Spatiotemporal Variations in Ozone and Carbon Dioxide Concentrations in a Ventilation System of an Office Building

Jiang, Jinglin (1); Huang, Junkai (1); Wagner, Danielle N. (1); Tasoglou, Antonios (2); Stevens, Philip S. (3); Boor, Brandon E. (1); Jung, Nusrat (1)

1: Purdue University, United States of America; 2: RJ Lee Group Inc., United States of America; 3: Indiana University, United States of America

ID: 1331 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: ozone, carbon dioxide, mechanical ventilation, occupancy, indoor chemistry

Indoor air quality in office buildings can impact the health, well-being, and productivity of occupants. In most buildings, occupant exhaled breath is the major source of carbon dioxide (CO2). Mixing ratios of indoor CO2 are also strongly associated with the operational mode of the mechanical ventilation system. Ozone (O3) is an important driver of indoor oxidative reactive chemistry. It can react with volatile organic compounds in indoor air or compounds on indoor surfaces and initiate the formation of secondary organic aerosol (SOA), which may have an adverse impact on human health. LEED-certified office buildings often implement outdoor air supply in their HVAC systems to dilute high concentrations of CO2 and other indoor air pollutants. Meanwhile, outdoor O3 can be delivered to indoor spaces and further impact indoor air chemistry and SOA formation. Understanding the trade-offs between the introduction of O3 and removal of CO2 under high outdoor air ventilation rates will help us better understand indoor air pollutant dynamics and to determine appropriate ventilation strategies to improve indoor air quality. Investigating how occupancy and mechanical ventilation modes impact the spatiotemporal distribution of O3 and CO2 mixing ratios is an important step towards that.

A five-month field measurement campaign was conducted in one of the four living laboratory offices at the Purdue University Ray W. Herrick Laboratories, a LEED-certified office building. An integrated building automation system was used to achieve real-time monitoring and precise control of the HVAC system. Supply, return, and outdoor airflow rates were adjusted under different ventilation modes to achieve different air exchange rates (AERs) and pressurization conditions. Occupancy was tracked via chair-embedded thermocouples. O3 and CO2 analyzers were used to monitor O3 and CO2 mixing ratios, respectively. A multi-point sampling system was built to sample O3 and CO2 at eight locations throughout the HVAC system.

Both occupancy and ventilation mode were found to significantly impact indoor O3 and CO2 mixing ratios. Indoor CO2 mixing ratios exhibited similar diurnal patterns as occupancy. Outdoor O3 delivered to the occupied office was found to be major source of indoor O3, while occupants and indoor surfaces were found to be the major O3 sink in the office. In general, with the increase of the AER, indoor CO2 mixing ratios decreased, while indoor O3 mixing ratios increased. Significant spatial variations in O3 and CO2 mixing ratios were observed throughout the ventilation system, especially among the outdoor, supply, and return air sampling locations.

Monday, 12.06.2023 14:45-15:00 Room Ag Silver

Odour testing of building products: Examinations for an on-going development of the test standard ISO 16000-28

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1: University of Applied Sciences (HTW Berlin), Germany; 2: German Environment Agency (UBA), Germany; 3: Bundesanstalt für Materialforschung und -prüfung (BAM)

ID: 1386 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Building materials, odour, emission, test chamber, perceived intensity

Odours from building products can be measured by applying the standard ISO 16000-28. One of the described procedures is the assessment of perceived intensity using a comparative scale.

The sampling procedure and evaluation method of perceived intensity are investigated and shown to need improvement. New developments to increase the reproducibility of measurement results are discussed. Since odour tests are used for labelling, they have a major influence on the assessment of construction products.

In the original ISO standard, the evaluation is typically performed using a sampling container separated from the emission test chamber. For a better sample presentation, an adapter was developed to enable an odour assessment which is comparable to a direct measurement. The investigations show that losses of odourous substances can be greatly reduced, which is very desirable when seeking to obtain reliable results.

Another experimental series was carried out to reduce the measurement effort of evaluation of perceived intensity. Application of the developed 'greater than or less than/equal to' query could be helpful here. The results show that the query mostly leads to the same result as the evaluation of the perceived intensity using the method according to the standard, but is much easier to perform.

Monday, 12.06.2023 15:00-15:03 Room Ag Silver

Deposition of inhalable particles onto clothing: A manikin-based chamber study

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ID: 1123 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Particle dynamics, Textile, Clothing contamination, Inhalation exposure

Deposition is an essential pathway linked to indoor airborne particle concentration change and size distribution. A growing body of evidence has shown that clothing is an important mediator of human inhalation exposure to particles; however, studies on deposition on the textile surface are limited. In this study, we experimentally quantified the influence of four variables on particle deposition on clothing of a thermal manikin in sitting posture and compared them with a baseline scenario of a bared skin manikin. The investigated variables included common clothing types: (a) short-sleeve T-shirt (63% cotton, 34% polyester, 3% elastane) (b) long-sleeve T-shirt (98% cotton, 2% elastane) (c) short-sleeve T-shirt (100% polyester), (d) fleece (100% polyester), and (e) sweater (68% wool, 32% poliamida); degree of wrinkles on clothing (flat and wrinkled); indoor airflow speed (0.19, 0.26, and 0.33 m/s), and deposited particle size (20 size bins between 0.298 and 6.787 µm). The study was conducted in a stainless controlled chamber (0.9 m x 1 m x 2 m). Polydisperse ISO A1 dust was injected into the chamber for 1 min followed by 40 min deposition time. Particle counters (GRIMM 11-D & METONE 804) were used to measure particle concentration and to check the spatial concentration uniformity. The results show that the deposition coefficient on clothing was strongly related to the clothing types, airflow speed and particle sizes, while the wrinkle effect on deposition was not significant. The results of the study can provide practical reference data for evaluating and controlling human inhalation exposures associated with worn clothing indoors.

Monday, 12.06.2023 15:03-15:06 Room Ag Silver

Relationship of building material emissions and odour perception: perceived intensity, hedonic tone and reasonableness

Schieweck, Alexandra; Schulz, Nicole; Kohlhagen, Jennifer

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ID: 1129 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: Chamber tests, model rooms, airborne pollutants, indoor air quality, odour assessment

Odour perception of building product emissions has received increasing attention over the last decades. Manufacturers aim at reducing undesired odours which might result in annoyance and health impairments of occupants. The testing protocol of the German AgBB evaluation scheme has implemented sensory testing of building product emissions on a voluntary basis after a testing period of 28 days. However, the detection and identification of odorous substances might be limited against the background of instrumental sensitivity. Also, the relationship between the odour perception of single product emissions and real indoor air in dependence of the materials installed and the environmental parameters, such as the air exchange, are not sufficiently known. Thus, it has to be examined how odour effects might differ and will be influenced by each other.

During a three-years research project, both single building materials and 30 m³-model rooms of different construction types (acc. to EN 16516, 2020) are subjected to emission testing and odour assessment (acc. to AgBB, 2021). Chamber tests are performed over a testing time of 28 days. Besides active sampling of a broad range of organic volatiles, namely (very) volatile organic compounds (VVOC/VOC), low molecular aldehydes and carboxylic acids, the perceived intensity, the hedonic tone, the odour quality and also the reasonableness will be assessed after 7 and 28 days. All participating subjects are trained in accordance with DIN ISO 16000-28 (2021) which provides procedures for the parameters acceptability (untrained panel), perceived intensity (trained panel) and hedonic tone (untrained panel). The parameter reasonableness will be additionally considered.

It will be investigated how odour assessment varies in dependence of i) single material emissions, ii) composite material emissions, and iii) indoor air in model rooms. Influences and dependencies will be clearly identified. Moreover, the question will be answered if there are any analytical limitations regarding the detection of odour-related substances and if the laborious odour assessment can be simplified. It will also be assessed how odour-related substances influence the fulfillment of test protocol requirements (passed or failed) and if the use of materials which passed the tests ensures an acceptable indoor air quality. Thus, the results will be a major contribution to the disclosure of odorous substances and their impact on indoor air quality and occupants.

Monday, 12.06.2023 15:06-15:09 Room Ag Silver

Modeling the emission and transport of endocrine disrupters in French daycare centers

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ID: 1186 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Semivolatile organic compounds, building materials, consumer products, phthalate, flame retardant

Following the French National Endocrine Disruptor Strategy (SNPE) published in 2014, investigations of endocrine disrupters (EDs) have been conducted in French dwellings and schools. However, no study has characterized children's exposure to EDs in French daycare centers attended by children under three years of age who are vulnerable to these chemicals. In this context, the present work proposes a modeling approach to address the source emission of EDs from building materials and consumer products and the transport of EDs into multiple indoor phases, i.e., the gas phase and the absorbed phases in airborne particles, settled dust, and sink surfaces. The modeling work aims to determine the partition coefficient of EDs between the gas phase and those absorbed in multiple indoor sink surfaces (Ks) to fill the gap between the emission of EDs from individual sources used in four selected daycare centers and the overall chemical concentrations in the air and dust of the four environments. The model has been developed based on SVOC (semivolatile organic compound) emission and partitioning theories to predict the SVOC concentrations in the gas and absorbed phases. To obtain the source emission data, dry sources, such as vinyl flooring, and liquid sources, such as surface cleaning products, used in the selected daycare centers will be sampled. The SVOC emission parameters, i.e., the SVOC concentration adjacent to the building materials (y0) and the SVOC emission rate of the consumer products, will be determined based on emission measurements in environmental chambers. To obtain the SVOC concentrations in the gas and absorbed phases in the selected daycare centers, in-situ sampling will be conducted, and the samples will be analyzed. The source emission data will be input into the SVOC model to calculate an optimized Ks to obtain the best estimate of the SVOC concentrations in the multiple phases compared to those measured in situ. The relationship between the Ks and the octanol/gas partition coefficient (Koa) will be analyzed for a better understanding of the gas/surface partitioning mechanisms and a reliable estimation of the Ks for future SVOC models.

Monday, 12.06.2023 15:09-15:12 Room Ag Silver

Investigating the impacts of cooking and cleaning on indoor air quality under different room furnishing configurations

Harding-Smith, Ellen (1); Davies, Helen (1); O'Leary, Catherine (2); Shaw, David (1); Winkless, Ruth (2); Shaw, Marvin (2); Dillon, Terry (2); Carslaw, Nicola (1)

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ID: 1229 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: VOC, cooking, cleaning, indoor air chemistry

People in developed countries spend approximately 90% of their time indoors, mostly at home. Consequently, exposure to airborne pollutants mostly occurs indoors, whether those pollutants originate indoors or outdoors. As energy efficiency measures are adopted and homes become increasingly airtight, indoor pollutant sources have the potential to become increasingly important for indoor air quality, and therefore to personal exposure and health impacts. Cooking and cleaning are both activities that occur in most homes, and are known to produce a wide variety of pollutants including volatile organic compounds (VOCs) and particulate matter. These are the focus of the EPSRC-funded IMPacts of Cooking and Cleaning on indoor Air quality: towards healthy BuiLdings for the future (IMPeCCABLE) project, which aims to measure and model primary emissions and secondary chemistry from cooking and cleaning on a range of spatial scales, from the process level to the UK housing stock.

As part of IMPeCCABLE, this study investigates VOC emissions during scripted cooking and cleaning activities in a room scale environment, using both experimental and computational modelling techniques. Cooking and cleaning experiments were repeated in a room in either a furnished or unfurnished state, to determine the effects of different indoor materials on the evolution of cooking and cleaning-related pollutants. A suite of online and offline instrumentation was used to identify and quantify VOCs, particulate matter, and trace gases during short activity experiments, and for many hours afterwards, to characterise the evolution of activity-related pollutant concentrations. Real time concentrations of over 40 targeted VOCs were measured using selected-ion flow tube mass spectrometry (SIFT-MS) at a time resolution of <10s and particle number size distributions were measured using an electrical low-pressure impactor (ELPI). VOC emission rates were then obtained from experiments and input into an indoor chemistry box model (INCHEM-Py) to follow the production of potentially harmful secondary products, such as organic nitrates, peroxyacylnitrates and glyoxal.

Here, a combination of experimental and simulation data will be presented that show the characteristic VOCs released during different cooking and cleaning activities, and the profile of secondary species that are produced as a result, in different indoor room configurations.

Monday, 12.06.2023 15:12-15:15 Room Ag Silver

Assessing Indoor Air Quality and ventilation systems to limit the spread of airborne pathogens - a review

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ID: 1296 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: indoor air quality, aerosol dispersion, ventilation, numerical modelling, computational fluid dynamics, assessment

The corona pandemic stressed the weaknesses in Indoor Air Quality (IAQ) and ventilation that researchers have been underlining for years. To quantify the lack of IAQ and ventilation, researchers explored several indicators that, through different approaches, assess the IAQ and the ventilation performance in indoor spaces. This paper gives an overview of those indicators and assessment methods used to evaluate IAQ and ventilation regimes focusing specifically on airborne pathogens. This review considers studies from before and during the COVID-19 pandemic. Online databases were used to search for six concepts: performance, ventilation, air quality, indoor spaces, and parameters. The indicators found fit into three categories: air pollutants, environmental conditions, and ventilation efficiency. Air pollutants include CO2 concentrations, used as a proxy for the virus, and the microbiology of the indoor environment at breathing level. Environmental conditions used are temperature and relative humidity, which affect the droplet lifetime and aerosolisation and the deactivation of pathogens in the air. Lastly, ventilation efficiency is determined through ventilation rate, air distribution patterns, and mean age of air. These parameters mainly depend on the type of ventilation and the position and configuration of air inlets and outlets. Studies exploring assessment methods found in this review are grouped according to their themes: aerosol dispersion, ventilation, infection risk, design parameters, and human behaviour. Aerosol dispersion studies encompass aerosol-generating tasks under different conditions. Ventilation studies assess pollutants' concentration or the airflow patterns and their space distributions. Infection risk assessment studies quantify the infection probability of a disease and test preventive control strategies. Studies that include design parameters focus on the impact of room size and volume and the size and position of doors, windows, air inlets and outlets of the ventilation system. Finally, studies that cover human behaviour include the movement of individuals and the opening and closing of windows. The review showed

a lack of connection between IAQ indicators and their interactions, leading to the need for a holistic definition for IAQ indicators that includes all indicators, whether related to air properties, occupant's perception, or health effects. This resulted in the definition of a new term "Airscape" that encompasses all indicators. The review also revealed the lack of an optimisation tool for a room's design parameters tailored to minimise the spread of airborne pathogens. Ultimately, to reach the desired indoor Airscape, where the spread of airborne pathogens is minimised, a better coordination between different fields is also needed.

Session 6 Monday Oxygen - Urban setting & communities

Time:
Monday, 12.06.2023 14:00-15:30

Room: O2 Oxygen

Chair:
Touchie, Marianne
University of Toronto

Co-Chair:
Ju, Yuchen
Aalto university

Monday, 12.06.2023 14:00-14:15 Room O2 Oxygen

Data analytics as a cornerstone for healthy and sustainable buildings and communities

Lampkowski, Marcelo (1); Pan, Zhiyu (2); Hernández Moral, Gema (4); Marinakis, Vaggelis (3); Monti, Antonello (2)

1: ICLEI - Local Governments for Sustainability, Freiburg im Breisgau, Germany; 2: A E.ON Energy Research Center, RWTH Aachen University, Germany; 3: School of Electrical and Computer Engineering, Decision Support Systems Laboratory, National Technical University of Athens, Athens, Greece; 4: CARTIF Technology Centre, Parque Tecnológico de Boecillo, Boecillo, Valladolid, Spain

ID: 2511 Extended Abstract
Topics: 10. Community- and urban-scale challenges and solutions
Keywords: holistic, big data, analytics, energy efficiency, planning

This practical session will explore how holistic data-based building planning is a cornerstone for expanding sustainable infrastructure while supporting occupant health and well-being, and the central role that data analytics tools play here.

As communities and facilities and seek to improve energy efficiency to meet EU climate and net-zero goals, using digital tools such as MATRYCS may help identify "win-win" energy conservation measures (on the building and municipal scale), while also increasing building occupant comfort and satisfaction.

Additionally, the benefits of energy efficiency in buildings are not only economic, but also include social factors such as the alleviation of energy poverty and the impact on health-related issues such as mortality due to the prolonged exposure to indoor cold and inadequate cooling in the summer (heat waves); cases of asthma and other respiratory problems; air pollution-related mortality, etc.

The MATRYCS Toolbox can offer a process for analyzing large amounts of existing data to prioritise buildings and provide energy and health-related improvement recommendations. During the session, participants will be invited and encouraged to test and try the MATRYCS tools.

Monday, 12.06.2023 14:15-14:30 Room O2 Oxygen

Developing radiative cooling paint to harvest renewable cooling for buildings

Yu, Xinxian (1); Yao, Fengju (1); Huang, Wenjie (1); Xu, Dongyan (1); Chen, Chun (1,2)

1: Department of Mechanical and Automation Engineering, The Chinese University of Hong Kong, Hong Kong S.A.R., China; 2: Shenzhen Research Institute, The Chinese University of Hong Kong, Shenzhen, China

ID: 1244 Extended Abstract
Topics: 06. Heating, ventilation, air conditioning & cooling, 10. Community- and urban-scale challenges and solutions
Keywords: Radiative cooling, Renewable energy, Cooling paint, Cool roof, Glass bubbles

In this warming world, radiative cooling is believed to be one of the most promising techniques for keeping cool without increasing greenhouse gas emissions. Glass bubbles have been proposed as a component of high-performance radiative cooling paints because of the bubbles' controllable size and their enhancement of light scattering. However, the current radiative cooling paints with glass bubbles suffer from low solar reflectivity because of their large particle size. In this study, we propose the idea of breaking glass bubbles by means of ball milling to enhance the cooling performance of radiative cooling paints. The ball-milling process increases the solar reflectivity from 93.3% to 97.3% with the thermal emissivity of ~93.4%, while the temperature difference with the ambient air is increased from 1.8 oC to 3.5 oC at noon. When the paint is covered with nanoporous polyethylene film, the temperature is 8.5 oC below the ambient air temperature at noon and 14.1 oC at night. Simulation results show that the annual cooling electricity for a strip mall in Shenzhen can be reduced by 5.3% if the original roof is covered with this radiative cooling paint. The superior radiative cooling capability of the paint and the record-setting temperature difference achieved in Hong Kong demonstrate its excellent cooling performance, while the simple preparation method and ease of application make this paint promising for commercialization and large-scale production in buildings.

Monday, 12.06.2023 14:30-14:45 Room O2 Oxygen

Incorporating Novel Desiccant Dehumidification Technologies into Conventional Air Conditioning Systems: Effects on Urban Microclimate and Energy Consumption

Younes, Jaafar; Ghaddar, Nesreen; Ghali, Kamel

American University of Beirut, Lebanon (Lebanese Republic)

ID: 1169 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 10. Community- and urban-scale challenges and solutions
Keywords: Desiccant dehumidification, energy conservation, urban heat island

Integrating desiccant dehumidification systems into conventional air conditioning (AC) systems reduces their electric energy consumption, while increasing their waste heat released into the environment which intensifies the urban heat island effect in cities. Research in the field of desiccant materials has led to the development of novel desiccants such as metal organic framework composites (MOFs) capable of removing large latent loads with low regeneration energy requirements, hence reducing waste heat discharged into urban microclimates. This study evaluates the impact of MOFs-based desiccant systems when integrated with the AC systems of buildings on energy consumption and microclimate in an urban scenario. Using a validated model, the study was applied in a case study of the city of Beirut. On two humid summer days in a densely populated neighbourhood of Beirut, the Silica-Gel system resulted in a 16% average reduction in the electric power of AC units, whereas the MOFs system resulted in a 21.4% reduction. The MOFs system discharged 13% less sensible waste heat compared to Silica-Gel which resulted in a 0.48℃ lower pedestrian air temperature. AC with MOFs-based desiccant systems required less thermal and electric energy and had less adverse impacts on the microclimate compared to conventional desiccant systems.

Monday, 12.06.2023 14:45-15:00 Room O2 Oxygen

Research on the influence of building façade material design on micro-climate in building complex

Li, Zhengrong; Chen, Qianru; Wang, Heyu; Ma, Chenliang; Feng, Xiwen

Tongji University, China, People's Republic of

ID: 1163 Full paper
Topics: 10. Community- and urban-scale challenges and solutions
Keywords: Micro-climate, building façade, numerical simulation, wind-thermal coupling, thermal accumulation

With the gradual increase in the scale of urban construction, high-density building complex has become the main trend of urbanization development. This has led to the thermal accumulation phenomenon inside the building complex, aggravating the energy and environmental crisis. Furthermore, the use of different building façade materials makes the micro-climate more complicated. This study took a 3×3 dot formed building complex as the research object. According to the thermal properties of materials, four typical building façade materials were selected, namely brick, alloy, smooth marble, and dark paint. PHOENICS was employed for simulation. The building surface temperature and outdoor air temperature were taken as quantitative indicators to evaluate the micro-climate of buildings with different façade materials under the wind-thermal coupling. The results revealed that the building surface temperature was affected by the coupling effect of solar radiation and convective heat transfer, and showed different changes in different orientations. Under the wind-thermal coupling, the convective heat transfer between the outdoor air and the surface made the air temperature in the building complex rise suddenly, resulting in the phenomenon of thermal accumulation. Materials with low absorptivity are better choice for improving the micro-climate, which provides an important route to reduce building energy consumption.

Monday, 12.06.2023 15:00-15:03 Room O2 Oxygen

Research on quantitative description method of residential building group layout

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1: School of Mechanical and Engineering, Tongji University, Shanghai, China; 2: College of Electronic and Information Engineering, Tongji University, Shanghai, China

ID: 1164 Full paper
Topics: 10. Community- and urban-scale challenges and solutions
Keywords: Thermal environment, Layout of residential building group, Spatial characteristics, Image recognition

For the study of building thermal environment, the quantitative description of building group layout is of great significance. Most of the existing methods focused more on the architectural composition of the group, ignoring the connection between the buildings in group. Moreover, the spatial scale of the method was too large, which was not suitable for the study of building thermal environment. This study has proposed a function method to quantitatively describe the residential building layout at group scale. We used Image recognition to evaluate the applicability of the method. The results showed that the matching accuracy between the actual building group layout and the function could reach 90%. This method has great potential in quantitatively expressing the feature of residential building group layout, which lays the foundation for the building thermal environment research.

Monday, 12.06.2023 15:03-15:06 Room O2 Oxygen

Keeping warm in Northern China: Do rural households benefit from clean heating policy?

Wang, Shuye (1); Bleil de Souza, Clarice (1); Perisoglou, Emmanouil (1); Golubchikov, Oleg (2)

1: Welsh school of Architecture, Cardiff University, United Kingdom; 2: School of Geography and Planning, Cardiff University, United Kingdom

ID: 1202 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 10. Community- and urban-scale challenges and solutions
Keywords: Rural houses, Cold regions, Indoor thermal comfort, Thermal adaptation, Energy poverty

Northern rural China experiences large heating demand during winter. To address carbon emissions and air pollution, the Chinese government has developed clean heating policies seeking to switch from traditional biomass to modern energy in this region. However, to what extent these policies register with rural households' living experiences is little researched. This study investigates households' practices to keep warm during winter and the indoor thermal environment in a village in northern China. Qualitative and quantitative data were gathered in a field study conducted in January 2022, the coldest month in a year. The data demonstrate that despite the possibility to connect to the village gas infrastructure and the general availability of electric heaters, solid-fuel stoves remain by large the most adopted heating method by households. Even so, households cannot afford to heat their homes to the government-prescribed 14°C benchmark for indoor temperatures. To cope with the cold, residents complement limited space heating by warming their bodies through clothes and hot drinking. These results indicate a gap between political expectations and rural households' practices regarding winter heating. This study can also act as a reference to other countries that are working on energy transition affecting low-income groups.

Monday, 12.06.2023 15:06-15:09 Room O2 Oxygen

Human Mobility Data as Proxy for Occupancy Information in Urban Building Energy Modelling

Hewamalage, Hansika (1); Chen, Kaixuan (1); Rana, Mashud (2); Sethuvenkatraman, Subbu (2); Xue, Hao (1); Salim, Flora (1)

1: University of New South Wales, Australia; 2: CSIRO

ID: 1179 Extended Abstract
Topics: 07. Occupant behavior & controls, 10. Community- and urban-scale challenges and solutions
Keywords: Energy Forecasting, Machine Learning, Foot Traffic Data

Accurate forecasting of building energy consumption is of utmost importance for efficient load scheduling and renewable energy management activities in urban environments. Occupants' behaviours within indoor environments have significant influence on commercial and residential loads. Yet, getting access to sufficient data related to occupants' behaviours can be difficult due to privacy concerns. On the other hand, the usage of spatial-temporal mobility data has become increasingly popular for other tasks such as traffic management, human trajectory prediction and epidemiological modelling. Borrowing these ideas, in this work we conduct an empirical analysis to investigate the feasibility of predicting aggregated energy consumption of buildings using spatial-temporal mobility data by applying a deep learning model, namely, Convolution Neural networks (CNN). Experimental results demonstrate that pedestrian data can act as a proxy for missing building occupancy data for forecasting energy. Utilisation of pedestrian data in addition to other weather related inputs helps the models to improve the prediction accuracy.

Monday, 12.06.2023 15:09-15:12 Room O2 Oxygen

A combined deep learning and physical modelling approach for characterizing contaminant source in street canyons

Zhou, Yiding (1); An, Yuting (1); Huang, Wenjie (1); Chen, Chun (1); You, Ruoyu (2)

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ID: 1294 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 10. Community- and urban-scale challenges and solutions
Keywords: Deep neural network, Computational fluid dynamics, Markov chain model, Air pollutant source, Street canyon

Airborne contaminants in street canyons has become a major threat to public health. Roadside air pollution monitoring stations have become frequently available for street canyons. However, limited number of air pollution monitoring stations cannot fully represent the air pollutant distribution in the whole street canyon with high spatial resolution. Moreover, the source locations and emission profile are not available, which may limit the effective source control measures. To efficiently characterize contaminant source information, this study developed a combined deep learning and physical modelling method using the monitoring data as inputs. First, a deep neural network (DNN) was constructed for locating the source. The training datasets were generated from numerical simulations by the computational fluid dynamics (CFD)-Markov chain model. An inverse method based on Tikhonov regularization was then used to estimate the source emission profile. A case study was conducted to evaluate the proposed method. For the continuous pollutant source with varying emission profile in the 3-D street canyon with an area of 25,600 m^2, the source in 36% of the cases were accurately located, and in another 52% of the cases, it was within 10 m from the true location.

Session 7 Monday Carbon - VOCs

Time:
Monday, 12.06.2023 16:00-17:30

Room: C Carbon

Chair:
Wargocki, Pawel
Technical University of Denmark

Co-Chair:
Gaskin, Janet
National Research Council Canada

Monday, 12.06.2023 16:00-16:15 Room C Carbon

Plasticizer concentrations in indoor environments: a data inventory

Wei, Wenjuan (1); Duca, Radu-Corneliu (2); Zoutendijk, Sebastiaan L. (3); Minnema, Jordi (3); Langer, Sarka (4); Niculita-Hirzel, Hélène (5); Golja, Viviana (6); Santos, Osvaldo (7); Virgolino, Ana (7); Kumar, Vikas (8); Blassiau, Clément (9)

1: Scientific and Technical Center for Building (CSTB), France; 2: Laboratoire national de santé (LNS), Luxembourg; 3: National Institute for Public Health and the Environment (RIVM), the Netherlands; 4: IVL Swedish Environmental Research Institute, Sweden; 5: University of Lausanne, Switzerland; 6: NIJZ National Institute of Public Health, Slovenia; 7: Instituto de Saúde Ambiental, Faculdade de Medicina da Universidade de Lisboa, Portugal; 8: Universitat Rovira i Virgili, Spain; 9: French agency for food, environmental and occupational health & safety (ANSES), France

ID: 2488 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Semivolatile organic compounds, building materials, phthalate, dust, air

Background:

Endocrine-disrupting chemicals (EDCs), such as a variety of phthalates, flame retardants, and biocides, can be emitted continuously or intermittently from building materials, furniture, and consumer products. Following source emissions, EDCs exist in the indoor air and are absorbed on material surfaces and in settled dust. Moreover, EDCs of outdoor origin, such as some agricultural biocides, can enter indoor environments through ventilation and infiltration. As a result, the mixture of EDCs of both indoor and outdoor origins leads to occupants' non-dietary exposures via air inhalation, dermal contact, and dust ingestion in indoor environments.

To enable the transition to the risk assessment of the mixture of EDCs, the EU's PARC (Partnership for the Assessment of Risks from Chemicals) project aims to develop a holistic approach that allows the integration of main indoor and outdoor sources as well as the environmental and dietary exposure pathways. Since people spend more than 90% of their time indoors, realistic assessments are needed to address indoor non-dietary EDC exposure and its contribution to the overall dose for the general population. In this context, inventories of EDC emission and transport models and parameters need to be developed for the characterization of various EDCs, their sources, indoor concentrations, exposure routes, and overall doses. Research gaps between sources and doses for each EDC and the mixture needs to be identified and filled to allow aggregation of occupants' exposures from multiple routes under a holistic framework.

Aims and scope:

This workshop is associated with but not limited to the ongoing research work in the EU's PARC project (Work Package 6.2.1). The main topics that will be presented and discussed include:

- The characterization of indoor emission and transfer of semi-volatile organic compounds (SVOCs) especially EDCs from building materials, furniture, and consumer products;
- The development of source-dependent emission models and the integration to characterize the mixture in built environments;
- The identification of gaps between the source emission and the exposure dose for future theoretical and experimental developments (including concentration levels and exposure factors).

Monday, 12.06.2023 16:15-16:30 Room C Carbon

Controlling PAH in indoor air by using an emissions barrier

Mattsson, Johan (1); Larsson, Lennart (2); Bloech, Henning (3)

1: cTrap, Ltd.,Sweden; 2: Lund University, Sweden; 3: The Sustaineer, Germany

ID: 1304 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: PAH, emissions barrier, adsorption, creosote, tar

Indoor air quality may be compromised by the spread of potentially harmful emissions from building materials. Such emissions may include volatile and semi-volatile organic compounds from previously applied impregnation agents and wood preservatives, from flooring products and other building materials, from mold, and other sources. The causes for these emissions are frequently – but not always – moisture related. Here we present case studies where an adsorbtive emissions barrier was used to reduce concentrations of polycyclic aromatic hydrocarbons (PAH) in indoor air. Notably, some PAH are known carcinogens.

We studied an old cultural building where a tar-based material had been used as a moisture barrier on a wall. There was a strong disturbing odor inside the building which was suspected to originate from PAH; the smell persisted even after the tar material had been removed. Indoor air concentrations were 1726 ng PAH/m³ (naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, anthracene, fluorants, pyrene, biphenyl, and dibenzofuran). An emissions barrier was installed on about 75 percent of the wall surface.Due to the uneven surface structure it was not possible to cover the entire wall. We used the cTrap, a flexible, breathable, and air-tight four-layer laminate developed at Lund University Sweden where a hydrophilic polymer functions together with an adsorption layer. The cTrap cloth was attached at the wall surface by using an adhesive tape. After the cloth had been installed there were no longer complaints regarding odor, and the air concentrations of PAH decreased to 139 ng/m³ thus corresponding to a reduction of 92 percent.

We also studied a building of historical value where the removal of contaminated building structures and emission sources was prohibited. Finally we will present the case of an apartment building with an air concentration of naphthalene more than 20 times higher than the threshold limit value. In both buildings a creosote tar layer had been used as a moisture barrier resulting in odor complaints. In all cases, the cTrap cloth was installed, the emission concentrations rapidly decreased to acceptable levels, and the odor disappeared.

We will demonstrate that an emissions barrier may be a useful tool in preventing PAH in persistent building materials from reaching the indoor air.

Monday, 12.06.2023 16:30-16:45 Room C Carbon

Sensitivity analysis of parameters determining DEHP concentrations in indoor settings

Mansouri, Aya (1,2); Blondeau, Patrice (2); Wei, Wenjuan (1); Mandin, Corinne (1)

1: CSTB (Scientific and Technical Center for Building), Marne la Vallée, France; 2: LaSIE (Laboratoire des Sciences de l'Ingénieur pour l'Environnement), La Rochelle University, France

ID: 1165 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: DEHP, indoor concentration, climate change, modeling

Exposure to semi-volatile organic compounds (SVOCs) can affect human physical and mental health. Humans spend most of their time in their homes, schools, and offices, so environmental exposure excluding diet mostly occurs indoors. A dedicated indoor air quality (IAQ) model was developed at CSTB to predict the concentrations of SVOCs indoors. This model was used to carry out a sensitivity analysis of di (2-ethylhexyl) phthalate (DEHP) concentrations in the gas phase, particulate phase, settled dust, and surfaces. DEHP is an endocrine disruptor, primarily used as a plasticizer and ubiquitous in the indoor environment. The aim of the study was to determine the most influential model inputs or parameters on concentrations as a way to guide numerical and experimental developments.

The range of each model parameter was determined based on data from the literature. Three sensitivity analysis methods were tested, namely Morris, Sobol, and RBD-FAST methods. The calculated sensitivity indices allowed ranking of the parameters by order of their contribution to the output. They also allowed quantifying the order of magnitude of the effect of parameters on the SVOC concentrations, although some methods were not accurate enough.

Monday, 12.06.2023 16:45-17:00 Room C Carbon

Emission rates of bio-based building materials, a comparison between cork panels and reference building materials

de Kort, Janneke; Gauvin, Florent; Loomans, Marcel; Brouwers, Jos

Eindhoven University of Technology, Netherlands, The

ID: 1224 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: VOC, indoor air quality, GC-MS, toluene equivalent, group equivalent

Emissions from materials affect the indoor air quality (IAQ). Use of new materials, such as bio-based materials, are in need of such information in order to learn that they don't form a health hazard when applied indoors. This research wanted to measure the emission (type and rate) from expanded cork and compare them to currently applied building materials. Gas chromatography-Mass spectrometry (GC-MS), applying two different methods, is used for this analysis. The difference in methods is also reflected in the temperature applied. A qualitative and quantitative is performed. For that, besides the toluene equivalent approach, a group equivalent approach is introduced. Results show that there is an effect in the type of components emitted as function of the temperature for bio-based materials. Quantitively, assessed according to a part of the German AgBB, no health risks are identified for the emitted components. Application of the toluene versus group equivalent approach did reveal that the toluene equivalent approach in many cases underestimates the quantitative emission rate. Therefore, the group equivalent approach is regarded more fit for analysis of the amount emitted for a chemical component. It challenges the information available in literature. That generally has been obtained with the toluene equivalent method.

Monday, 12.06.2023 17:00-17:03 Room C Carbon

Effect of Applying Alcohol to Wooden Surfaces on VOC Emissions and Perceived Air Quality

Akamatsu, Nami (1); Inasaka, Marina (2); Ikeuchi, Kosuke (1); Sugano, Soma (1); Kim, Hyuntae (3); Tanabe, Shin-ichi (1)

1: Waseda University, Japan; 2: Shimizu Corporation (Former Graduate Student, Waseda University), M. Eng.; 3: Yamaguchi University, Japan

ID: 1218 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Acetaldehyde, Alcohol Sterilization, Chemical Emission Rates, Sensory Evaluation, Solid Wood

The COVID-19 pandemic has increased the use of alcohol on indoor wood surfaces; however, knowledge of chemical emissions and perceived air quality is scarce in these cases. This study aimed to determine the effects of applying alcohol to indoor wood surfaces on volatile organic compound (VOC) emissions and perceived air quality. Experiments were performed on clean unpainted wood with 130 mL/m² of alcohol and conducted in a 1 m³ stainless-steel chamber. Four types of wood (Japanese cedar, cypress, Japanese lime, and plywood made from Pinaceae) were used in this study. The VOC concentrations in the chamber were measured using gas chromatography/mass spectrometry and high-pressure liquid chromatography. Furthermore, a sensory evaluation of the captured chamber air was conducted using human subjects. The results showed the acetaldehyde concentration of Japanese cedar and cypress increased under the alcohol-applied condition. This is because alcohol dehydrogenase in wood oxidizes ethanol. Therefore, the indoor air quality decreased from cleaning unpainted wooden surfaces with alcohol. Conversely, perceived air quality showed a decrease in odor intensity and increased acceptability of cypress at the 125th minute under the alcohol-applied condition. This might result from the alcohol-neutralization effect of terpenes in cypress, which had the highest airborne concentrations of pinene.

Monday, 12.06.2023 17:03-17:06 Room C Carbon

Impact of relative humidity on uptake and release of indoor VOCs by fabrics

CARON, Florent (1); VERRIELE, Marie (1); NICOLAS, Melanie (2); THEVENET, Frederic (1)

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ID: 1139 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: indoor surfaces, adsorption, secondary emission, heterogeneous chemistry

To understand the fate of VOCs indoors, interactions with surfaces are considered. Among the diversity of indoor materials, fabrics are widespread surfaces with interesting physical properties, such as specific surfaces. The contrasted chemical nature of their fibrous constituents is a key driver of fabric interactions with VOCs. Beyond direct interaction with pollutants, fabrics can uptake primarily water molecules, depending on relative humidity (RH), which can in turn affect VOC uptake.

This work aims at quantifying uptakes of typical indoor VOCs on representative fabrics under contrasted RH, in order to (i) determine the contribution of fabrics to indoor air quality, and (ii) provide relevant experimental datasets to indoor air modelers to include heterogeneous processes in models.

A 16-VOC mix, with high indoor occurrences, containing from 1 to 10 carbon atoms is exposed first to cotton, second to polyester fabrics. Three RH levels (25, 50 and 75%) are used to operate Field and Laboratory Emission Cells (FLEC) coupled with Selected Ion Flow Tube Mass Spectrometer (SIFT-MS) for VOC monitoring. Individual VOC concentrations at FLEC-inlet are in the 100-ppb range. From uptake under defined RH, partitioning coefficients (K) of each VOC are determined after equilibration on fabric samples. Beyond equilibration, the VOC flow is stopped and fabrics are exposed to zero-air to quantify the reversible fraction of taken up VOCs.

From uptake experiments, individual behaviors of VOC are reported as a function of RH. On cotton, RH affects K-values of VOCs negatively. Decreases by ca. one order of magnitude are observed. On the contrary, uptakes of ethanol and formaldehyde are enhanced. K-value of formaldehyde on cotton is promoted by two orders of magnitude from 25 to 75% RH. On polyester, K-values are higher than on cotton, but with almost no dependence on RH level. Only formaldehyde uptake is promoted by RH on polyester. Uptake results between both fabrics are compared and discussed in terms of water coverage.

From reversibility experiments, oxygenated VOCs (formaldehyde, acetone, acetaldehyde and ethanol) are fully released from cotton while from 90 to 20% of other VOCs remain adsorbed under RH below 50%. When RH reaches 75%, all monitored VOCs are fully released from cotton. On polyester, reversibility of taken up VOCs exceeds 60% whatever the RH level. Considering high reversibility, results evidence the buffering role of fabrics on VOC dynamics. Fabrics contribute to mitigate VOC concentration peaks and may act as transient secondary sources under less polluted conditions.

Monday, 12.06.2023 17:06-17:09 Room C Carbon

What's new in formaldehyde emissions from household activities? Impact of biocidal formaldehyde releasers from cleaning products on IAQ

Verriele, Marie (1); Rossignol, Gabriel (1,2,3); Nicolas, Mélanie (2); Thevenet, Frédéric (1)

1: IMT Nord Europe, Institut Mines-Télécom, Univ. Lille, Centre for Energy and Environment, F-59000 Lille, France; 2: Centre Scientifique et Technique du Bâtiment (CSTB), 38400 Saint-Martin-d'Hères, France; 3: Agence de la transition écologique (ADEME), France

ID: 1146 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 07. Occupant behavior & controls
Keywords: formaldehyde releaser; full scale studies, cleaning activities, Bronopol

For sanitation reasons, in the post-COVID19 period, cleaning activities have been intensified, even though they are now clearly acknowledged as practices contributing to the deterioration of indoor air quality from the chemist point of view. Significant actions have been successfully undertaken to limit direct emissions of VOCs and especially of formaldehyde (eco-labelling, REACH Regulation). However, it turns out that some substitutes to regulated VOCs can lead to new modes of contamination of indoor air. Formaldehyde releasers are used in household products, as preservative and biocidal agents; Bronopol® (2-Bromo-2-nitropropane-1,3-diol) is sorely represented in this category of products. Its degradation pathway in aqueous mediums leads to the release of formaldehyde, acting as an indirect indoor source. This path of formaldehyde emission needs to be addressed.

Individual chronic risk assessment data linked to the use of household products are lacking. The key question is: to what extent available emission factors describing a cleaning activity are reliable and applicable to realistic scenarios? The objective of this work is to fully address the formaldehyde release from cleaning products containing Bronopol® from lab scale to real scale. The final goal is to assess the contribution of this third way of emission of formaldehyde to indoor air quality.

1/ Analytical developments are first carried on to enable simultaneous quantification of Bronopol®, its by-products and formaldehyde. It unlocks the quantification of Bronopol® in commercial household products, and also kinetic studies to correlate

Bronopol® degradation with formaldehyde release in aqueous solutions. 2/ Knowledge on drivers of the degradation of formaldehyde releasers in solution and subsequent transfer of formaldehyde to the gas phase are then acquired at lab scale. 3/ Finally, formaldehyde emission during a cleaning activity involving Bronopol-based products is assessed. Distinctions are made between different types of cleaning activities (floor, furniture surface and window cleaning) and subsequently between different types of product formulations.

This work evidences that household activities have to be taken into account for risk assessment studies in line with formaldehyde exposure. Since our approach relies on real scale evaluation, it provides robust emission factor datasets, directly available to epidemiologist and toxicologist communities.

Monday, 12.06.2023 17:09-17:12 Room C Carbon

Residential radon concentrations before and after building code change in Winnipeg, Canada

Gaskin, Janet (1); Li, Karen (2); Zhou, Liang Grace (1)

1: National Research Council Canada, Canada; 2: University of California, Berkeley

ID: 1324 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: radon, building code, radon membrane, indoor air quality

Problem: Radon is a naturally occurring radioactive gas that can seep into housing through the foundations. Any increase in indoor radon concentration is associated with an increased risk of lung cancer. Since 2010, the National Building Code of Canada (NBC) has required a 6 mil polyethylene radon membrane to be installed below the slab to reduce radon ingress. The aim of this study was to investigate the radon concentrations in housing built in the decade before and after the 2010 NBC radon control measures were adopted in Winnipeg, Canada.

Method: A radon survey was conducted by the National Research Council Canada in Winnipeg, focussed on areas where a substantial number of new dwellings have been built since the year 2000. A postcard campaign offered free radon testing to every home in the target areas, and testing kits were mailed to the 238 eligible residents recruited. Residents were eligible to participate in the study if they were over 18 years old and living in a detached home, a semi-detached home, or a townhouse built between 2001 and 2021, excluding 2011, the year the new building code provisions were adopted. Homes where post occupancy radon mitigation measures had been implemented were also excluded. Indoor radon measurements and home questionnaires were completed by 172 participants (72%), using alpha-track radon detectors deployed for an average duration of 91 days between February and June, 2022.

Results: Radon concentrations in housing built during both 2001-2010 and 2012-2021 were lognormally distributed. There was no evidence of decreased indoor radon in detached homes after the adoption of the building code change. The indoor radon concentration in detached houses was defined by a geometric mean (GSD) of 122 (1.8) Bq/m^3 in the 83 homes built in 2001-2010, and 109 (2.0) Bq/m^3 in the 71 homes built in 2012-2021, but the difference was not statistically significant. An analysis by type of home was possible in those built in 2012-2021, which included different types of homes. The analysis showed a statistically significant difference in indoor radon between home types, described by a lower geometric mean in the 17 semi-detached and townhouses than in the 71 detached houses, at 61 (2.1) Bq/m³ and 109 (2.0) Bq/m³ respectively.

Conclusions: These results suggest that stronger radon control measures will be required in future building codes to reduce all residential radon exposures and the associated lung cancer burden for the general public.

Monday, 12.06.2023 17:12-17:15 Room C Carbon

Round robin tests of odour and VOC emissions from building products– what have we learned so far

Horn, Wolfgang; Wilke, Olaf; Richter, Matthias

Bundesanstalt für Materialforschung und -prüfung (BAM), Germany

ID: 1374 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Emission, Building product, VOC, Odour, round robin

Emission testing of volatile organic compounds (VOC) and odour from materials and products is commonly based on emission test chamber measurements. These measurements are often the basis of labelling procedures. To ensure the comparability of results from different testing laboratories their performance must be verified. For this purpose, Bundesanstalt für Materialforschung und -prüfung (BAM) organizes international proficiency tests (round robin test, RRT) every two years using well characterised test materials (sealants and mainly a dried lacquer) with defined VOC emissions. It is important that the materials fulfill the requirements of homogeneity, reproducibility and stability. Therefore, BAM developed a suitable reference material for the use in test chamber measurements with a multi VOC-mixture. A lacquer system added with a VOC mixture in suitable amounts was used as test material. It was easy to prepare, and homogeneity was ensured in several round robin tests. For the purpose of odour tests some VOCs with known low odour threshold values were also added. For VOC-tests more than 50 different labs and for odour tests up to 20 laboratories take part in this round robin tests. Over the years we observed that the number of correct identified and quantified compounds had risen. The VOCs were analysed following the EN 16516 and the connected ISO standards. For the evaluation of odour two different procedures were used as described in ISO 16000-28, these are acceptance and perceived intensity. Robust statistical methods for the evaluation of proficiency tests were used. Findings from former round robin tests and further trends will discussed.

Session 8 Monday Silver - Healthy building concepts

Time:
Monday, 12.06.2023 16:00-17:30

Room: Ag Silver

Chair:
Bluyssen, Philomena
Delft University of Technology

Co-Chair:
Lorenz, Clara-Larissa
RWTH Aachen

Monday, 12.06.2023 16:00-16:03 Room Ag Silver

Indoor Air Management of Airborne Pathogens: A National Academy of Sciences Virtual Workshop Series

Thévenon, Audrey Davidson; Butler, David Alan

National Academies of Sciences, Engineering, and Medicine, United States of America

ID: 1194 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: infectious agents, ventilation, interventions, health

As a follow-up to a 2020 workshop on the airborne transmission of SARS-CoV-2, the Environmental Health Matters Initiative of the U.S. National Academies of Sciences, Engineering, and Medicine is carrying out a virtual workshop series that explores strategies for airborne disease control and risk reduction in the built environment and other enclosed spaces. The workshops are addressing established and familiar infectious agents--including SARS-CoV-2--as well as emerging and novel pathogens.

To accomplish these tasks, an interdisciplinary group of natural, physical, and social scientists is being convened together with facilities managers, ventilation engineers, and representatives of populations using public and private facilities. Through panel discussions and participatory exercises, the participants are 1) reviewing the state of knowledge concerning building management, ventilation, and air cleaning for airborne pathogens, 2) discussing experiences with the management of enclosed spaces during the pandemic, and 3) identifying promising practices for making these places safer.

Specifically, the workshops are addressing the following critical questions:

- What scientific progress has been made since 2020? How has the knowledge base increased to help further refine and inform public health decisions and guidance?
- What is the state of knowledge with regard to the concentration of infectious aerosols and droplets in inhaled air and the risk for infection? Do we know enough to specify targets for infection control?
- What have we learned about the profile of building ventilation in critical venues and other enclosed environments? How did the management of facilities adapt to the pandemic? What were the tradeoffs?
- Do we have accurate methods for assessing building ventilation for infection control?
- Do we have evidence on the effectiveness of air-cleaning? Sterilization?

- Are tested approaches and toolkits for interventions available?

A proceedings in-brief capturing the presentations, discussions, and promising practices identified by the participants will be published in late 2022 or early 2023. As the workshop series has not yet been completed, it is not yet possible to provide further detail.

Monday, 12.06.2023 16:03-16:18 Room Ag Silver

Healthy Homes Barometer 2022: Its impact on health and life satisfaction, as well as its wider socio-economic costs

Christoffersen, Jens (1); Grollov, Sune Tobias (1); Philips, William (2); Hafner, Marco (2)

1: VELUX A/S; 2: RAND Europe

ID: 1174 Full paper
Topics: 09. Public health, occupational & environmental health
Keywords: Health, Sustainable, Indoor Climate, Life Satisfaction, Economic benefits

Since spring 2020, nationwide lockdowns forced millions of Europeans to work, learn and live at home. The role of our buildings is changing and the housing inequalities that exist revealed the urgency of providing sustainable, healthy and affordable housing where all citizens can thrive. There is strong evidence that poor indoor climate in our buildings has a significant impact on people's health and well-being, and that in turn has wider socio-economic consequences. The objective of this study was to undertake a detailed analysis of the impact of the indoor climate across all age groups in the EU, UK, Norway and Switzerland. For this purpose, the study utilised a targeted data review of the key factors associated with indoor climate hazards, a literature review focusing on identifying and assessing evidence from existing systematic reviews, the health of particular population groups, and the wider socio-economic costs. In addition, living with indoor climate hazards was found to be associated with lower levels of life satisfaction and its macroeconomic cost. The analysis clearly shows that key initiatives through a Renovation Wave could tackle the climate crisis by decarbonising our building stock, but policymakers need to address the opportunity to invest in sustainable buildings.

Monday, 12.06.2023 16:18-16:33 Room Ag Silver

Program of Requirements Healthy Dwellings

Loomans, Marcel (1); Hensen-Centnerova, Lada (1); Beuker, Tim (2); Jacobs, Piet (3)

1: Eindhoven University of Technology; 2: bba binnenmilieu; 3: TNO

ID: 1215 Full paper
Topics: 09. Public health, occupational & environmental health, 11. All other IEQ, ergonomics & health topics
Keywords: indoor environmental quality, performance criteria, user interaction

Program of Requirements (PoRs) provide a means for clients to express their wishes with regard to a new or to be renovated building. In The Netherlands, PoRs have been developed for the indoor environmental quality (IEQ) for offices and schools. They are presented in classes (A/B/C) that define quality levels for the IEQ that support health and comfort. The PoRs 'Healthy Offices' and 'Fresh Schools' are available for more than a decade and well received. They are currently applied on a regular basis in practice. As a follow-up, a PoR for the IEQ of dwellings has been developed (titled: PoR Healthy Dwellings). That PoR is, amongst others, based on the information available from offices and schools. However, the influence of the user on the actual performance is much larger in dwellings, and its occupation is much more diverse. Therefore, for this PoR assumptions have been made to allow for these differences. In this paper, the conditions for and the development of the PoR are explained and some examples are provided. The PoR Healthy Dwellings has been launched in 2022. Developments are ongoing with respect to verification protocols, which is also less straightforward than for offices and schools.

Monday, 12.06.2023 16:33-16:48 Room Ag Silver

Correlations between indoor conditions and human health: the methodology behind the development of a monitoring and warning system

Botto, Sara; Porta, Matteo; Spigliantini, Giorgia

RINA Consulting Spa, Italy

ID: 1297 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling, 09. Public health, occupational & environmental health
Keywords: Healthcare management system, IEQ, Healthcare facilities, Occupants health

The monitoring of indoor ambient conditions is usually focused on the thermo-hygrometric comfort of the occupants, being regulated by standards. The correlations between the internal environmental quality and the occurrence of health diseases, especially in fragile people, are still under investigation without specific related norms. This study presents the literature research performed during iBECOME project, outlining the parameters for the development of a healthcare management system for nursing homes. Indoor temperatures above 26°C and below 20°C are the most associated with health risks for the exacerbation of pre-existing cardiovascular and respiratory symptoms in elderly and fragile people. An increased incidence of respiratory and viral infections, as well as severe allergic and asthmatic reactions are correlated with relative humidity below 40% and above 60%. Lower cognitive functions, drowsiness, headaches, sleepiness and increased heart rate are associated with CO2 level above 1000 ppm. As a result, 33 different cases of alerts and recommendations have been identified for the development of a healthcare management system. The scenarios aim to warn about potential threats for the health of the occupants of care homes, indicating actions to mitigate them.

Monday, 12.06.2023 16:48-16:51 Room Ag Silver

Healthy Building database connects scientifical analysis with comprehensive condition assessments of public buildings

Koskinen, Vesa (1,2); Murtoniemi, Timo (1); Lappalainen, Vuokko (1,3); Katajisto, Jouko (4); Vehviläinen, Tommi (1)

1: Sirate Group Oy, Finland; 2: University of Turku, Department of Physics and Astronomy, Finland; 3: University of Eastern Finland, Department of Environmental and Biological Sciences, Kuopio, Finland; 4: University of Turku, Department of Mathematics and Statistics, Finland

ID: 1361 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: condition surveys, Indoor air quality, database, risk assessment, public buildings

Extensive indoor environment data generated from hundreds of comprehensive building moisture and condition assessments of public Finnish buildings has and will be collected into a structural database and analysed statistically. The dataset contains tens of thousands of technical measurements and classified microbial, chemical, and mineral fibre samples. According to Finnish guidelines, the assessments have been made by certified building health experts and both the assessed buildings and collected data are highly categorized. In this paper, the current state of the project, that will be completed in 2024, is reported together with the first preliminary results. As a preliminary result based on the total of 277 comprehensive assessments, there is no significant statistical difference in the prevalence of significant damp and mould damages between the assessments made due to an IAQ problem or without. On the contrary, the analysis of 3954 MMMF samples analysed in four laboratories revealed statistically significant differences ($p<.001$) between the laboratories.

Monday, 12.06.2023 16:51-16:54 Room Ag Silver

Time marches on: Supporting holistic health in older adults through the built environment

Ruiz, Shelby; Rothlisberger, Sierra; Day, Julia K.

Washington State University, United States of America

ID: 1443 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia, 11. All other IEQ, ergonomics & health topics
Keywords: senior living, holistic health, well-being, equitable design, narrative research

To capture the lived experiences in buildings of older adults, this pilot study implemented qualitative and narrative methods to interview over 60 seniors living in full-time assisted or independent living communities in Washington State in the USA to better understand how the passing of time has changed their relationships and interactions within the built environment. In particular, the focus of this paper is to share stories from these individuals surrounding their ever-changing experiences in buildings from their formative years, through their adult life, and into their senior years in care facility settings. As lifelong building occupants, these individuals expressed how their relationship with buildings has changed over time and how that has impacted their physical, mental, and cognitive well-being. We identified many opportunities for substantial improvements that are needed in current buildings to best address safety, equity, and comfort in ways that can increase and support well-being. Findings suggest older adults should be consulted when selecting materials, building features, lighting, thermal conditions, controls, and more. There is a need for a more empathetic design approach that considers older individuals' abilities and day-to-day activities in ways that are supportive of holistic health.

Monday, 12.06.2023 16:54-17:09 Room Ag Silver

Housing and health survey results from Finland indicate changes in exposure factors

Kempe, Minna; Haverinen-Shaughnessy, Ulla

University of Oulu, Finland

ID: 1184 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: indoor environment, health, safety, homes, survey

We would like to present the current status of the quality, health, and safety of living in Finland, and also how it has changed in the past 15 years. We will be presenting results from the ALTTI survey, which was earlier conducted in 2007 and 2011, and is now repeated in 2022. The 2022 survey includes 93 questions about key residential environment quality problems, e.g. indoor air quality, environment impurities, moisture and mold damage, heat, noise and sound conditions, ventilation adequacy, as well as the health, safety, and discomfort experienced by residents. The questionnaire used in 2022 is comparable to the ones used before in 2007 and 2011, with the exception of a few questions (e.g. some questions related to COVID19 were added).

The survey was sent out to a random sample of 3000 people living in Finland. The persons were Finnish-speaking and 18–75-year-olds at the time of data collection. People were selected one per residential unit. In 2007 the response rate was 44% (1312 persons) and in 2011 it was 30% (884 persons). The data for the 2022 survey is still being collected, the response rate being at 27% at the moment. We believe that the results from the 2022 survey will also be mainly generalizable to the Finnish population. In addition to the survey, also information about the inhabited apartment and the background of the research participants were obtained.

The data now being collected will be analyzed to determine the current status and what has changed since the previous studies. In 2007 and 2011, housing quality, health, and safety were mostly similar between the years. Differences then, in data collected four years apart, were observed e.g. in satisfaction with the apartment, heating methods, and differences in experiencing thermal conditions. The level of equipment improved from 2007 to 2011 and the residents' knowledge of housing health issues increased. Now 15 years later we expect to see more extensive changes.

The ALTTI study aims to assess the quality of the housing stock in Finland and the health and security perspectives and model its connection to the health and well-being of residents. The ALTTI study is important for us to better understand and predict housing-related phenomena, and the database can also be used as up-to-date reference material for studies dealing with building health issues.

Monday, 12.06.2023 17:09-17:12 Room Ag Silver

System-analytical economic assessment – Engineering a building strategy that balances health, economic and environmental impact

Hörhammer, Iiris (1); Halminen, Olli (1); Haverinen-Shaughnessy, Ulla (2); Karvonen, Anne (3); Kempe, Minna (2); Kuurola, Pentti (2); Lahdensivu, Jukka (4); Leivo, Virpi (4); Pakkala, Toni (4); Torkki, Paulus (1); Täubel, Martin (3); Pekkanen, Juha (1)

1: Helsinki University, Department of Public Health; 2: University of Oulu, Structures and Construction Technology; 3: Department of Health Security, The Finnish Institute for Health and Welfare; 4: Tampere University, Faculty of Built Environment

ID: 1393 Extended Abstract
Topics: 09. Public health, occupational & environmental health, 10. Community- and urban-scale challenges and solutions
Keywords: economic modeling, retrofit, moisture damange, asthma

Buildings consume over 40% of energy in the Nordics. Improved insulation and ventilation optimization are among the most impactful ways to reduce CO2 emissions from buildings and therefore combat climate change. However, such retrofits can further increase the risk of moisture damage that is already predicted to increase due to climate change. Moisture damage has been identified as one of the five major threats to health in Finland due to climate change, notably causing onset and exacerbation of asthma.

In order to design sustainable building strategies, the co-effects of ventilation, optimization and moisture damage repairs need to be balanced. System-analytical economic modeling can enable the engineering of national-level building strategies that allow balancing the health, economic and climate impacts of different repair interventions.

We present a system-analytical economic model to assess and compare the impact of different building repair interventions. The model is applied in the context of a risk of development of new asthma. It considers the intervention impacts on health-economic outcomes, carbon footprint, and costs of repair and energy consumption for a national building stock during a 30- and a 50-year time-window. In the model, intervention effect on asthma incidence is attributed mainly to moisture damage. Health-economic outcomes include direct and indirect costs of asthma and asthma-related quality of life.

The model also considers changes in population structures, national building stock and area-specific weather conditions.

The model is a part of the BALANCE project, a multidisciplinary effort by leading research groups in Finland from the research fields of environmental and public health, economics, construction engineering, and microbiology that aims to identify the most cost-efficient national building repair strategy in the Finnish building stock for climate change mitigation and adaptation.

The BALANCEd system-analytical economic model can be used to project energy savings, emission reductions, and health-related societal impact of building insulation and optimization retrofits and moisture damage repairs in the Finnish building stock. Opportunities to accommodate national climate change scenarios in the model, and to apply the model in other national contexts and for other indoor air -related health outcomes are discussed.

Monday, 12.06.2023 17:12-17:15 Room Ag Silver

Affordability-led decisions impacting households' health and economic wellbeing - A transdisciplinary perspective

Elghandour, Aya

School of Architecture, The University of Sheffield, UK

ID: 1419 Extended Abstract
Topics: 08. Psychology, psychophysics, performance & productivity, 09. Public health, occupational & environmental health
Keywords: Design, Health, Wellbeing, Decision-making, Affordability of housing

Household's health and wellbeing (H+W) is one of the most important determinants of public health. In the UK, the impact of poor housing on households costs the National Health Service (NHS) over £1 billion a year. In times of economic challenge, these pressures can increase. On the one hand, low- and low-to-middle-income communities may sacrifice quality of life to reduce spending. On the other hand, with the housing crisis, there is a risk that unfit properties will be deemed affordable, overlooking aspects of H+W. Design can play a key role through the decisions made at the design development stages, therefore helping to reduce these pressures on the public sector and remove potential risks. For example, decisions about parameters of size, position and material of windows affect daylight and noise levels, connectedness with nature, and the residents' sense of privacy, the lack of which have been linked to mental health symptoms in Europe, according to the World Health Organization (WHO). These parameters also influence ventilation and thermal comfort and therefore correlate with mould growth and respiratory illnesses. So far the literature on the impact of design on household's H+W is fragmented when it comes to guiding the design process of affordable homes. Moreover, there is a lack of a comprehensive perspective on the design of healthy homes that promote wellbeing and yet are affordable. Therefore, the study will take a transdisciplinary approach to promote mutual learning between housing stakeholders engaged in the design and affordability of housing, and the health and wellbeing of households, in order to inform the study. This approach aims to explore and map existing knowledge to demonstrate a designer potential contribution to household's H+W. To this end, an extensive literature review and interviews with stakeholders from the health and housing sectors will be conducted. This would enable the development of a design taxonomy for household's H+W, to provide an effective tool for designers to prioritize the household's H+W and support the their decision-making during the design process.

Session 9 Monday Oxygen - Airborne transition & COVID-19

Time:
Monday, 12.06.2023 16:00-17:30

Room: O2 Oxygen

Chair:
Kort, Helianthe
Eindhoven University ofTechnology

Co-Chair:
Ding, Er
Delft University of Technology

Monday, 12.06.2023 16:00-16:15 Room O2 Oxygen

COVID-19 transmission risks associated with environmental contamination in workplace and public toilets

Higham, Ciara A. (1); Noakes, Catherine J. (2); López-García, Martín (3); Fletcher, Louise (2)

1: EPSRC Centre for Doctoral Training in Fluid Dynamics, University of Leeds, United Kingdom; 2: School of Civil Engineering, University of Leeds, United Kingdom; 3: School of Mathematics, University of Leeds, United Kingdom

ID: 1423 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: Disease transmission, CFD, toilets

Shared toilets are a known facilitator of disease transmission. The COVID-19 pandemic has illustrated the need to reduce the risk of transmission in such an essential and highly frequented environment. Two key mechanisms of transmission when an individual uses a toilet are respiratory emission and the toilet plume generated when flushing the toilet. Both types of emission release pathogens into the environment via aerosols and droplets which may be infectious. Pathogens released in larger droplets settle on surfaces quickly while smaller ones which evaporate can remain airborne for hours, eventually being removed by ventilation or settling on surfaces. When a susceptible individual uses the toilet they can potentially become infected, through airborne or fomite routes. This risk will depend on the design of the toilet facilities, ventilation system, frequency of use as well as behavioural aspects.

This study explores the exposure from a flush aerosol and while it focuses on the infection risk for the SARS-CoV-2 virus it is applicable to other pathogens. Experiments are conducted flushing a toilet in a controlled ventilated chamber using inert particle and biological surrogates, with measurements taken of particles and microorganisms in air, as well as microorganism deposition on surfaces. Computational Fluid Dynamics (CFD) is used to model the experimental scenario to quantify the distribution of droplets and aerosols produced. The model is developed using ANSYS Fluent and uses a Lagrangian particle tracking methodology to represent the time varying dispersion and deposition of aerosols released from a defined source. Results show the comparison between air and surface contamination from the experimental and modelling studies, considering the variability in concentrations and the influence of ventilation conditions. We aim to use this data to develop a Quantitative Microbial Risk Assessment (QMRA) model to estimate the risk of infection to a susceptible individual when using the toilet through both fomite and airborne routes. Effectiveness of mitigation strategies such as ventilation, UV-C and room layout will be analysed using CFD to determine the most appropriate measures.

Monday, 12.06.2023 16:15-16:30 Room O2 Oxygen

Effects of COVID-19 pandemic control and prevention measures on ventilation in secondary schools in the Netherlands

Ding, Er; Zhang, Dadi; García-Sánchez, Clara; Bluyssen, Philomena M.

Delft University of Technology, Netherlands, The

ID: 1295 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Classrooms, ventilation, children, COVID-19

During the COVID-19 pandemic, the importance of ventilation for ensuring occupants' health was widely stressed. New protocols of ventilation were implemented in school buildings worldwide. In the Netherlands, school classrooms were first required to keep the windows and doors opened, and later more stringent measures such as reduction of occupancy were introduced. However, the actual effects of such measures on ventilation in the classrooms remained unclear. In this paper, a field study conducted among 31 classrooms of 11 Dutch secondary schools is presented. All the schools were first visited between October and December 2020, soon after which a national lockdown took place, and all the schools were closed until the end of February 2021. Later between March and June 2021, the schools were visited for the second time. Each visit lasted for one school day, during which the indoor and outdoor CO2 concentration were continuously monitored, inside the classrooms and at the entrance/courtyard of the schools. Occupied teaching hours and numbers of student occupants were recorded for each selected classroom. The total ventilation rate (VR, l/s), ventilation rate per person (VRp, l/s/p), and ventilation rate per floor area (VRa, l/s/m²) were calculated accordingly, based on the steady state method. Before the lockdown, the classrooms were used under full occupancy, with windows and doors often opened during the teaching hours. The results showed that in more than 40% of the classrooms, the average VRp was lower than the minimum requirement prescribed by the Dutch Fresh Schools guidelines (6 l/s/p). After the lockdown, the occupancy in the classrooms was almost halved, in order to keep 1.5 distance between the students, while the numbers of opened windows and doors remained similar. Significant increase was observed in VRp with all the classrooms having an average VRp higher than 6 l/s/p, while no significant difference was found in VR or VRa. It is concluded that after the lockdown the ventilation rate per student increased mainly due to the measure of

decreasing occupancy. Moreover, adequate ventilation in school classrooms cannot be ensured only via the operation of windows and doors.

Monday, 12.06.2023 16:30-16:45 Room O2 Oxygen

Regional Cohort Analysis of COVID-19 Outbreaks within British Columbia's Long-Term Care Homes: Comparing the Impact of Single-Person versus Multi-Person Bedrooms

Buchanan Dee, Brendan; Rysanek, Adam

University of British Columbia, Canada

ID: 1452 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia, 09. Public health, occupational & environmental health
Keywords: long-term care, COVID-19 transmission, single-person bedroom versus multi-person bedroom, regional cohort analysis

Throughout the pandemic, severe outbreaks of COVID-19 have struck long-term care homes (LTCHs) with high levels of infections and case fatalities borne by elderly residents. Among the multiple variables that may influence disease transmission in LTCHs, this study examines the building design factor of resident population size. This regional cohort study considers LTCHs in British Columbia (BC), Canada, synthesizing administrative survey data from the BC Office of the Seniors Advocate (BCOSA) and public health data from the BC Centre for Disease Control (BCCDC). Between March 5, 2020–February 9, 2022 (707 days), a total of 333 COVID-19 outbreaks were reported at 200/355 (56.3%) of BC's LTCHs with a total of 4,367 resident cases and 960 deaths (22.0% case fatality rate). Correlation analyses determined that resident population size was weakly correlated with the presence and duration of a second outbreak. Of the 34 BCLTCHs that experienced an outbreak with a resident attack rate exceeding 35%, 23 (67.6%) were medium-sized facilities with 31-99 residents, whereas 11 (32.4%) were large-size facilities with more than 100 residents. This study suggests that while facilities with larger resident populations are at greater risk of outbreak occurrence and recurrence, LTCHs with fewer residents (<100 residents) are more susceptible to severe outbreaks when they occur with a greater proportion of residents becoming infected.

Monday, 12.06.2023 16:45-17:00 Room O2 Oxygen

Experimental assessment of CO2 tracer gas and aerosol particles during breathing, coughing, and sneezing.

Nabilou, Fatemeh; Derwein, Dennis; Rewitz, Kai; Müller, Dirk

RWTH Aachen, Germany

ID: 1167 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: breathing coughing and sneezing, breathing manikins, CO2 tracer gas, aerosol particles, transport behavior

Human breathing, coughing, and sneezing are indoor biological contaminant sources. Therefore, it is essential to study the spatial dispersion of those pollutants. Breathing manikins developed with tracer gas techniques, especially carbon dioxide (CO2), simulate respiration actions. However, the suitability of the CO2 tracer gas method to resemble the behaviour of both exhaled gaseous and particle pollutants needs further experimentation. This study aimed to compare the transport behaviour of different-sized particles with CO2 during breathing, coughing, and sneezing. Accordingly, a breathing manikin was developed to simultaneously exhale aerosol particles and CO2. The concentrations were measured at five points in the Aachen Comfort Cube (ACCu) conditioned with a mixing ventilation strategy. Based on the results, fine particles during breathing showed less tendency to propagate than CO2. While during more violent exhalation events (sneezing and coughing), they traveled further in the jet direction. Additionally, ultrafine particles were concentrated more in the front and on the side seat of the emitter, depending on the respiration action. Contrary to particles, the tracer gas results showed an almost uniform distribution of CO2 at the measurement points. The findings of this study help to have a better understanding of the way contamination by transmissible respiratory diseases occurs.

Monday, 12.06.2023 17:00-17:03 Room O2 Oxygen

Comparing the mitigation effects of fan configuration and operation on indoor airborne transmission risk

Yang, Fan (1); Cheung, Toby (1); Li, Jiayu (2); Tham, Kwok Wai (1)

1: National University of Singapore, Singapore; 2: Berkeley Education Alliance for Research in Singapore, Singapore

ID: 1309 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: airborne transmission, air movement, ceiling fan, desk fan

In indoor environments, expiratory activities from infected individuals transmit pathogen-laden droplets and aerosols that pose health risks to other healthy occupants. Especially under the COVID-19 pandemic, evidence has shown that airborne transmission is the dominant route of transmission. Therefore, minimising the exposure risk of airborne transmission at the inhalation zone is crucial. Besides the engineering control of ventilation systems, the use of fans has been increasingly advocated to operate with the ACMV system to mitigate the exposure risks. In this study, an empirical experiment was conducted to compare the effect of single and combined use of different fans to mitigate airborne transmission risks. To replicate the scenario of two people having a conversation at a close distance, SF6 tracer gas was used as the surrogate for exhaled aerosols from the infected individual, and a breathing thermal manikin as the healthy individual. Special focus has been placed on the exposure risks at breathing zone. Among different fan operating scenarios, the use of ceiling fan reduced the exposure risks at breathing zone effectively, and the combined operation of ceiling fan and desk fan achieved the lowest SF6 concentration, thus was the most effective mitigation overall in the indoor environment of this study.

Monday, 12.06.2023 17:03-17:06 Room O2 Oxygen

Assessing the effects of transient weather conditions on airborne transmission risk in naturally ventilated hospitals.

Edwards, Alexander Jon (1); Noakes, Catherine (2); López-García, Martín (3); King, Marco-Felipe (2); Peckham, Daniel (4,5)

1: EPSRC Centre for Doctoral Training in Fluid Dynamics, University of Leeds, Leeds, UK; 2: School of Civil Engineering, University of Leeds, Leeds, UK; 3: School of Mathematics, University of Leeds, Leeds, UK; 4: School of Medicine, University of Leeds, Leeds, UK; 5: Leeds Teaching Hospitals NHS Trust, Leeds, UK

ID: 1162 Extended Abstract
Topics: 09. Public health, occupational & environmental health
Keywords: CONTAM, Transient, Weather conditions, Airborne Transmission, Hospital

Having the ability to understand and model airflow in indoor built environments is a useful tool for many scenarios, especially when considering the transmission of airborne infections. However, many models assume steady state airflows; it is important not to overlook the effects of the external environment and weather conditions. Many traditional UK hospital building designs often rely heavily on natural ventilation as their main source of airflow in patient wards and thus, is difficult to manage. This uncertain method of ventilation opens up the opportunity of unpredictable flow patterns between indoor spaces, potentially leading to the unexpected transport of infectious material to other connecting zones. Through exploration of the effects of transient wind-driven flow on a multi-zonal indoor environment, we are able to use the network-based ventilation model, CONTAM, to apply transient external environmental conditions to quickly assess the consequences this has on connected indoor spaces. We propose a multi-zonal CONTAM model of a naturally ventilated hospital respiratory ward, exploring various weather conditions over different time scales to analyse the resulting inter-zonal flow values. Coupling this with transient occupancy and behaviours, we are able to use a previously developed multi-zonal transient infection model to provide an assessment of the risk in this space, focussing on particular occupancy, disease and ventilation scenarios within a healthcare setting. Our results suggest that the use of natural ventilation with varying weather conditions, when explored over longer periods, can cause irregularities in the inter-zonal flows rates of the connected zones and thus, lead to occasional unexpected peaks in the concentration of airborne pathogen in particular rooms, increasing the risk

of infection. Our model emphasises the need for consideration of transient external conditions when assessing the risk of transmission of airborne infection in indoor environments.

Monday, 12.06.2023 17:06-17:09 Room O2 Oxygen

Evaluation of intervention strategies on controlling airborne respiratory particles in isolation wards

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ID: 1221 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: COVID-19, Indoor environment, Computational fluid dynamics (CFD), particle transport, simulations

Coronavirus disease 2019 (COVID-19) is an ongoing pandemic, caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), resulting in more than 6.4 million deaths as of August 2022. Airborne transmission is proved as an important route for the spread of SARS-CoV-2. To protect the healthcare workers and reduce the cross-infection between patients, it is essential to control the airborne transmission of respiratory particles in isolation wards. Thus, in this study, three potential intervention strategies, i.e., the use of curtains, ceiling-mounted air cleaners, and periodic ventilation were numerically investigated to explore effective control measures in isolation wards. A real 4-beds isolation ward was selected as the study object. And computational fluid dynamics (CFD) with the Lagrangian model was used to calculate the particle dispersion and deposition. The particle concentrations in patients' breathing zones and the whole ward with and without the control strategies were compared. The results show that the use of ceiling-mounted air cleaners is effective in reducing the airborne transmission of SARS-CoV-2 in such wards, because lots of respiratory particles were removed before spreading throughout the ward. Curtains can effectively reduce the cross-infection between the adjacent patients but would increase the risk of the opposite patient. And although periodic ventilation can reduce the trapping of particles in the recirculation zone, it might increase the exposure of other patients.

Monday, 12.06.2023 17:09-17:12 Room O2 Oxygen

Effectiveness of Airflow Generation and Extraoral Vacuum Suction as Infection Control Measures in a Dental Office

Hasama, Takamasa (1); Yumino, Saori (2); Kondo, Koji (2); Koga, Takashi (2); Watanabe, Keisuke (3); Shoji, Yoshio (3); Tanabe, Tomoki (3); Arata, Naoya (3); Fujii, Kazuyuki (4); Ishigaki, Yoshiki (4); Shibui, Takeo (4); Kobayashi, Ryutaro (4)

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ID: 1280 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Dental office, COVID-19, SARS-CoV-2, airflow, circulator, extraoral vacuum suction

For dentists and dental hygienists, providing medical treatment and care in a patient's oral cavity is considered high probability of exposure to the expiratory aerosols. Aerosol transmission is a major path of COVID-19 (SARS-CoV-2) infection, they may be suffered high risk of the infection. To investigate effective measures to reduce the risk of transmission from asymptomatic infected persons to dentists and dental hygienists, the authors conducted several experiments in a dental treatment room of The Nippon Dental University. "Simulated saliva", a mixture of water, salt and protein, was sprayed for 5 seconds from the side of mouth of a thermal manikin as a dental patient, and the number of particles was measured by a particle counter placed in front of the mouth of a manikin as a dentist. The measurements were carried out in five cases: a) the basic case (conventional air conditioning), b) a case with the circulator placed in the center of the room and operated at high air flow mode, c) a case with the circulator placed behind the patient and operated at low air flow mode, d) a case using an extraoral vacuum suction as local exhaust, and e) a case attaching a portable neck fan hanging on the dentist manikin. In the basic case, during normal air conditioning, highly concentrated aerosols remained around the mouths of dentists and dental hygienists for about 1 minute, but in cases b, c, and e, the residence time for highly concentrated aerosols was reduced, and case d showed no increase in the number of concentration of aerosols. The aerosol concentration in the breathing zones of dentists and dental hygienists could be reduced by the dilution and convection of aerosols caused by the air flow generation and by the collection of aerosols near the source, resulting in a potential to reduce the COVID-19 infection risk.

Monday, 12.06.2023 17:12-17:15 Room O2 Oxygen

CFD as a Tool for Preparing for the Next Pandemic

Karvinen, Aku

VTT Technical Research Centre of Finland, Finland

ID: 1284 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: COVID-19, CFD, pandemic, airborne decease

At the beginning of 2020, frightening news began to emerge around the world. The unknown threat caused a lot of pneumonia and other several illnesses. Soon it turned out that the cause was the coronavirus closely related to 2002-2003 SARS (Severe Acute Respiratory Syndrome) virus. New virus was later named SARS-CoV-2 (SARS Corona Virus 2) and the disease was named COVID-19 (Corona Virus Disease 19). At first, it was thought that the virus would not be transmitted from human to human, but when this turned out to be the case, it was time for urgent measures. Different methods to prevent the spread of the disease were applied, including full lockdowns. At first, it was thought that the virus was transmitted mainly through droplets and fomites. The research community started soon, however, to speculate whether the virus can also be transmitted by small particles floating in the air called aerosol particles. When this transmission route turned out to be important, perhaps even dominant, it was time to start look for, research, and develop the methods to prevent aerosol transmission.

This paper explains how to use simulations to study methods to prevent the aerosol transmission of diseases. The main simulation tool used is a computational fluid dynamics (CFD), which allows the movement of individual aerosol particles to be predicted and visualized in different situations, such as in different ventilation strategies. The simulation also enables the assessment of the effectiveness and development of various methods of preventing transport, such as air purifiers and UV lights. The method has also been used to illustrate for the public how the virus spreads, facilitating, among other things, daily decision-making on which facilities are safe and when the use of a respirator is necessary. In addition to COVID-19 situation, the methods developed will be used to prepare for the next pandemic.

This paper presents some simulation results using detached eddy simulation turbulence model and validation of the results against experimental results measured in a room sized test chamber.

Parallel sessions

Tuesday

Session 10 Tuesday Carbon - Air supply systems

Time:
Tuesday, 13.06.2023 11:00-12:30

Room: C Carbon

Chair:
Wilde, Dominik
Viessmann Climate Solutions SE

Co-Chair:
El-Mokadem, Mahmoud
RWTH Aachen University

Tuesday, 13.06.2023 11:00-11:15 Room C Carbon

Experimental and numerical evaluation of the efficiency of an indoor air cleaner under different conditions

Sabanskis, Andrejs; Vidulejs, Dagis Daniels; Teličko, Jevgēnijs; Virbulis, Jānis; Jakovičs, Andris

Institute of Numerical Modelling, University of Latvia, Latvia

ID: 1418 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: air filtering, COVID-19, computational fluid dynamics, aerosol transport

For an efficient indoor air purification, it is important to know the detailed air flow distribution in the room. A series of numerical simulations are carried out for four heating regimes using air-air heat pump, capillary mat at the ceiling, heated floor, and radiator. The most homogeneous temperature field is obtained for the case with heated floor. The highest velocity is obtained for the air-air heat pump, while the lowest – for capillary mat at the ceiling and heated floor. An air cleaner is introduced in the model, and its influence on the velocity and temperature distributions is calculated. The simulated air cleaner is based on a prototype device which is currently being developed. Also considered in the simulations is the transport of the infectious aerosol and its purification inside the air cleaner. The concentration time-dependence is exponential, and the purification rate depends on the air cleaner orientation and heating regime. The efficiency is higher for a vertically orientated purifier, compared to a horizontal one. In the experimental part, NaCl solution is dispersed in the air and the efficiency of purification is evaluated by measuring the time-dependent particle concentrations. These results are used for the validation of the numerical model.

Tuesday, 13.06.2023 11:15-11:30 Room C Carbon

The influence of colliding supply jets on predicted and perceived thermal comfort

Maula, Henna; Sivula, Arttu; Radun, Jenni; Tervahartiala, Iida-Kaisa; Hongisto, Valtteri

Turku University of Applied Sciences, Finland

ID: 1208 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: draught, thermal comfort, test chamber, PMV, perception

The aim of this study was to examine the effect of draught caused by colliding supply jets from above the occupant on thermal comfort in laboratory conditions. The study had a repeated measures design with two conditions: A) temperature T=23.2 °C, air speed v<0.1 m/s, draught rate DR < 10 %, supply airflow Q= 30 l/s, and B) T=22.8 °C, v<0.4 m/s, DR < 30 %, Q= 70 l/s. Thirty-six volunteer university students participated in the experiment. Participants' clothing insulation was estimated to correspond 0.71 clo and the main task was typing (activity level 1.1 met). The session lasted altogether 2.5 hours including a preparation phase and both test condition phases. Overall thermal comfort, local thermal comfort, and sensation of draught were assessed with questionnaires. The difference between conditions was mainly seen in subjective measures, but small difference was also observed in the work performance. The study highlights the importance of airflow patterns in the occupied zone of an office. The results can be used in the planning and product development of air conditioning and supply air distribution in offices.

Tuesday, 13.06.2023 11:30-11:45 Room C Carbon

Dataset for Validating Complex Ventilation Flow Simulations: Post-processing and Analysis using Bootstrapping

Mamulova, Eugene (1); Al-Assaad, Douaa (2); van Hooff, Twan (1)

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ID: 1231 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling
Keywords: validation data, displacement ventilation, indoor flows, field measurements, bootstrapping

There are almost no datasets available to individuals who seek to validate numerical simulations of complex ventilation flows. This research constitutes a preliminary step towards the creation of such a dataset. In this study, several air temperature datapoints, measured in a classroom equipped with displacement ventilation, are processed with the aim of obtaining a time-averaged value for every measurement point. Using the mean temperature values, the resultant temperature field is analysed. The study showcases the use of bootstrapping as a means of estimating the uncertainty of the mean temperature. In addition, the study identifies flow phenomena that are characteristic of displacement ventilation, such as thermal stratification. The temperature values obtained can be used to validate time-averaged numerical simulations, such as Reynolds-averaged Navier–Stokes simulations, of complex displacement ventilation cases involving multiple heat and carbon dioxide sources. The results show that bootstrapping with replacement is a useful method for estimating the uncertainty of the mean temperature. Work on the dataset is currently ongoing and will be extended using air velocity and carbon dioxide concentration measurements, in the interest of compiling a large dataset for simulating complex indoor phenomena.

Tuesday, 13.06.2023 11:45-12:00 Room C Carbon

Novel computational tool for indoor air quality

Siilin, Niko (1); Salmela, Hannu (2); Kulmala, Ilpo (2); Taipale, Aimo (2)

1: VTT Technical Research Centre of Finland, Espoo, Finland; 2: VTT Technical Research Centre of Finland, Tampere, Finland.

ID: 1252 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Indoor air quality, Modelling, Ventilation, Filtration, Air purifier, Morbidity, Sick leave.

This article introduces a novel computational tool for analysing concentrations of particles and gaseous impurities in mechanically ventilated indoor spaces. The computation routine exploits mass balance model assuming well-mixed conditions, and accounts for the most significant means of entry and loss of contaminants. The analysis inputs include time-dependent outdoor concentrations, indoor generation rates, filtration efficiencies and deposition rates. The model was validated using size resolved particle concentrations measured during an experimental campaign. The predicted indoor concentrations were in good correlation with experimental data over wide particle size range. To demonstrate the computational capabilities, indoor concentrations of particles and carbon dioxide were analysed with various combinations of supply air filtration efficiency, ventilation rate, recirculation ratio, air purifiers, and occupancy. Subsequently, a relative sick leave estimate based on time-averaged exposure to total particle mass concentrations was computed. The results emphasised the effectiveness of supply air filtration to limit the exposure to ambient air pollution. Replacing a coarse filter with a high efficiency filter resulted in reduction of an order of magnitude in the relative sick leave estimate. In comparison, increasing recirculation ratio or exploiting air purifiers demonstrated noticeable, but lesser impact.

Tuesday, 13.06.2023 12:00-12:03 Room C Carbon

Air flow patterns and draught risk caused by the collision of supply jets

Sivula, Arttu; Maula, Henna; Koskela, Hannu; Hongisto, Valtteri

Turku AMK, Finland

ID: 1288 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: draught risk, thermal comfort, airflow pattern, air speed

In office buildings, complaints about the thermal environment are often related to temperature or sensation of draught. Some of the challenges in finding solutions when designing comfortable workspaces are related to the complexities of the air flow patterns. In this paper, the effect of the collision of supply air jets on the airflow pattern and the draught risk in a single office room were analysed. The experimental situation created for the study is a typical draught situation in offices, where high heat loads has led into increased cooling to sustain the room temperature at a desired level. This paper is part of a larger study on thermal comfort and the draught situation was created for the purposes of human experiment. The focus of this paper is in analysing the airflow pattern under the created draught conditions. The airflow pattern was visualized with smoke and quantified with physical measurements and the draught risk was calculated. The downfall jet from the colliding supply jets caused local maximum air speeds directly above the workstation and the calculated draught risk was above the recommended values. The results show the strong effect of convective airflows on air distribution.

Tuesday, 13.06.2023 12:03-12:06 Room C Carbon

Performance evaluation of desiccant cooling system with water coil combined with radiant ceiling panel through experiments

Jang, Hyusan (1); Liu, Shuo (2); Yeo, Myoung-Souk (3)

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ID: 1368 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Desiccant cooling system, Radiant ceiling panel, Dry coil operation, High-temperature chilled water coil

The radiant ceiling cooling system improves human comfort with cold radiation rather than air currents compared to conventional cooling systems through convection, and reduces the primary energy by supplying high temperature chilled water and reducing fan power compared to all air systems. In order to improve the performance of RCP, a number of studies have been conducted to evaluate it in combination with various dehumidifying devices. The purpose of this study is to show the differences by analyzing the indoor temperature and humidity distribution, indoor comfort, and system performance of the water-type desiccant system without RCP and with RCP through experiments. In this study, the indoor temperature and humidity distribution, indoor comfort, and system performance were analyzed for the water type desiccant system without RCP (System1) and the combined RCP system (System²), and the differences were identified. The results of this paper are as follows. (1) Both System 1 and System 2 controlled condensation of indoor comfort and chilled water coils. (2) On the other hand, System 1 and System 2 showed a major difference in the indoor air cooling rate and the operation method of CC2. When cooling indoor air, convective heat transfer lowered the indoor temperature more quickly.

Tuesday, 13.06.2023 12:06-12:09 Room C Carbon

Numerical study of air supply positioning and its effect on Contaminant Removal Effectiveness in turbulent mixed air flow cleanrooms

Pfender, Ferdinand; Lange, Julia; Cetin, Yunus Emre; Kriegel, Martin

Technical University of Berlin, Hermann-Rietschel-Institut, Germany

ID: 1373 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: cleanroom, energy efficiency, distribution of contamination, flow pattern, contamination control

This paper presents a numerical study about the influence of different patterns and arrangements of air inlet and outlet positions in turbulent mixed air cleanrooms and its impact on
contamination removal effectiveness. The results were performed using RANS-based CFD
simulations on a grid whose base size and number of cells was determined using a grid independence study. It has been shown that positioning the air extraction in the floor area for higher air exchange rates (ISO 7) entails more effective contamination extraction, but is better not implemented for lower air exchange rates (ISO 8). On the other hand, the positioning of the air extraction on the ceiling brings a constant effectiveness of the contamination extraction, which brings a suitable margin for a possible contamination-dependent or load-guided control of turbulent mixed air cleanrooms.

Session 11 Tuesday Silver - Mould & microorganisms

Time:
Tuesday, 13.06.2023 11:00-12:30

Room: Ag Silver

Chair:
Lamberts, Roberto
UFSC

Co-Chair:
Hugentobler, Walter
École Polytechnique Fédérale de Lausanne

Tuesday, 13.06.2023 11:00-11:15 Room Ag Silver

Characterization of microbial secondary metabolites in floor dust of 50 public elementary schools in the US

Park, Ju-Hyeong (1); Sulyok, Michael (2); Cox-Ganser, Jean M. (1)

1: CDC/National Institute for Occupational Safety and Health, Respiratory Health Division, Morgantown, WV, USA; 2: University of Natural Resources and Life Sciences, Center for Analytical Chemistry, Department of Agrobiotechnology, Vienna, Austria

ID: 1268 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Microbial secondary metabolites, School classrooms, Floor dust, School staff

Characterization of secondary metabolites potentially produced by indoor microbes has been understudied, and health implications of their exposures are not fully understood. We characterized microbial metabolites on the floor of school classrooms in Philadelphia, PA. In a 2015 study designed to examine associations between microbial exposures and measures of health among school worker occupants, we conducted environmental assessments, including: (a) vacuuming floor dust from 500 classrooms in 50 elementary schools to collect one composite sample for each classroom, (b) collecting dampness/mold (water damage) information for the classrooms by visual and olfactory assessment, and (c) screening 550 target microbial secondary metabolites with liquid chromatography-tandem mass spectrometry (MS/MS). Endotoxin and ergosterol were analyzed with Limulus amoebocyte lysate assay and gas chromatography-MS, respectively. Multiple linear regressions including water damage, school location, floor materials, floor level, and concentration of ergosterol or endotoxin were performed for the log transformed concentrations of 11 metabolites found in more than 50% of classrooms. All statistical analyses were performed with JMP.

We identified 174 metabolites in 489 samples for which dust was available to be analyzed. Of these, 18 metabolites were found in more than 30% of classrooms. The 11 metabolites (>50% in prevalence) included asperglaucide (100% prevalent), asperphenamate (99.8%), usnic acid (99.4%), cyclo(L-Pro-L-Tyr) (98.6%), enniatin B (97.3%), lotaustralin (97.3%), 3-nitropropionic acid (93.9), cyclo(L-Pro-L-Val) (89.6%), N-benzoyl-phenylalanine (83.6), enniatin B1 (71.0%), and linamarin (59.3%). Of these

11, linamarin was found with the highest concentration (median: 124 ng/g of dust; median absolute deviation: 69.7), followed by lotaustralin (65.9; 32.4), cyclo(L-Pro-L-Tyr) (64.9; 23.6), and asperglaucide (50.2; 22.5). The median number of metabolites per classroom was 17 (range: 8–41). Six mycotoxins (citrinin, deoxynivalenol, fumonisin B1, ochratoxin A, sterigmatocystin, and zearalenone) were detected with low prevalence (< 2%, except for deoxynivalenol [17.2%] and sterigmatocystin [7.4%]). The level of ergosterol was significantly (p-value<0.05) and positively associated with the levels of seven of the 11 metabolites, except for cyclo(L-Pro-L-Val), cyclo(L-Pro-L-Tyr), lotaustralin, and 3-nitropropionic acid. Endotoxin was significantly and positively associated with nine metabolites, except for cyclo(L-Pro-L-Val) and N-benzoyl-phenylalanine. Water damage was associated only with the level of N-benzoyl-phenylalanine in the model including endotoxin.

Our study indicated that a large number of microbial metabolites were present in variable concentrations in school environments, of which diversity and characteristics are different from those of office or residential building environments. Health effects of the exposures to the metabolites in school staff will be further examined in future analyses.

Tuesday, 13.06.2023 11:15-11:30 Room Ag Silver

Laundry drying: a major interface of gas-surface exchanges indoors

CARON, Florent (1); VERRIELE, Marie (1); NICOLAS, Melanie (2); THEVENET, Frederic (1)

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ID: 1140 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: household activity, relative humidity, laundry, VOC transfer, hygrothermal

Domestic use of tumble dryers accounts for second energy expense after heating systems. To mitigate energy consumption of households, environmental agencies recommend open-air drying. However, it generally means drying of laundry inside dwellings. This typical and widespread indoor activity remains unexplored while it may affect hygrothermal balance of homes and indoor VOC budget. The objective of this work is to address the global impact of laundry drying in terms of (i) moisture, (ii) temperature, and (iii) VOC budget. A special attention is paid to transfer of gases (water and VOCs) at the laundry interface.

Experiments are performed in the 40 m³ experimental room IRINA (Innovative Room for INdoor Air studies). It allows a full-scale investigation of the drying process. Based on representative consumer practices, model laundry is defined in terms of: (i) clothes, (ii) detergents, and (iii) washing programs. Laundry is hung in IRINA on a drying-rack allowing continuous monitoring of laundry weight. Temperature, humidity and concentration profiles of VOCs are monitored along the drying process.

First, the kinetic of water transfer from wet laundry to indoor air is characterized along with its effect on temperature. Endothermal evaporation of 1000 to 2000 g of water from laundry directly influences temperature of the room. This aspect is interestingly correlated with the spin speed of the washing program.

Second, VOCs emitted along the drying process are examined. Impacts of the nature of detergent (liquid or powder) and the use of fabric softener are discussed in terms of VOC nature and diversity. Discussions point at (i) the unexpected contribution of fabric softener to decrease VOC emissions and (ii) the absence of correlation between VOC composition of detergents and VOC emission patterns along drying.

Third, laundry drying is not only examined as VOC source but its impact on the VOC budget involving uptake processes is studied. Focus is given to the concentration dynamic of formaldehyde in the experimental room along drying. Interestingly, wet clothes act as a remarkable but transient indoor sink of HCHO.

This work evidences that laundry drying is a major unbalancing activity of the indoor environment. It allows quantitation of the hygrothermal effects as well as the determination of the impact on the VOC budget indoor. The final goal of this work is to provide recommendations on best practices related to laundry drying in order to combine energy savings with satisfying indoor air quality.

Tuesday, 13.06.2023 11:30-11:45 Room Ag Silver

selection of thresholds to prevent heat-related health risks

Alessandrini, Jean-Marie (1); Wei, Wenjuan (1); Molesin, Simon (2); Dominati, Thomas (2); Pelé, Charles (1); El Kadri, Mohamad (1); Sabre, Maéva (1); Gervasi, Pierrick (1)

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ID: 1205 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: Heat stress, heat strain, thermal-physiological model, temperature threshold, elderly people

Indoor heat exposure can lead to occupants' health risks such as hyperthermia. To help the building managers to take technical and behavioural actions to protect occupants from heat exposure, a heat-related health risks assessment is needed to quantify the health impact of indoor over-heating and its probability of occurrence. Therefore, the present work aimed to establish and quantify a thermal stress threshold adapted to people according to their heat sensibility. The target population was determined using the population typology developed by the French Public Health Agency according to people's vulnerability to heat and the current and projected 10-year demographics of tenants of RIVP, a social housing owner of 60000 dwellings in Paris. Thermal stress thresholds for adults and the elderly were quantified according to the relationship between heat stress (indoor thermal characteristics) and heat strain (body core temperature) determined by a modified thermophysiological model. The results highlighted that: (1) the elderly were more vulnerable than adults to heat, and a threshold temperature of 32 °C led probably to exposure risks, and (2) a radiant temperature close to an air temperature of 24 °C at night can help the body to reduce the heat stress accumulated during the day.

Tuesday, 13.06.2023 11:45-12:00 Room Ag Silver

Update of the AWMF guideline for medical clinical diagnostics of indoor mould exposure

Hurraß, Julia (1); Heinzow, Birger (2); Walser-Reichenbach, Sandra (3); Aurbach, Ute (4); Becker, Sven (5); Bellmann, Romuald (6); Bergmann, Karl-Christian (7); Cornely, Oliver A. (8); Engelhart, Steffen (9); Fischer, Guido (10); Gabrio, Thomas (11); Herr

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ID: 1276 Full paper
Topics: 09. Public health, occupational & environmental health
Keywords: Mold, indoor, clinical diagnostics, disposition, health assessment

In 2016, the AWMF guideline for the medical clinical diagnostics of indoor mould exposure was introduced in Germany. The guideline is currently being revised for an update. Indoor exposure to dampness and mould can principally result in infections, sensitization and allergies, toxic reactions, olfactory effects, and impairment of well-being. Medical professionals involved with mould-exposure related health problems are challenged by the lack of a dose-response relationship, the lack of limit values for airborne mould, and the fact that health responses and sensitivities vary in the human population. Therefore, causality between a specific mould exposure and specific health problems or diseases is difficult to prove. Risk assessment and remediation of mould infestation indoors requires interdisciplinary cooperation. Individual health risks of mould exposure indoors ought to be evaluated by a physician, based upon the assessment of patient's underlying diseases and individual susceptibility, as a predisposition-based risk-assessment. Especially vulnerable risk groups to be protected are individuals with immunosuppression according to the 3 risk groups of the Commission for Hospital Hygiene and Infection Prevention at the Robert Koch Institute, individuals with cystic fibrosis, and individuals with asthma. Newly determined vulnerable risk groups are individuals suffering from severe influenza or from severe COVID-19.

Tuesday, 13.06.2023 12:00-12:03 Room Ag Silver

Relevance of indoor exposure to mycotoxins for human health

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ID: 1277 Full paper
Topics: 09. Public health, occupational & environmental health
Keywords: Mould, indoor, mycotoxins, health effects, risk assessment

Moisture damage and mold infestation are most relevant indoor air problems and are associated with various health effects. Mycotoxins are important secondary metabolites of molds. Numerous species can produce mycotoxins, of which about 500 different toxins have been identified. They can be found indoors in low concentrations on building materials, in house dust and in bioaerosols. Depending on their concentration, they may have negative health effects. Nevertheless, it is currently uncertain, whether nonspecific symptoms like fatigue, sleep disturbances or neurologic symptoms can be causally attributed to mycotoxin exposure indoors. The aim of the present work is to critically review the international literature and assess the evidence on possible mycotoxin-associated health disorders in the indoor environment. The results of the systematic literature search still indicates that evidence for the „toxic mold syndrome" is insufficient and that the hypothesis that mycotoxin exposure in indoor environments is etiologically associated with intoxication and a variety of health conditions (e.g. autoimmune disease, cancer, etc.) is unproven.

Tuesday, 13.06.2023 12:03-12:06 Room Ag Silver

Moisture damage/mold and the development of asthma: a systematic review and meta-analysis.

Täubel, Martin (1); Pekkanen, Juha (1,2); Juntunen, Miina (1); Mendell, Mark J (3); Karvonen, Anne M (1)

1: Environmental Health Unit, Finnish Institute for Health and Welfare, Finland; 2: Department for Public Health,University of Helsinki, Finland; 3: Air Quality Section, California Department of Public Health, CA, United States

ID: 1281 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: Moisture damage, mold, asthma development, review, meta-analysis

Reviews from the Institute of Medicine (2004), the World Health Organization (2009), Mendell (2011) and Kanchongkittiphon (2015) have concluded that indoor dampness and mold are associated with increased risk for asthma exacerbation and asthma development. The earlier reviews on development of new asthma do not reflect the most recent work , in some cases do not include formal meta-analyses, or are limited in more detailed aspects, such as the location of the moisture damage, differences between children and adult populations, and of self-reported versus objectively observed visible mold. This motivated us to perform an updated systematic review and meta-analysis of studies reporting on the association between indoor moisture damage and mold and the development of new asthma. We included 1) prospective cohort studies on more than 10 buildings, where the moisture damage assessment (self-reported or inspection-based) had been done before onset of asthma; and 2) incident case-control studies on more than 10 buildings where the moisture damage assessment was based on building inspection post enrollment as case/control. We excluded studies where moisture assessments were not based on building observation.

The literature search in PubMed resulted in 1748 publications that were screened, and ultimately, 30 publications based on 21 different studies were included in the analysis. Definitions of moisture damage were highly inconsistent between studies and challenging to categorize, whereas definitions for visible mold and mold odor were more uniform. We performed separate analyses for the following variable categories: moisture damage, mold, mold odor and moisture & mold. Considering all studies and observations in the whole house, risk associations were strongest for mold odor (aOR

[95% CI]: 2.07 [1.63; 2.62]) compared to visible mold (1.33 [1.15; 1.53]) and moisture damage (1.20 [1.03; 1.40]). Generally, findings were strongest for observations in areas where people spend a large amount of time, i.e., in the bedroom and living areas. Estimates for observations of mold odor were generally higher and heterogeneity tended to be larger when self-reported compared to objective inspection assessment. We identified only two adult studies, but the limited data suggest that moisture damage-associated increase in risk in adults is similar or even higher than in children. We found insufficient data to adequately address exposure response in new asthma and therefore recommend using multilevel moisture damage estimates in future studies. Most indicators of indoor moisture or mold in homes were associated with increased risk of developing new asthma.

Tuesday, 13.06.2023 12:06-12:09 Room Ag Silver

Quantification and identification of microorganisms (bacteria, fungi, virus) onto an air-handling-unit filter

Pavard, Gaetan (1,2); Joubert, Aurélie (1); Le Cann, Pierre (2); Andres, Yves (1)

1: IMT Atlantique, GEPEA, CNRS UMR 6144, Nantes, France; 2: EHESP, Inserm, IRSET - UMR_S 1085, Rennes, France

ID: 1377 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Indoor air quality, air handling units, fibrous filter, microorganisms, cultivable and molecular analysis

The presence of airborne microorganisms in indoor environments degrades the air quality and can affect the human health and well-being. The ventilation of buildings allows to decrease the indoor pollutant concentration and maintain the indoor air quality. Especially, the fibrous filters implemented in the air handling unit (AHU) collect the airborne particles including bioaerosol such as bacteria, fungi and virus. The filters can become a source of contamination, e.g. by microbial reentrainment during the restart of ventilation. Moreover, the filters can be considered as a long-term sampler to evaluate the microbial indoor air quality in the building. Thus, the characterization of the microbial concentration onto the AHU filters in terms of concentrations, identification and viability, is essential for health risk analysis. The study aimed to characterize over 12 months the microbial concentration (bacteria, fungi and virus) onto a fibrous filter implemented in the air handling unit of the extracted air compartment of a low-energy building from cultivable and molecular biology based methods.

The methodology used coupons constituted of the same filtering media as the filter studied (i.e. a glass fiber filter classified ePM1 60% according to the standard ISO 16890). The coupons were sampled once a month, the microorganisms were extracted with a solution and analysed using several methods for quantification and/or identification : culture base-method with five different media promoting bacteria and/or fungi growth (R2A, LB, MEA, DG18, DRBC); qPCR for bacteria and fungi and RTq-PCR for virus.

The results from the cultivable and q-PCR based methods revealed the same trend: the microbial concentration onto the filter was almost stable over the 12 months. For instance bacterial and fungal concentrations were comprised between 102 and 103 colony forming unit (CFU)/cm². The qPCR analysis, expressed in equivalent CFU, revealed higher concentrations (+ 1-2 log), e.g. for A. niger or C. cladosporioides. The fungal and bacterial genera encountered correspond to contribution from the building occupation (e.g. Micrococcus genus) but also from the outside air. Two different virus were identified on the filter (human Adenovirus and Coronavirus OC43). Nevertheless, the coupons revealed low DNA or RNA concentrations, limiting the analysis. Further investigations will allow to optimize the methodology.

Tuesday, 13.06.2023 12:09-12:12 Room Ag Silver

AIRWAYS MUCOSAL DEFENSE OF ELDERLY AND SICK PEOPLE NEEDS SUPPORT FROM BUILDING SERVICES AGAINST AIRBORNE THREATS

Hugentobler, Walter

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ID: 1411 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: hygro-thermal indoor conditions, 1st line defense, mucosa of upper airways, air-conditioning by nose

The upper respiratory tract bears two critical tasks: 1st complete saturation of the inhaled air and warming to 37°C on the path to the alveoli and 2nd protection of the lung against harmful airborne agents. Both tasks occur along the air-conducting tract, with the nose being far more efficient than the lower conducting airways in accomplishing these goals.

The mucosal lining of our upper respiratory system is long known to be the 1st line of defence against airborne threats. This includes trapping and disposal of airborne microbes and contaminants, so called mucociliary clearance (MCC), physical, chemical and immunological barriers of mucus, periciliary layer, epithelia, submucosa and associated lymphoid tissue. Adequate hydration is required for the efficiency of all mentioned protective mechanisms. Mucus water content of 96-98 wt% ensures its ideal viscoelasticity and is a biomarker for respiratory mucosal health, while mucociliary transport velocity (MTV) reflects its functionality. Visualization of the direct impact of subsaturated breathing air on MTV and cilia beating frequency in the tracheal mucosa became possible by video microscopy (lamb trachea) and fluorescent nanoparticles (mice trachea).

Most people spend up to 90% of their lifetime indoors, where 80 to 90% of relative humidity readings in mechanically ventilated buildings are below 40% in the winter quarter of temperate climate. What are the consequences for the 1st line defence and respiratory health of the population, especially the elderly, ill and vulnerable? We review the evidence that exposure to dry air reduces the ability to fight airborne infectious and toxic threats and conclude with a call for action to incorporate moisture management into indoor air quality standards.

The established view is that air dryness has no impact on nasal MTV – owing to short term exposure experiments with young, healthy subjects, which were then assumed to apply to the general population. Yet mounting evidence paints a different picture: nasal MTV is slowed or even stopped by conditions such as dry air, age over 50, allergic and atrophic rhinitis, diabetes, hypertonia, infections, divergent nasal shapes, smoking and air pollution (study list will be presented). Persistently reduced pre-conditioning and pre-filtration by a dehydrated, over-loaded, blocked or bypassed nose damages cellular repair and defence against microbes and pollutants in the lower airways and finally result in chronic lung diseases.

Tuesday, 13.06.2023 12:12-12:15 Room Ag Silver

Risk assessment of mould contamination from flooding after remediation. The Australian Assurance program

Neumeister-Kemp, Heike Gudrun

Mycotec, Australia

ID: 2469 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: mould, risk assessment, assurance program, standarts

Discussed Climate change has increase bushfire and flooding events all over the world. Recent severe weather events in Australia, due to a 3 year la Nina phenomenon, have led to widespread flooding and water inundation from above into commercial and domestic buildings, especially on the east coast of Australia. Unprecedented rainfall amounts and duration have altered the usual environmental conditions to being much warmer and wetter than the measured averages previously. Buildings where partially completely submerged in black water for weeks. Many of the affected areas are remote making access difficult due to roads being washed away. Because of the sheer volume of claims, assessment and remediation of buildings where often delayed for month, especially if electricity could not be restored.

Mycotec was commissioned by insurers to roll out an Assurance program to validate mould remediation efforts after Strip out (PRV) of dwellings and to conduct Final Clearance Testing (CLT) after the reinstatement of. Legal protection for Builders and Remediators as well as “peace of mind” for owner/occupiers and data for re-insurance of dwellings were the main factor driving this program.

A 3 part risk assessment was developed, including cultural and non-cultural methods for air and surface mould testing, moisture assessment and IAQ parameters.

Data from more than 1300 dwellings will be presented, outlining success and failure of remediation efforts based on different methods used.

Fungal species prevalence on different type of building materials will be shown, taking into question which fungi are most likely associated with water damaged buildings and if Key indicator species are enough of a representation of total microorganism present.

As reported by the insurance council of Australia today the CAT event 221 is worth AS$ 5.28 billion with 233 thousand claims lodged. Only 44.1% of these claims are closed out, mainly due to communication problems and lengthy delays between restoration and reinstatement.

There is an absolute need for international accepted guidelines and standards for remediation and assessment of mould in Australia. The data gained from this assurance program will form the base for research at the newly found Training Centre for Advanced Building Systems Against Airborne Infection at QUT in Brisbane Australia.

Session 12 Tuesday Oxygen - Productivity & sleep quality

Time:
Tuesday, 13.06.2023 11:00-12:30

Room: O2 Oxygen

Chair:
Toftum, Jørn
Technical University of Denmark

Co-Chair:
Syndicus, Marc
RWTH Aachen University

Tuesday, 13.06.2023 11:00-11:15 Room O2 Oxygen

Does pure CO2 affect sleep quality?

Matsuo, Kazuya (1,2); Fan, Xiaojun (2); Wargocki, Pawel (2)

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ID: 1455 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: sleep quality, CO2 concentration, experiment, sleep capsule, human bioeffluent

The concentration of carbon dioxide (CO2) is widely used as an indicator of indoor air quality and ventilation sufficiency. Though poor air quality has been associated with worse sleep quality, there are few studies examining the effects of CO2 on sleep quality. This raises an important question as CO2 levels in bedrooms tend to be high and have been shown to correlate with different aspects of sleep quality. It is also essential to investigate whether CO2 itself also influences sleep quality simultaneously. Consequently, we experimented to investigate this issue.The experiment took place in specially designed capsules (2.4m x 1.1m x 0.9m), each placed in one of the twin stainless steel chambers. Twenty healthy subjects without sleep dis orders were recruited to sleep under three different conditions in capsules: 1) high ventilation with CO2 concentration of 800 ppm; 2) high ventilation as in (1) with added pure CO2 with concentration of 3,000 ppm; 3) poorly ventilated so that the CO2 concentration was 3000 ppm. Preliminary results of sleep tracker showed that poor ventilation might be associated with less deep sleep and longer light sleep. Pure CO2 condition also showed even less deep sleep and longer light sleep.

Tuesday, 13.06.2023 11:15-11:30 Room O2 Oxygen

A 10-year Cohort Study for Validating Risk of Death from Cardiovascular Disease According to Indoor Environment

Wakiyama, Hayato (1); Ando, Shintaro (1); Umishio, Wataru (2); Ikaga, Toshiharu (3)

1: The University of Kitakyushu, Fukuoka, Japan; 2: Tokyo Institute of Technology, Tokyo, Japan; 3: Keio University, Tokyo, Japan

ID: 1415 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Prospective cohort, Cox proportional hazards analysis, propensity score analysis

Cardiovascular disease is the second leading cause of death in Japan after cancer, with approximately one in four people dying of cardiovascular disease each year. Against this background, research on the living environment has been conducted in Japan from the perspective of the built environment and medical care, and it is becoming clear that the thermal environment is associated with risk factors for cardiovascular disease such as hypertension. However, no cohort studies have analyzed the effects of thermal environment on survival and cardiovascular disease mortality among residents. Therefore, this study examined the effect of cold-related living conditions on the risk of death from cardiovascular disease over a 10-year period based on Cox proportional hazards analysis and propensity score analysis.

Cohort validation was performed using a questionnaire survey in Yusuhara, Kochi Prefecture in 2008 as well as a 10-year field survey dataset from 2008 to 2018.

Cox proportional hazards analysis was performed to verify that housing performance is a predictor of risk of death from cardiovascular disease. The results showed that the hazard ratio (HR) for mortality after 10 years was significantly higher for those living in houses with condensation (HR=3.232, 95% confidence interval CI=1.094-9.554, p=0.034) .

Furthermore, a prospective cohort validation with a high level of evidence that focused on housing performance and living elements suggested that the occurrence of condensation and users of “electric heater or kotatsu alone” had an impact on the risk of death from cardiovascular disease. Results similar to those described above were obtained by propensity score analysis.

The results of this study showed the dangers of living in a cold, condensation-prone living environment as well as heating habits that expose the house to cold for long periods of time. It is expected that improvements in living conditions and housing performance may contribute to reducing the risk of death from cardiovascular disease.

Tuesday, 13.06.2023 11:30-11:45 Room O2 Oxygen

Effects of changing ventilation on sleep quality and next-day work performance: a field intervention study in Belgium

Fan, Xiaojun (1); Liao, Chenxi (2); Matsuo, Kazuya (3); Verniers, Kevin (4); Laverge, Jelle (2); Neyrinck, Brecht (4); Pollet, Ivan (4); Fang, Lei (1); Lan, Li (5); Sekhar, Chandra (6); Wargocki, Pawel (1)

1: Technical University of Denmark; 2: Ghent University; 3: Waseda University; 4: R&D Department Renson Ventilation NV,; 5: Shanghai Jiao Tong University; 6: National University of Singapore

ID: 1319 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Bedroom, Mechanical ventilation, Air quality, Sleep quality, Next-day work performance

As a part of ASHRAE research project TRP 1837 on bedroom ventilation, we conducted a field intervention study in bedrooms in Belgium in October 2021. Forty-four participants were recruited. They slept in their own bedrooms equipped with the mechanical extract ventilation system. The participants were divided into two groups: (1) intervention group, the bedroom ventilation was changed on a weekly basis in a balanced design to achieve 3, 10, and 30 m^3/h; (2) control group, no changes were made. The ventilation was remotely changed for the intervention group by changing the damper's opening in the control unit where the extract fan was located; the trickle vent on the bedroom window was operated in the minimum position. Doors and windows to the bedroom were closed. During the experiments we measured sleep quality using a wrist-worn sleep tracker. The CO2, temperature, relative humidity, PM^2.5, light, and noise levels were monitored continuously. The participants rated their bedroom environment in the morning and evening and performed a simple task measuring their cognitive performance. The study began with a week (adaptation) during which all measurements were made but no interventions were made. The results are being analyzed and will be reported during IA2022. They will be compared with the recently proposed tentative relationship between sleep quality and bedroom ventilation characterized by the level of CO2.

Tuesday, 13.06.2023 11:45-12:00 Room O2 Oxygen

A preliminary analysis of indoor air quality in work-from-home settings

Manu, Sanyogita; Rysanek, Adam

University of British Columbia, Canada

ID: 1322 Full paper
Topics: 09. Public health, occupational & environmental health, 11. All other IEQ, ergonomics & health topics
Keywords: . Indoor environmental quality, indoor air quality, monitoring, work-from-home, workspace at home, COVID

In March 2020, the COVID-19 pandemic forced about 4.7 million Canadian workers to switch to working from home, similar to the global trend. While various studies have investigated the work-from-home (WFH) context from different perspectives such as behavioural, psychological, and sociological, there has been limited research on the impact of indoor environmental quality (IEQ) in WFH settings. The aim of this paper is to present an analysis of IEQ conditions in WFH settings based on a field study conducted during the summer of 2022. To accomplish this, the study utilized 95 low-cost IEQ monitors that were installed in workspaces at homes to measure air temperature, relative humidity, and CO_2. The preliminary analysis of the IEQ data revealed that the daily average indoor air temperature in WFH settings within the study sample ranged from 16.0-31.2°C, with a mean value of 23.0°C (SD = 2.4°C). Furthermore, the mean indoor relative humidity was 54% (SD = 7%) and the mean indoor CO_2 concentration was 635 ppm (SD = 201 ppm). Additionally, the study found that there were statistically significant associations between the IEQ variables and factors such as type and size of residence, type of workspace, availability of operable windows, and mechanical cooling.

Tuesday, 13.06.2023 12:00-12:03 Room O2 Oxygen

Well-being and Workplace Productivity of Workers Combining Office Work and Working from Home

Shinno, Toshiki (1); Ukai, Masanari (1); Fukawa, Yuta (1); Murakami, Takuya (3); Iihara, Kosuke (4); Kiyota, Osamu (2); Kunitomo, Osamu (2); Nishida, Hiromichi (2); Tanabe, Shin-ichi (1)

1: Waseda University, Japan; 2: Tokyo GAS Co., Ltd., Japan; 3: Takenaka Corporation, Japan, (Former Graduate Student, Waseda University), M. Eng.; 4: Obayashi Corporation, Japan, (Former Graduate Student, Waseda University), M.Eng.

ID: 1326 Full paper
Topics: 08. Psychology, psychophysics, performance & productivity, 09. Public health, occupational & environmental health
Keywords: Office work, Working from home, Telework, Well-being, Workplace productivity

With the COVID-19 pandemic in 2020, a work style that combines office work and working from home (WFH) has rapidly spread in Japan. This change in work style is thought to have changed the lifestyle of workers and affected their well-being, which represents their physical, mental, and social health. The purpose of this study is to clarify the effects of work style, combining office work and WFH, on the well-being of workers, and the effects of changes in workers' well-being on their workplace productivity. For this study, a questionnaire survey was conducted on workers, and a statistical analysis was conducted on the data obtained from 339 workers. The results showed that the physical, mental, and social health of approximately 50% of the workers improved as a result of combining office work and WFH. The analysis also found that of the three health dimensions of well-being, mental health in particular had a significant impact on workplace productivity and satisfaction in WFH. Furthermore, physical and social health have been shown to influence workplace productivity and satisfaction through their effects on mental health. This study showed a relationship between the three health dimensions of well-being and their relationship with workplace productivity and satisfaction.

Tuesday, 13.06.2023 12:03-12:06 Room O2 Oxygen

Keeping Diverse Residents Healthy at Home during Power Outages in a Net Zero-Energy House

Imai, Minayo (1); Kim, Jungmin (1); Inaba, Manae (2); Akimoto, Mizuho (1); Amada, Kanta (1); Fukawa, Yuta (1); Tanabe, Shin-ichi (1); Kashihara, Seiichi (3); Chiba, Yosuke (3); Watanabe, Naoya (3)

1: Waseda University, Japan; 2: Former Graduate Student, Waseda University; 3: Asahi Kasei Homes Corporation

ID: 1372 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: net Zero Energy House, Resilience, Power Outage, Storage Battery, Vulnerable Groups

In Japan, where natural disasters that cause power outages are increasing, increasing the number of net zero-energy houses (ZEHs) with high resilience is important. In addition, pregnant women, infants, patients with intractable diseases, and the elderly should consider disaster prevention measures. The purpose of this study is to evaluate the resilience of ZEHs to power outages based on household composition and storage battery (BT) capacity. The original schedule during the power outage was created for each household composition based on previous research. Next, the self-sufficiency rate of electricity and thermal environment in representative periods were calculated for each household composition and BT capacity. Additionally, the self-sufficiency rate of electricity was calculated for 29 scenarios in January and August. As a result, operational methods, such as increasing the BT capacity to store energy for power outages, were proposed to increase the self-sufficiency rate of electricity.

Tuesday, 13.06.2023 12:06-12:09 Room O2 Oxygen

The Relationship between Personal Attributes and Environmental Preferences upon Workers of Activity Based Working Offices

Seto, Minami (1); Saito, Yuki (1); Tanabe, Shin-ichi (1); Takahashi, Mikio (2); Wada, Kazuki (2); Tokumura, Tomoko (2); Takahashi, Hiroki (2); Kuwayama, Kinuko (2)

1: Waseda University, Japan; 2: Takenaka Corporation, Japan

ID: 1445 Full paper
Topics: 07. Occupant behavior & controls, 08. Psychology, psychophysics, performance & productivity
Keywords: workplace productivity, Activity-based working, office, environmental preference

Recently, Japan is facing a serious population decline, and we must improve workplace productivity and health of workers for our country's sustainable growth. A conceivable solution for this challenge is ABW (Activity-Based Working) offices, a workplace where workers can select where to work according to their workstyle or environmental preference. However, ABW offices are uncommon in Japan since these concepts are relatively new. Previous studies focusing on workplace productivity and environmental satisfaction have revealed positive effects by introducing ABW offices. Other studies have revealed the importance of considering the diversity of workstyles and environmental preferences for office workers. However, studies combining and integrating worker attributes, workstyles, and environmental preferences are few. The purpose of this study is to clarify and organize the relationship between worker attributes and environmental preferences in ABW offices. Questionnaires were conducted to analyze attributes and environmental preferences upon workers of ABW offices. By cluster analysis, workers were grouped into 6 clusters, "Balanced Preference", "Environmental Tolerant", "Seating Environment Considering", "Comprehensive Preference", "Nature Considering", and "Location Considering", based on their environmental preferences. Results show different worker attribute characteristics for each cluster. This indicates that considering various attributes while designing offices could lead to higher environmental satisfaction and productivity.

Tuesday, 13.06.2023 12:09-12:12 Room O2 Oxygen

Influences of indoor thermal environment on occupant productivity: A brief review

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ID: 1323 Extended Abstract
Topics: 07. Occupant behavior & controls, 08. Psychology, psychophysics, performance & productivity
Keywords: productivity, thermal environment, indoor temperature, building control

Buildings are often designed and operated with energy use as the sole metric and overlook occupant aspects such as comfort and satisfaction. This unilateral or simplified approach not only violates the thermal comfort experience of occupants by using static and narrow comfort ranges, but also compromises their indoor environment quality (IEQ), collectively leading to long-term health and well-being impacts that are hard to quantify. From a building operator's perspective, trading off occupant comfort for energy savings could result in a loss of occupant productivity that is relatively easier to quantify in monetary terms. Jones Lang LaSalle's 3:30:300 rule highlights that for every unit of space, a building operator spends $3 on utilities, $30 on rent, and $300 on staff. Simply put, the occupant-related expenses constitute 90% of the total operating costs, and therefore ignoring occupant productivity considerations or the physical factors leading to the loss of occupant productivity such as the indoor environment could lead to huge economic losses.

Even though the extant review efforts highlight that IEQ factors, particularly thermal environment influence occupants' productivity, there has been no consensus on the nature or size of such effects that could be useful in informing building design and controls strategies. This paper through a systematic literature review aims at identifying the association of office occupant productivity with the indoor thermal environment to provide actionable insights for optimal building design and control considering the total costs. The scope of this review is limited to office environments. The broader goal is to support occupant-centric building design and control and reduce economic losses attributable to loss of productivity. The preliminary findings from the review revealed that the magnitude of thermal discomfort (i.e., deviation from comfort temperature), nature of tasks, and duration of exposure to the thermal environment are the key influencing factors that impact occupant productivity. Moreover, there exist varied methods of measuring occupant productivity ranging from objective indices to subjective methods to self-evaluation techniques, however, a standardized method to evaluate occupant productivity is required. This paper spotlights the need for developing a quantitative objective function that could be utilized by architects, engineers, or facility managers for optimal building design and control.

Tuesday, 13.06.2023 12:12-12:15 Room O2 Oxygen

The impact of indoor carbon dioxide on human cognition and decision-making

Flagner, Stefan (1,2,3); Kuenn, Steffen (3); Meissner, Thomas (4); Plasqui, Guy (2)

1: Department of Finance, School of Business and Economics, Maastricht University; 2: Department of Nutrition and Movement Sciences, Faculty of Health Medicine and Life Sciences, Maastricht University; 3: Department for Macro, International & Labour Economics, School of Business and Economics, Maastricht University; 4: Department of Microeconomics and Public Economics, School of Business and Economics, Maastricht University

ID: 1299 Extended Abstract
Topics: 07. Occupant behavior & controls, 08. Psychology, psychophysics, performance & productivity
Keywords: CO2, CANTAB, oxygen consumption, risk preferences

There is increasing evidence that higher levels of carbon dioxide (CO_2) inside buildings are negatively associated with the cognitive performance and decision-making capabilities of occupants. Many studies measure CO_2 to estimate indoor air quality because CO_2 concentrations are strongly correlated with other substances such as volatile organic compounds (VOC). However, it is still unclear if the VOCs or CO_2 itself can cause such effects. This interdisciplinary project aims to contribute new insights by examining the effect of 8-hour exposure to CO_2 on the cognitive performance and financial decision-making of humans.

The study used a cross-over design, in which 20 healthy white-collar workers were exposed to two test days of eight hours to either 0.08% (800 ppm) CO_2 or 0.3% (3,000 ppm) CO_2 in a respiration chamber. VOCs were filtered out from the air to examine the pure effect of CO_2. Cognitive performance was measured using the CANTAB test, which includes the cognitive domains of psychomotor control, executive functioning, and memory tasks. Additionally, multiple price lists from economics literature were used to measure the risk and time preferences of humans when faced with a decision between two financial payments which can be received with a certain likelihood. Lastly, a heuristics battery from behavioural psychology literature was used to measure biased behaviour in decision-making. Physiological parameters such as oxygen consumption, heart rate, respiration rate, blood CO_2 concentration, blood pressure, and skin temperature were measured continuously to further investigate a possible mechanism explaining the effect of indoor CO_2 on cognition. Mixed linear modelling was used to examine the proposed hypotheses.

Preliminary statistical analysis indicated no significant effect of CO_2 on results of the domain of psychomotor control. A significant positive effect of high CO_2 on spatial planning and short-term memory has been found ($p < 0.05$), which is opposing the hypothesis formulated above. Additionally, there has been no significant effect of high CO_2 on risk-taking behaviour or impatience to receive a financial outcome, however, during the high CO_2 condition, the tremble error expressing random choosing of a payment was significantly reduced ($p < 0.05$).

We could not replicate the negative effects of pure CO_2 exposure found in other studies. For some cognitive domains, we found an opposing effect of CO_2. However, further analysis will be conducted to examine more thoroughly the possible effects of indoor CO_2 on the above-mentioned outcomes, as well as the physiological parameters.

Session 13 Tuesday Carbon - Air cleaning & air purifiers

Time:
Tuesday, 13.06.2023 13:30-14:45

Room: C Carbon

Chair:
Müller, Dirk
RWTH Aachen University

Co-Chair:
Rewitz, Kai
RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

Tuesday, 13.06.2023 13:30-13:45 Room C Carbon

Can Air Cleaners Remove VOCs from Classroom Air? Insights from Time-resolved Field- and Laboratory Measurements

Sørensen, Sara Bjerre; Kristensen, Kasper

Department of Biological and Chemical Engineering, Aarhus University, Denmark

ID: 1213 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor air quality (IAQ), school, clean air delivery rate (CADR), removal efficiency, proton-transfer-reaction mass spectrometer (PTR-MS)

In densely populated classrooms, volatile organic compounds (VOCs) may constitute an important source of indoor air pollution. To constrain this, air purification has gained ground as an addition to source control and enhanced air exchange. Consequently, mobile air cleaners are becoming increasingly popular despite the limited evidence of their effect. At present, air cleaner efficiency is denoted by clean air delivery rates (CADRs) most often evaluated from the removal of airborne particle matter (PM). In contrast, VOCs cover a broad range of chemical compounds with different properties thereby making it difficult to evaluate their removal. Often toluene or formaldehyde is used as a proxy of all VOCs with measurements performed prior to- and post air cleaner operation in test chambers. Thus additional in depth knowledge on air cleaner efficiency, limitations and possible side effects in terms of VOCs are highly warranted.

In this work, commercial air cleaners for removal of VOCs were installed in a Danish primary school classroom. In order to assess their effect in a real environment, real-time measurements of VOCs were performed using a proton-transfer-reaction time-of-flight mass spectrometer (PTR-TOF-MS) one week prior to- and post installation. In addition, a laboratory protocol for evaluation of air cleaner performance in terms of VOC- and PM removal was developed. The protocol included nine VOCs of different size, chemical functionality and volatility, which have previously been identified as common indoor air pollutants in classrooms. A total of eight air cleaners with different design and technologies were tested and possible limitations and side effects were identified.

In the studied classroom, VOCs from both classroom interior and occupants were identified as significant sources of indoor air pollution, with the latter resulting in strong diurnal variations in indoor VOCs. Although dimensioned to three times the size of the studied classroom (based on CADR) limited effect of the air cleaners was observed on VOCs from either sources. Using PTR-TOF-MS, laboratory tests revealed vastly different VOC removal efficiencies depending on the properties of the specific compound. The time-resolved measurements of the in and out-flow of the air cleaners showed that VOC removal varied greatly over time and in all cases, reemission of the compounds were observed. For air cleaners using photocatalytic oxidation (PCO) results suggested limited removal of the compounds investigated and production of by-products. For all air cleaners, CADR for VOCs were dissimilar to those of PM, thus questioning this measure of air cleaner performance.

Tuesday, 13.06.2023 13:45-14:00 Room C Carbon

Rating the Effectiveness of Air Purifiers on Aerosol Removal in a Classroom with Numerical Flow Simulations

Ostmann, Philipp; Derwein, Dennis; Kremer, Martin; Rewitz, Kai; Müller, Dirk

RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

ID: 1126 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: SARS-CoV-2, classroom, window ventilation, numerical flow simulation, mobile air cleaners

Motivated by the SARS-CoV-2 pandemic, ventilation of indoor environments, such as classrooms was intensively discussed in public. In the early stages of the pandemic, window ventilation through opened windows was, in most cases, the only option to reduce the aerosol concentration in the room. The negative impact of window ventilation on thermal comfort motivated the use of mobile air purifiers. To evaluate the effectiveness of mobile air purifiers on aerosol removal and their influence on the complex flow field within a classroom, we developed a numerical flow model. Every person (28 students and one teacher) emits CO_2 and a traceable, individual aerosol. For each 45 min, 11 different simulation results for different combinations of ambient temperatures as well as position and volume flows of the air purifier are evaluated. A strong influence of the outdoor air temperature on the overall effectiveness of window ventilation is observable. The established comfort levels are violated for up to nearly 20 minutes. When operating a mobile air purifier, a significant reduction in aerosol concentration is observed. The removal effectiveness of the air purifiers is mainly dependent on the air purifier’s position and volume flow, while the local air exchange efficiency is also influenced.

Tuesday, 13.06.2023 14:00-14:15 Room C Carbon

Developing an Accessible, Low-Cost Air Cleaner for Safer Spaces During Wildfires

Stinson, Brett William; Gall, Elliott Tyler

Portland State University, United States of America

ID: 1150 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 10. Community- and urban-scale challenges and solutions
Keywords: air cleaning, wildfires, CADR, particulate matter

With resource and cost restraints in mind, we developed an air cleaner that utilizes common household fabrics that can be affixed to a box fan. We experimentally determined the clean air delivery rate (CADR) of the prototyped device using two distinct methods. First, we conducted laboratory testing with five fabrics attached, and for comparison, tested two popular, homemade air cleaning configurations with and without flowrate-increasing shrouds. Of the five fabrics tested, cotton batting yielded the highest CADR: at the highest fan speed setting with a single layer of fabric, average CADRs of 98, 80, and 192 m^3/h were realized at particle size ranges of 0.02–0.3, 0.3–1, and 1–2.5 microns, respectively. Secondly, particle decay testing in a controlled chamber was conducted on the device with a cotton batting filter attached, including alternative configurations that featured a second filter and flowrate-increasing shroud. Across triplicate experiments, the device with two layers of fabric and shroud yielded the highest average CADRs: 190, 158, and 243 m^3/h at particle size ranges of 0.02–0.3, 0.3–1, and 1–2.5 microns, respectively. While single-pass fabric removal efficiencies are generally low, large surface areas and high air flowrates make for an effective, low-cost air cleaning device.

Tuesday, 13.06.2023 14:15-14:18 Room C Carbon

Quantitative Evaluation of the Effect of Portable Air Cleaners on Aerosol Transmission Control

XIANG, Yiming (1); OCHIAI, Ryo (2); TOMIZAWA, Yusuke (1); OGATA, Masayuki (3); HORI, Satoshi (4); TANABE, Shin-ichi (1)

1: Department of Architecture, Waseda University, Japan; 2: Takenaka Corporation (Former Graduate Student, Waseda University); 3: Tokyo Metropolitan University, Japan; 4: Juntendo University, Japan

ID: 1192 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: air cleaner, air change per hour, aerosol transmission, mechanical ventilation, COVID-19

The existing methods for mitigating the risk of aerosol transmission of Coronavirus disease 2019 through individual actions are insufficient. Hence, there is a requirement for implementing engineering-based approaches, among which the deployment of portable air cleaners (PACs) is a cost-effective and low-impact solution for thermal comfort. This study evaluates the particle-removal efficiency in a mechanically ventilated classroom by calculating the equivalent air change per hour (ACHEq). This evaluation was performed by considering various parameters, such as the number of units, airflow patterns, and setting locations. The findings indicate that an increase in the clean air delivery rate from PACs improves ACHEq. However, placing the PAC near the exhaust air of mechanical ventilation (MV) resulted in a lower ACHEq than in the other scenarios. Additionally, substantial disparities in particle-removal efficiency were observed at different measuring points, suggesting that achieving uniform particle-removal efficiency in a room by combining PACs with mechanical ventilation is challenging. Furthermore, the ACHEq measured at the points near the supply air of the MV was inclined to be easily improved compared to those measuring points near the exhaust air of the MV.

Tuesday, 13.06.2023 14:18-14:21 Room C Carbon

Deep-Reinforcement-Learning Control of Window and Air Cleaner for Energy-Efficient Indoor Particle Removal

AN, Yuting; NIU, Zhuolun; CHEN, Chun

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ID: 1230 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Deep reinforcement learning, Indoor $PM^2.5$, Energy consumption, Window actuator, Air cleaner

For naturally ventilated apartments equipped with air cleaners, it is of great significance to develop a smart approach that automatically controls the window actuator and the air cleaner in order to reduce indoor PM2.5 (particulate matter with aerodynamic diameter less than 2.5 μm) pollution with lower energy consumption by the air cleaner. This investigation first employed the deep-reinforcement-learning based approach to train a smart controller that minimizes the total economic loss due to $PM^2.5$-related health risks and air cleaner energy consumption. The controller was trained offline in a virtual apartment constructed on the basis of a particle dynamics model with typical building parameters. The inputs required for the controller were the real-time indoor and outdoor PM2.5 concentrations, which could be easily measured by low-cost sensors. To test the trained deep Q-network (DQN) controller, a series of experiments were conducted in two identical laboratory chambers. Both the indoor $PM^2.5$ concentrations and the operating time of the air cleaner were compared between the trained DQN controller and different benchmark controllers with various outdoor $PM^2.5$ levels under different chamber conditions, in order to assess the controller performance. The trained DQN controller outperformed the benchmark controllers in reducing the total economic loss due to indoor $PM^2.5$-related health risks and air cleaner energy consumption by 2.4% to 43.7% for all 18 cases. Although the DQN controller was trained offline in a virtual apartment with typical building parameters, it could still achieve ideal and robust performance in the chamber experiments even when the parameters were very different from the typical values.

Tuesday, 13.06.2023 14:21-14:24 Room C Carbon

Testing gas-phase air cleaners based on perceived air quality

Amada, Kanta (1,2); Vesth, Simon (2); Fang, Lei (2); Olesen, Bjarne Wilkens (2); Wargocki, Pawel (2)

1: Waseda University, Japan; 2: Technical University of Denmark, Demmark

ID: 1261 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Air cleaner, ionizer, activate carbon, ventilation, volatile organic compounds

The aim of this study was to develop the method for testing of gas-phase air cleaners as a part of the IEA Annex 78. Three air cleaners (ionizer, activated carbon) were examined in field laboratories at the Technical University of Denmark. Testing was conducted at different ventilation rates and with different sources of pollution (building materials and human bio-effluents). Particle and ozone concentration were measured before air cleaners turn on and after 6 hours running of air cleaners. Chemical measurements were conducted when ventilation rate was the lowest. The results showed that passive air cleaner performed better than active air cleaner. The performance of the air cleaner can be compared with effect of increased ventilation. With regard to chemicals, it was shown that the passive air cleaner significantly removed Volatile Organic Compounds. However, the effect of air cleaners cannot be compared to that of ventilation, as this experiment did not involve chemical analysis at high ventilation rate. No significant differences in particle and gas removal effectiveness were found for different pollution sources. The methods examined and experience gained will be used to draft the method for testing the performance of gas-phase air cleaners that can be included in a standard.

Tuesday, 13.06.2023 14:24-14:27 Room C Carbon

The role of air cleaners beyond the pandemic

Schumacher, Stefan; Caspari, Anna; Varzandeh, Kiarash; Staack, Katharina; Asbach, Christof

Institut für Umwelt & Energie, Technik & Analytik e.V. (IUTA), Germany

ID: 1349 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: air cleaner, indoor air, ultrafine particles, infection risk, energy efficiency

During the COVID-19 pandemic, the relevance of infection transmission by aerosol particles has gained a broad public attention. Air cleaners have turned out as a useful measure to reduce infection risks, as they are capable of filtering viruses and virus-laden droplets. Since the awareness of the pandemic currently seems to decline, the question arises which role air cleaners will play in future for a healthy environment in buildings. Therefore, it is important to remember that other airborne pathogens exist beyond SARS-CoV-2 and that the group of particulate pollutants that can negatively influence human health consists of more than only bioaerosols. It has been shown in various epidemiological studies that fine dust from various indoor and outdoor sources has negative impacts on human morbidity and mortality. Furthermore, airborne particles such as pollen or animal-hair allergens can cause allergic reactions. These particles appear in a broad spectrum of sizes, materials and morphologies and are only partially captured by recent testing standards for air cleaners. For example, ultrafine particles are especially correlated with negative health impacts but are not considered at all. Thus, we developed novel test methods to cover the whole size range from individual viruses to coarse pollen grains by combining different test aerosols and measurement techniques. The experiences gathered also drive the development of IEC 63086 as first international testing standard for air cleaners. Tests in real environments such as classrooms, seminar rooms, and offices show that the cleaned air is homogenously distributed within the room even without the artificial mixing in a test chamber setup. The key parameters determined in the experiments were used as input for a mathematical model to estimate the exposure reduction by operation of an air cleaner for typical scenarios with different pollutants. Besides the cleaning efficacy, also related aspects such as noise and energy efficiency have to be considered when discussing the use of air cleaners. By comparing filters with different efficiency in the same appliance, we demonstrate that the use of high-efficiency filters, which are typically associated with an increased pressure drop, is often at the expense of energy efficiency and noise. We show the combination of several small air cleaners can positively contribute to reducing noise and energy consumption without any detriments to the cleaning efficacy.

Tuesday, 13.06.2023 14:27-14:30 Room C Carbon

Standardizing the testing of air cleaners against virus aerosols

Uhde, Erik (1); Clauß, Annette (1); Schulz, Jochen (2)

1: Fraunhofer WKI, Department of Material Analysis and Indoor Chemistry, Braunschweig, Germany; 2: Institute for Animal Hygiene, Animal Welfare and Farm Animal Behaviour, University of Veterinary Medicine Hannover, Foundation, Hannover, Germany

ID: 1394 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Air cleaning, performance, test organism, CADR

Virus particles spread via aerosols are a health hazard especially for indoor environments. While source control and ventilation are known to reduce the infection risks, air cleaners are discussed as additional measure to control infectious aerosols, especially in workplaces or public buildings.

Several international standards exist to assess the effectivity of air cleaners in a comparable way, but these usually significantly in their technical approaches and are usually defined for just one or few pollutant type(s). As a consequence of the SARS-COV-2 pandemic, a project was started in Germany to develop a standard procedure for testing of air cleaners in a more holistic way: In addition to testing the virus and particle removal efficiency, the effectivity to remove other pollutants, the occurrence of possible by-products and other parameters like noise production ware assessed together. The procedure focusses on filter-free air cleaners intended for workplaces and schools.

Session 14 Tuesday Silver - Interfaces & user engagement

Time:
Tuesday, 13.06.2023 13:30-14:45

Room: Ag Silver

Chair:
Andersen, Rune Korsholm
Technical Univeristy of Denmark

Co-Chair:
van Marken Lichtenbelt, Wouter
Maastricht University

Tuesday, 13.06.2023 13:30-13:45 Room Ag Silver

An Occupant-participatory Approach for Fault Detection and Diagnosis in Buildings

Nojedehi, Pedram; Gunay, Burak; O'Brien, William

Carleton University, Canada

ID: 1477 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: Fault detection and diagnosis, crowdsourcing, Participatory sensing, Occupant discomfort

Despite the development of numerous fault detection and diagnostic (FDD) technologies for buildings, many errors remain undiscovered or are not discovered promptly, which reduces energy efficiency and occupants' satisfaction. Crowdsourcing applications that continuously collect building occupants' feedback as additional sensors can improve the accuracy and promptness of FDD methods. This proof-of-concept paper introduces and tests a method to simultaneously collect occupant input and run an FDD algorithm. This method deploys a smartwatch clock face app. It nudges occupants to complete a survey that has a fixed set of questions focusing on occupants' perceptions of thermal comfort and air quality. The second part of the methodology uses occupants' feedback to prompt rule-based FDD methods via an application programming interface to access the sensor readings of building automation system. Then, FDD rulesets take the data to compute process variable errors and generate alarms. Four different faults were imposed on an office building to assess how occupants' feedback improves FDD. Findings showed that occupants' feedback can reliably verify alarms and enable a faster and more accurate FDD. In an experiment, 95.8% of votes correctly found indoor air temperature comfortable or preferred warmer while FDD rules generated 77 false high-temperature alarms in fourteen days.

Tuesday, 13.06.2023 13:45-14:00 Room Ag Silver

Energy use, indoor environment parameters and residents' engagement in indoor environment control in energy efficient homes - field study in Poland

Baborska-Narożny, Magdalena (1); Bandurski, Karol (2); Grudzińska, Magdalena (3)

1: Wrocław University of Science and Technology, Poland; 2: Poznan University of Technology, Poland; 3: Lublin University of Technology, Poland

ID: 1366 Full paper
Topics: 07. Occupant behavior & controls
Keywords: occupant-building interaction, energy performance gap, residential buildings, IEQ, low energy residential buildings, practice theory

Thermal balance and indoor environment quality of energy efficient homes is strongly influenced by residents' practices. Despite a growing body of literature on building - occupant interaction an interdisciplinary perspective is required for an understanding of the dynamics of households operating in energy efficient homes and the motivations underpinning the observed indoor environment control practices. This paper reports preliminary results of a one year long in-depth performance evaluation of almost identical six semi-detached energy efficient homes in Poland. All homes are equipped with heat pumps and MVHR ventilation, however the systems vary between buildings, and two homes use wood stoves. The aim was to capture the home use practices settled after the adaptation process of early occupancy. Data collection lasted between September 2021 and August 2022. Energy consumption data was provided by an energy supplier. The preliminary results reveal very high quality of the internal environment, with some overheating issues of varied severity. The results also point to the key role of performance indicators for meaningful comparisons of energy consumption data between households of varied size living in same size dwellings. Occupancy intensity (person-months) is aligned with the increased energy consumption, therefore standard results presentation in (kWh/m²/a) may be misleading.

Tuesday, 13.06.2023 14:00-14:15 Room Ag Silver

Methodology to develop interfaces to help office users better understand control strategies of climate systems

Spiekman, Marleen (1); te Duits, Noa (1); Lange, Vera (2); Jeurens, Jasper (2); Sluis-Thiescheffer, Wouter (2)

1: TNO, The Netherlands; 2: HAN University of Applied Sciences, The Netherlands

ID: 1117 Full paper
Topics: 07. Occupant behavior & controls, 08. Psychology, psychophysics, performance & productivity
Keywords: Feedback, interface, office climate systems, user centred design, co-creation.

To meet our climate goals, we are making buildings increasingly smart. Smart controls linked to sensors and driven by algorithms try to make our offices as energy efficient as possible and the indoor climate comfortable and healthy. Despite all these controls, office employees want to be able to adjust their workplace to their own needs. In practice, we see that this can lead to conflicts: Occupants don't understand what the system is doing, they don't always know how to intervene, are often unaware of the consequences of their actions and therefore regularly take counterproductive actions. In the Brains4Building project, we investigate how to improve the interaction between building systems and users. The goal is to make smart buildings and users work better together, so that together they provide for an efficient, comfortable and healthy building. To achieve this, we developed a method that allowed us to capture intangible thoughts, wishes and needs of office building users, which we will use for the development of more user centric interfaces. These user centric interfaces will contain feedback from the system to the users that will help them understand what the system does and what they effectively can do if they are uncomfortable.

Tuesday, 13.06.2023 14:15-14:18 Room Ag Silver

User centric assessment of comfort and health in offices

Jacobs, Piet (1); Hoogervorst, Coen (2); Rijs, Agata (2); van der Harst, Sander (3); Keyson, David (4)

1: TNO, Netherlands, The; 2: Spie Nederland; 3: Unica Groep; 4: Delft University of Technology

ID: 1336 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: voting box, thermal comfort, indoor air quality, offices

An indoor Climate Label was developed for office buildings. To determine subjective comfort levels one time per year a survey is carried out under all office occupants. The goal of our study was to develop a method which could continuously gather comfort feedback from office occupants, requiring a minimal level of perceived effort and minimal distraction. During the summer of 2022 a pilot study in an existing Dutch office building was conducted. User feedback was gathered via two methods, self-standing vote boxes and QR codes placed on tables in the office rooms. Both methods were compared to use of a yearly web-based survey list.

Based on the analysis of the results gathered, the vote boxes led to a relatively high response rate as compared to use of the QR codes. This was most likely due to the ease of giving feedback using the vote boxes as compared to the QR codes. Data from the vote box, as compared to results obtained using the yearly survey, yielded similar average perceived comfort levels. Scores from the vote box, tended to be more extreme in terms of positive or negative votes, as compared to data collected using the yearly survey.

Tuesday, 13.06.2023 14:18-14:21 Room Ag Silver

Heat of the moment: Reshaping energy efficiency decisions made by building occupants

Colligan, Zachary; Ruiz, Shelby; Day, Julia

Washington State University, School of Design and Construction, United States of America

ID: 1441 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 07. Occupant behavior & controls
Keywords: tenant engagement, education, energy saving campaign, comfort, pro energy behaviors

To address occupant behaviors‘ critical role in overall building energy use, our team implemented an occupant engagement program on a large university campus in Pullman, WA, USA to help address the division between building operators and occupants, reduce energy use on campus, and increase health and comfort outcomes. Through this engagement, the occupants displayed greater responsiveness to our efficiency-driven efforts. To realize these goals, a mixed methods study was implemented, which included a range of interventions such as installing Smart power strips (SPS), educational training, marketing materials, and dedicated in-person engagement. Departmental representatives were responsible for the dissemination of educational materials to their peers. The SPS study also included a series of surveys and interviews to capture participants' weekly schedules, energy habits, and perceptions of comfort in their office spaces to predict use patterns more accurately. Based on this work we found a range of estimated annual energy savings between 1.5-10% depending on the office conditions and behaviors. Findings also showed that several building occupants were attempting to improve their comfort by using high-wattage space heaters. This paper features strategies used in this campaign, as well as promising findings and persistent challenges of personal energy use management and occupant engagement.

Tuesday, 13.06.2023 14:21-14:24 Room Ag Silver

Use of equivalent indoor air temperature profiles by forecast control of a heating system

Cholewa, Tomasz; Siuta-Olcha, Alicja; Bocian, Martyna; Dudzińska, Marzenna R.; Staszowska, Amelia

Lublin University of Technology, Poland

ID: 1353 Extended Abstract
Topics: 06. Heating, ventilation, air conditioning & cooling, 07. Occupant behavior & controls
Keywords: Forecast control, Model predictive control, Building energy model, Building controls, Energy efficiency

The forecast control of heating systems is important and relevant research topic, because the energy savings may be easily achieved in the new but especially in the existing buildings, which undergo energy renovation. Besides the outdoor parameters (such as outdoor air temperature, wind speed and solar insolation), the occupant behavior and preferences influence significantly the heat supplied to the buildings for heating. That is why, simple methods to include this aspect by forecast control of the heating systems is needed.

This work underlines the details how to easy include occupant behavior and preferences by the process of a forecast control of heating systems at the building level, because in such a case the heat supply may be properly adjusted to users needs in advance. The analyzed building (one multifamily and one public) are located in Lublin (Poland), where the design outdoor temperature is equal to -20ºC. In these buildings a traditional, central heating installation with vertical risers in each flat and convective radiators is used. The control of heating systems is realized by the use of a forecast control which work with the traditional weather base controller. The field measurements were performed in order to check the automatic operation of this forecasts control system which use proposed method to include users needs in the form of equivalent indoor air temperature. The results show that such an approach has many advantages such as possible use of decrease of indoor air temperature in periods where it is acceptable by the occupants.

Tuesday, 13.06.2023 14:24-14:27 Room Ag Silver

Definition of a methodology for occupants' feedback collection on perceived indoor environmental comfort

Fissore, Virginia Isabella (1); Saugo, Martina (2); Arcamone, Giuseppina (1); Puglisi, Giuseppina Emma (1); Shtrepi, Louena (1); Sassoli, Nicolas (3); Idone Cassone, Vincenzo (4); Paduos, Simona (5); Corrado, Vincenzo (1); Servetti, Antonio (2); Astolfi,

1: Department of Energy, Polytechnic of Turin, Turin, Italy; 2: Department of Control and Computer Engineering, Polytechnic of Turin, Turin, Italy; 3: Geoside S.p.A., Italgas Group, Bologna, Italy; 4: Ritsumeikan Center for Game Studies, Ritsumeikan University, Kyoto, Japan; 5: C2R Energy Consulting S.r.l., Turin, Italy

ID: 1407 Extended Abstract
Topics: 07. Occupant behavior & controls, 11. All other IEQ, ergonomics & health topics
Keywords: Indoor Environmental Comfort, Indoor Environmental Quality, subjective feedback, office.

People spend about 90% of their time in closed spaces and their well-being, comfort and work productivity are influenced by Indoor Environmental Quality (IEQ), that is, the characterization of indoor environments in terms of thermal, acoustic, lighting and air quality domains. As far as Indoor Environmental Comfort (IEC) is concerned, it is influenced by personal, contextual and behavioural variables, such as age, educational qualification, building orientation and workstation location. IEQ is assessed by means of on-site monitoring of parameters and indexes of the four domains, while IEC by means of occupants' subjective feedback collection. To assess accurately the relationship between IEQ and IEC, this work proposes an advanced methodology to collect subjective feedback, based on standards and literature, which fosters an increase on occupants' awareness and engagement too.

A questionnaire on IEC that investigates thermal, acoustic, visual and air quality perception, along with personal and behavioural questions, is administered by means of a tablet. A graphical interface that allows to answer the questionnaire on voluntary basis and only when deemed necessary by the user, to create an account and to visualize data of the parameters monitored in the environment, is developed. Furthermore, engagement strategies are defined to allow for efficient communication with occupants, increase in their motivation and interaction with the system, development of proactive behaviour. A pilot study that involves 12 workers in their everyday working environment for a one-month experimental campaign is in progress, therefore preliminary results on the application of this methodological approach and of the on-site validation will be discussed.

Tuesday, 13.06.2023 14:27-14:30 Room Ag Silver

Rethinking building interfaces for resilience, health, and well-being

Day, Julia K. (1); Heschong, Lisa (2)

1: Washington State University, USA, School of Design + Construction, Integrated Design + Construction Laboratory; 2: Fellow Illuminating Engineering Society, architect, author

ID: 1449 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia, 07. Occupant behavior & controls
Keywords: building controls, human building interactions, interfaces, operational range, well-being

Twenty years ago, it seemed unlikely that we would face a global pandemic, one that has turned our lives upside down. People and buildings alike were not prepared for what we have lived through in these last years. This challenging time, in addition to many extreme weather events around the world, has shed light on some of the ways in which our buildings have hurt us, rather than supported us and our health and well-being. For instance, when Hurricane Katrina hit the Louisiana coast years ago, occupants were forced to throw chairs through windows to get access to fresh air for lessened exposure to ever-growing moldy conditions. In another recent event, documented by the author's research, an older individual was struck by a heavy fire door during a rolling power blackout during summer heatwaves, and they later passed from the injury. COVID-19 concerns, along with other unseen bacterial and viral threats, have also triggered a conversation about touchless controls, HVAC, physical barriers, and more.

There are many points in our buildings where occupants can make decisions about how to use their buildings to control their comfort, health, and energy use. Human building interaction usability, and user experience research all offer ways in which we can begin to understand the characteristics of building controls and interfaces -- and how they may or may not support the people who live and work in these buildings. Yet, under extreme conditions, many building controls do not offer alternative methods of operation. If the power is lost, will it still work? If there is a wildfire outside, and windows cannot be opened, is the air quality indoors still acceptable, especially considering a novel virus that transmits indoors via aerosols, more than touch, or droplets?

The way our buildings are designed, built, operated, and occupied must change. We cannot continue to think and build in the same way. How can we step away from this precipice and join one another in a global fight to regain our health, and reimagine our buildings and resilience, while simultaneously tackling the significant issues we were already facing such as climate change, dwindling resources, and rapidly decreasing fresh water supplies? There is much to do. In this presentation, we will explore some of these daunting questions and offer one small solution, which we define as operational range, for designing buildings that support people in increasingly extreme and less predictable conditions.

Session 15 Tuesday Oxygen - Thermal comfort & climate change

Time:
Tuesday, 13.06.2023 13:30-14:45

Room: O2 Oxygen

Chair:
Frijns, Arjan
Eindhoven University of Technology

Co-Chair:
Pigliautile, Ilaria
University of Perugia

Tuesday, 13.06.2023 13:30-13:45 Room O2 Oxygen

Response to sensorial stimuli of people with autism in an indoor well-being framework: a scoping review

Zaniboni, Luca; Toftum, Jørn

Technical University of Denmark, Denmark

ID: 1185 Extended Abstract
Topics: 09. Public health, occupational & environmental health, 11. All other IEQ, ergonomics & health topics
Keywords: autism, well-being, multi-domain, design

More attention should be spent on the design of the indoor environment for people with special needs. In fact, the highest share of people's lifetime is spent indoors, and exposures from the indoor environment might be particularly affective in the case of people with fragilities. Moreover, a proper design of the indoor conditions can improve comfort, well-being and health of occupants, and also stabilize and decrease the building energy consumption. In this framework, studies on indoor well-being of people autism are of paramount importance. In fact, people with autism constitute a relevant and growing share of the overall world population. Moreover, they might experience different stimulations from the 5-senses, driving to possible different responses (hypo- or hyper- sensitive) to environmental stimuli, and different indoor well-being requirements. Nevertheless, technical standards lack information and design principles related with this theme. The present scoping review aims at exploring the present literature related to the topic of indoor well-being of people with autism, specifically: 1. A first section, covering the studies directly related to indoor well-being or comfort of people with autism; 2. A second section, briefly analyzing the studies related with the sensorial response of people with autism to the stimuli related with the four comfort domains (thermoreception for thermal, sight for visual, olfaction for indoor air quality, hearing for acoustics). The results can help to develop experimental methodologies and priorities, which can be used to further explore the topic of indoor comfort and well-being of people with autism, in order to build guidelines on the indoor design of environments to be occupied by this category of population.

Tuesday, 13.06.2023 13:45-14:00 Room O2 Oxygen

Occupant Thermal Comfort in Educational Buildings

Disci, Zehra Nur; Sharples, Steve; Lawrence, Ranald

The University of Liverpool, United Kingdom

ID: 1314 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Thermal comfort, Education buildings, Comfort temperature

The thermal environmental conditions in educational buildings, such as university libraries, affect the productivity and continuity of the students as well as their comfort and health. This paper will explore whether the thermal comfort standards and environmental management of educational buildings are sufficient for their occupants. A longitudinal study was conducted to investigate the thermal comfort of occupants in educational buildings. The Sydney Jones Library, at the University of Liverpool, was identified as an appropriate case study. For this study, users were asked to participate in an online survey that included questions to understand the factors affecting their thermal comfort and their views on the environmental conditions of the space. During the survey study, the temperature and relative humidity of the study area were recorded using data loggers. Statistical analysis of the results obtained from the survey revealed the effect of users' thermal perceptions and expectations on thermal comfort. The average indoor temperature varies between 19-20°C in winter, and 20-21°C in summer. This average temperature is below the recommended winter and summer comfort temperatures for library buildings in the UK. For this reason, the majority of the participants found the indoor temperature cool and wished it to be warmer.

Tuesday, 13.06.2023 14:00-14:15 Room O2 Oxygen

Thermal alliesthesia under whole-body cyclical conditions

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ID: 1113 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 08. Psychology, psychophysics, performance & productivity
Keywords: thermal sensation, thermal comfort, transient, dynamic, cyclical, thermal alliesthesia

A better understanding of how thermal alliesthesia affects human thermal perception during dynamic conditions is important in view of the emerging “smart grid” paradigm and associated demand-response (DR) programs that call for the implementation of set-point temperature modulations in buildings. In this paper, we report the results of an experiment exploring the subjective responses of 44 males and 76 females to four different whole-body warm and cool cyclical temperature modulations at different moments of the day (morning/afternoon) and in distinct seasons (summer/autumn). The study aimed to better understand how the relationship between thermal comfort and thermal sensation is framed by thermal alliesthesia. We found that temporal thermal alliesthesia significantly affects thermal comfort. This alliesthesial effect depends on both previous and actual thermal sensations and gets stronger as we move far from neutrality. The season was also found to significantly modify the relationship between thermal comfort and thermal sensation which confirms the existence of seasonal alliesthesia.

Tuesday, 13.06.2023 14:15-14:18 Room O2 Oxygen

Seasonal differences in thermal responses and cognitive performance in AC and semi-outdoor environments in Singapore

MIHARA, KUNIAKI (1); CHEN, SHISHENG (2); HASAMA, TAKAMASA (1); TAN, CHUN LIANG (3); LEE, JASON KAI WEI (4); WONG, NYUK HIEN (2)

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ID: 1273 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 08. Psychology, psychophysics, performance & productivity
Keywords: Thermal adaptation, neutral temperature, comfort temperature, tropical climate, cognitive tests

Seasonal differences in thermal responses and cognitive performance between northeast monsoon (NM) and southwest monsoon (SM) seasons were studied in an air-conditioned (AC) and a semi-outdoor environments in Singapore. A total of 89 participants joined the experiments. They were satisfied to thermal environment in both seasons in the AC and semi-outdoor environments. However, thermal comfort and thermal acceptability in NM season were 0.2 scales and 7% higher than in SM season in the AC and semi-outdoor environments ($p < 0.01$). Thermal sensation correlated to operative temperature in both seasons in the AC and semi-outdoor environments. The neutral operative temperature of 29.3 °C in SM season was higher than that of 25.3 °C in NM season in the semi-outdoor environment ($p < 0.001$). Thermal sensitivity in SM season was higher than that in NM season. There was a strong probability that SM season resulted in higher levels of selective attention, concentration, and creativity compared to NM season by Bayesian estimation. People could work without compromising thermal comfort and cognitive performance in both seasons in the AC space up to operative temperature of 26 °C and the semi-outdoor space of 26.9 °C SET in Singapore.

Tuesday, 13.06.2023 14:18-14:21 Room O2 Oxygen

Evaluation of Thermal Comfort Considering Spatial Characteristics in Semi-outdoor Environments

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ID: 1313 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Semi-outdoor Environment, Thermal Comfort, Thermal Adaptation, Spatial Characteristics

Semi-outdoor environments have recently begun to be introduced in urban and office to improve buildings' energy efficiency, and occupants' well-being. Thermal comfort conditions in semi-outdoor environments are relaxed compared to indoor comfort standards because of thermal adaptation. Few thermal comfort conditions have been studied considering thermal adaptation based on the space form and the matter in which natural outdoor elements are introduced. This study explored the effects of spatial characteristics on thermal comfort in semi-outdoor environments. Field surveys were conducted in five semi-outdoor spaces on a university campus in Tokyo, consisting of thermal environment measurements and questionnaires on thermal comfort and impressions of the surveyed spaces. Surveyed spaces are classified into two categories, namely, "outdoor tendency" and "indoor tendency," based on impressions of the overhead surface and elevation of surveyed spaces. Spaces with "outdoor tendency" exhibited higher upper limits of acceptable SET* than the spaces with "indoor tendency." The thermal comfort zone broadens because of psychological adaptation caused by differing environmental expectations. Occupant impressions of the space must be considered to achieve comfort and health for various uses in semi-outdoor environments. These findings are expected to be useful in the design of the component parts of semi-outdoor environments.

Tuesday, 13.06.2023 14:21-14:24 Room O2 Oxygen

Long-term prediction of the impacts of climate change on indoor climate and air quality using a new holistic model

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ID: 1210 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Future indoor climate, building hygrothermal simulation, indoor air physicochemical model, particle exposure, temperature dependent emissions, mold growth

In recent decades, climate change has been clearly seen through global warming and frequent extreme weather events. The changing climatic conditions such as temperature, humidity, and pollutant concentration further affect the indoor microclimate by altering the physical properties of the building, the dynamics of the indoor air, the chemical/physical reactions of pollutants, pollutants emission strength, and even microbial growth. The question therefore arises to what extent the changed processes influence the indoor air quality and the well-being of the occupants.

A practical solution is to apply model simulation. Numerous model systems have already been developed that focus on one or a few of the processes mentioned. There is still a need for a holistic model that combines all these main aspects and provides a complete picture of how climate change affects indoor air. The EKIEPI project was thus motived and funded by the German Environment Agency for developing the Indoor Air Quality Climate Change (IAQCC) model system. The IAQCC was constructed from five sub-models, each of which addresses one aspect:

1) The building physics model calculates the heat and moisture balance between the exterior and building envelope as well as between the building zones. 2) The emission model considers constant emission (e.g. building materials) and unit emission (e.g. from occupant activity) of gas and particle pollutants. 3) The chemical-physical model focuses on the key processes in the indoor environment from the aspect of mass transfer including aerosol dynamics and gas-phase reactions. The aerosol dynamics simulation is a particle size-resolved approach, including ventilation, outdoor

penetration, indoor particle deposition, and coagulation losses. Gas-phase reaction was developed based on Master Chemical Mechanism (MCM, v3.3.1). 4) The mold growth model assesses the mold risk on surfaces of building elements, accounting for the surface temperature, relative humidity, and exposure time. 5) The exposure model evaluates the results of the individual sub-models and estimates the human indoor exposure, including thermal comfort, deposition of particles in the lungs, inhalation of gas pollutants, and risk of exposure to microorganisms.

The key processes in each sub-model are all fundamentally linked to temperature and relative humidity, allowing long-term prediction of indoor climate and pollutant concentrations under various future climate scenarios, including different IPCC scenarios and emission reduction scenarios assuming different levels of air quality legislation. The results can provide a strong basis for future insulation, ventilation and IAQ improvement strategies and policies.

Tuesday, 13.06.2023 14:24-14:27 Room O2 Oxygen

Variations in subjective psychological responses to similar but distinct thermal environments

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ID: 1403 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 08. Psychology, psychophysics, performance & productivity
Keywords: pleasure, arousal, dominance, well-being, comfort

Purpose:

The current building codes for thermal conditions are based on comfort models introduced over three decades ago, which account for limited environmental and personal factors. In theory, different combinations of physical parameters lead to the same subjective thermal sensation based on such comfort models. This research aims to go beyond thermal sensation to characterise affective, emotional and other psychological responses of humans to thermal stimuli that differ in various thermal parameters but are expected to have the same thermal sensation.

Methodology:

In four indoor climate laboratories, 17 participants participated in up to four work-day-long scenarios each. In these scenarios, the environmental parameters of air temperature, radiation temperature, humidity, and air velocity were varied but designed for the same predicted thermal sensation of ‘slightly warm (PMV = +0.5).

During and at the end of the four workdays, the participants completed questionnaires to assess their psychological responses. Various aspects of satisfaction, comfort, emotion and sleepiness were evaluated in this study.

Findings:

Although existing building standards estimate all settings to be the same in terms of thermal sensation, results show how the indoor climate's solid and varied individual aspects influence other subjective responses of individuals.

Research implications:

This research helps to understand better and optimise how technical design, architectural planning, human psychological responses, and energy consumption interact in an age of scarce resources. In addition, the findings can be used to create less energy-intensive air conditioning regulations and enhance the use of naturally ventilated spaces.

Tuesday, 13.06.2023 14:27-14:30 Room O2 Oxygen

Can thermal sensation during work hours influence the way we interact socially after work?

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ID: 1465 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 08. Psychology, psychophysics, performance & productivity
Keywords: thermal sensation, empathy, social connectedness

Background: People are expected to face major challenges as a consequence of climate change. Studies warn that a rise in outdoor temperature conditions could have detrimental effects, which could impact societies in different levels. Additionally, extreme outdoor conditions could influence temperature conditions indoors if temperature conditions are not regulated. However, regulation of indoor temperature conditions could be difficult in the future due to the expected increases in gas prices caused by the limited gas availability. Some people might not be able to afford to regulate temperature conditions indoors and hence, people might be experiencing a higher range of thermal conditions. Evidence suggests that temperature is associated with changes in social conditions. However, there is limited evidence on the effect of different thermal sensations on social interactions.

Objective: Therefore, the current study aimed to investigate how different thermal sensations experienced in a cool and warm thermal environment could influence psychosocial aspects such as empathy and social connectedness.

Method: A sample of 31 participants (F=16, M=15) with an average age 40.7 was invited to attend a two-day hybrid study (a laboratory thermal experience and a field study). Participants attended two testing days, which were separated with a washout period of at least 1 day and they were exposed to two different conditions, a warm (28℃) and a cool (21℃) condition in a cross-over design. During the two testing days participants remained in a temperature-controlled simulated work environment for 8-hours to mimic an office space. Subjective measures on empathy, social disconnection, positive and negative affect and thermal sensation were administered before and after each testing day. In addition objective measures of indoor environmental conditions and peripheral skin temperature were continuously recorded with the use of sensors (commercial sensor and iButtons respectively).

Results: The results indicated that thermal sensation had a significant effect on reported empathy levels, positive and negative affect.

Discussion/Conclusions: Consequently, it is concluded that different thermal sensations of cool and warm conditions during work hours could influence the way we interact with other people. Implications of these outcomes will be discussed.

Session 16 Tuesday Carbon - Particulate matter

Time:
Tuesday, 13.06.2023 15:00-16:15

Room: C Carbon

Chair:
Shaw, David
University of York

Co-Chair:
Eilts, Jacob
University Hospital RWTH Aachen

Tuesday, 13.06.2023 15:00-15:15 Room C Carbon

Sensitivity analysis of the number of particles for indoor particle transport in a ventilated room with Lagrangian model

Eom, Ye Seul; Rim, Donghyun

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ID: 1444 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Indoor particles, Ventilation, Lagrangian particle tracking method, Computational Fluid dynamics (CFD)

Human exposure to indoor pollutants varies with source location and ventilation strategy. Several studies have revealed that indoor airflow distribution and ventilation conditions have notable effects on human exposure. However, there are few studies quantitatively evaluating how the source contribution to human exposure to particles varies with source location and ventilation conditions. The objective of this study is to (1) investigate the relationship between intake fraction and ventilation effectiveness; (2) evaluate the indoor particle concentration distribution in the micro-environment surrounding a human body depending on the source location. Computational fluid dynamics (CFD) simulation was conducted to predict the particulate pollutant transport in a full-scale chamber with a human body. We investigated two types of indoor pollutants to compare the effect of particle sizes: (1) 1.0 μm particles, which fall in the fine particle range; and (2) 10 μm particles, which represent respirable coarse particles. Two types of source locations were considered to reflect the indoor pollutant emissions situation. Intake fraction around the human body was evaluated under two airflow regimes: (1) momentum-driven mixing flow and (2) buoyancy-driven flow. Furthermore, three air mixing conditions (low, medium, and high mixing intensity) were considered for each airflow regime to analyze the effect of air mixing intensity on human exposure to particles. The results show that particle concentration in the breathing zone varies depending on air mixing intensity. In addition, particle concentration in the breathing zone for the buoyancy-driven flow is higher than momentum-driven mixing flow regardless of source locations. For the buoyancy-driven flow, ventilation effectiveness is lower than for momentum-driven mixing flow, although air mixing intensity increases.

Moreover, the results show that intake fraction decreased as ventilation effectiveness increased. The influence of ventilation effectiveness on human exposure was pronounced for the source located in front of the manikin's face region compared to the floor region. The results of this study provide the relationship between ventilation conditions and human exposure relative to the concentrations in the breathing zone under two airflow regimes.

Tuesday, 13.06.2023 15:15-15:30 Room C Carbon

Health Risks of Indoor Exposures to Fine Particulate Matter and Practical Mitigation Solutions - a U.S. National Academy of Sciences Study

Butler, David Alan

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ID: 1193 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: PM².5, exposure, health, mitigation, indoors

Particulate matter (PM) dominates the known health impacts of air pollution. Most exposure to PM from both indoor and outdoor sources takes place in indoor environments. Exposure to fine particulate matter (PM².5) is especially concerning because a large and growing body of scientific literature indicates that it is associated with adverse health outcomes.

In response to a request from the U.S. Environmental Protection Agency, the National Academy of Engineering of the National Academies of Sciences, Engineering, and Medicine has convened an expert committee to consider the state-of the-science on the health risks of exposure to PM².5 indoors and engineering solutions and interventions to reduce risks of exposure to it indoors, including practical mitigation solutions to reduce that exposure in residential and school settings. The committee is focusing on:

- synthesizing and summarizing recent scientific literature assessing the health risks of indoor exposure to PM².5; and

- the identification and analysis of practical intervention approaches for PM².5 indoors.

It will build on the knowledge gained during an international 2021 virtual workshop series that featured sessions on sources of indoor fine particulate matter, and the means of measuring assessing, and mitigating exposure.

This work will lead to a consensus study report with findings and recommendations regarding 1) the key implications of the scientific research for public health, including potential near-term opportunities for incorporating what is known into public health practice, and 2) where additional research will be most critical to understanding indoor exposure to PM²․5 and the effectiveness of interventions. Opportunities for advancing such research by addressing methodological or technological barriers or enhancing coordination or collaboration will be also be addressed. The study is underway and the committee's report will be released in Spring 2023.

The conference talk and extended abstract will summarize the results of this effort, reviewing the findings regarding the literature on the sources and composition indoor PM; its fate, transport, and transformation; human exposure; and PM health and biologic effects. Recommendations will be offered regarding practical mitigation measures. As the report has not yet been completed, it is not yet possible to provide further detail regarding the content.

Tuesday, 13.06.2023 15:30-15:45 Room C Carbon

Development of high accuracy particle concentration prediction model - an application of remote sensing and machine learning

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ID: 1428 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor Air Quality, Developing Nations, AOD, MERRA-2, Machine Learning, $PM^2.5$

Indoor air is a dominant exposure for humans as more than half of the body's intake during a lifetime is air inhaled indoors. Most of the buildings in developing nations are openly ventilated, and there is no significant difference between the outside and indoor air. Efforts are being made by authorities to build well-controlled indoor environments. Lack of air pollution monitoring systems is one of the major challenges in identifying high-risk zones where the development of healthy buildings is critical. Ground-based monitoring systems are sparsely distributed in major cities only. Whereas low-cost sensors come with challenges related to calibration, accuracy, and reliability. Satellites provide continuous global coverage with high-resolution AOD data. Though significant work has been done correlating AOD and PM2.5, still the models lack accuracy and transferability. The vertical distribution profile of the aerosols significantly affects the surface level concentration which is not accounted for by the majority of the studies done for AOD-$PM^2.5$ modeling. This study emphasizes the use of high-resolution AOD from CHRISTINE code and aerosol vertical distribution profile, along with meteorological parameters and factors affecting particle size distribution, to develop a step-down methodology for more accurate PM2.5 prediction and transferable a larger geographical range.

Tuesday, 13.06.2023 15:45-15:48 Room C Carbon

Assessment of PM levels in urban residential homes in four cities in India

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ID: 1251 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Particulate matter, Low-cost sensors, Indoor air quality, Ambient concentration, Cooking.

Towards assessing residents' indoor particulate matter (PM) exposures and its spatiotemporal variation, low-cost monitors (LCM)were deployed for ~24-48 hours in 6-9 homes each in four cities in India – Delhi, Mumbai, Bangalore, and Mysore. Average concentrations of PM1(PM2.5,PM10) were 60.0±22.7(80.6±26.5,88.5±24.4) for Delhi,

34.0±12.8(48.7±17.3,57.0±17.6) for Mumbai, 26.3±3.9(37.5±5.9, 44.9±8.4) for Bangalore, 24.2±8.0(33.2±11.7,38.7±15.2) μg/m³ for Mysore, exhibiting significant differences between cities ($p<0.05$), mostly due to differences in intensity and frequency of indoor sources. The daily average indoor levels during cooking were 30%(32%,35%) higher for PM1(PM2.5,PM10) than noncooking period and up to ~40% higher for homes having higher cooking duration (≥2 hours). Indoor PM levels traced outdoor levels as demonstrated by its association with outdoor PM levels and proximity to road. Indoor activities contributed only 6-15% to the overall daily indoor PM levels. The combined contribution of indoor and local outdoor sources to indoor PM was only 1/3rd of the total, remaining being accounted by the background outdoor PM. There was higher

variability in indoor PM within-home than between-homes, indicating single measurement a poor surrogate for the long-term indoor PM exposures. The study highlights how temporarily short-term generated indoor pollutants may be associated with acute exposures while outdoor sources can contribute greatly to chronic exposures.

Tuesday, 13.06.2023 15:48-15:51 Room C Carbon

Constituents of Human Particle, Microbial and Chemical Emissions and Exposures in Indoor Environments: An experimental overview

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ID: 1160 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Human emissions, gas-phase chemistry, nanoparticles, bioaerosols, oxidative stress

Humans have been recognized as an important but overlooked indoor air pollution sources that strongly influence the biological and chemical burden in such environments. The objectives of this project are to (i) characterize particles, microbes and volatile organic compounds emitted from humans and their transformations in indoor air under various conditions (air change rate, physical activity, and induced stress) and to (ii) examine the effect of ozone exposure on malondialdehyde (MDA) levels, a biomarker of lipid peroxidation.

One group of six and four groups of three healthy non-smoking adult participants occupied a controlled climatic chamber with a floor area of 25 m². Air temperature was kept at 23.5±0.5 °C and relative humidity was maintained at a range of 50±5%. Participants wore identically laundered and tumble-dried new sets of clothing and used the same provided fragrance-free personal hygiene products. The key experimental variables included the manipulation of following independent variables: air change rate (2.1 h^{-1},1.3 h^{-1}, 0.5 h^{-1}); physical activity by walking on a treadmill (light, intensive), and stress level (meditative, regular, stressed). Participants were exposed to two ozone conditions each lasting for several hours: 0 and 25 ppb. The samples for MDA analysis included nasal fluid, saliva, skin wipes and exhaled breath condensate. Each experimental set-up was replicated once.

In the chamber, gas phase volatile organic compounds (VOC) were measured online using two chemical ionization mass spectrometers under NO+ and H3O+ mode respectively. Additional gas phase measurements included CO2, O3, NOx, and NH3. The aerosol phase (1-55 nm) was monitored using Nano Condensation Nucleus Counter capturing aerosol nucleation (1-3 nm) in real time, and a Scanning Mobility Particle Sizer. Fluorescent biological aerosol particles were monitored using a Wideband Integrated Bioaerosol Sensor. Active collection of airborne particles onto filters with air pumps was done to facilitate downstream microbiota analyses.

An ongoing data analysis will yield a comprehensive dataset on: 1) indoor air quality that isolates the emissions from people and evaluates the importance of various personal and environmental factors in these emissions, 2) dynamics and fates of human-associated air pollutants and consequent inhalation exposures; 3) improved understanding of how ozone exposures influence human oxidative stress.

Tuesday, 13.06.2023 15:51-15:54 Room C Carbon

Risk Exposure to Particles – including Legionella pneumophila – emitted during Showering with Water-Saving Showers

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ID: 1255 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: Legionella; bioaerosols; risk assessment

The increase in legionellosis incidence in the general population in recent years calls for a better characterization of the sources of infection, such as showering. Water-efficient shower systems that use water atomization technology may emit slightly more inhalable bacteria-sized particles than traditional systems, which may increase the risk of users inhaling contaminants associated with these water droplets.

To evaluate the risk, the number and mass of inhalable water droplets emitted by twelve showerheads—eight using water-atomization technology and four using continuous-flow technology— were monitored in a shower stall. The water-atomizing showers tested not only had lower flow rates, but also larger spray angles, less nozzles, and larger nozzle diameters than those of the continuous-flow showerheads. A difference in the behavior of inhalable water droplets between the two technologies was observed, both unobstructed or in the presence of a mannequin. The evaporation of inhalable water droplets emitted by the water-atomization showers favored a homogenous distribution in the shower stall. In the presence of the mannequin, the number and mass of inhalable droplets increased for the continuous-flow showerheads and decreased for the water-atomization showerheads. The water-atomization showerheads emitted less inhalable water mass than the continuous-flow showerheads did per unit of time; however, they generally emitted a slightly higher number of inhalable droplets—only one model performed as well as the continuous-flow showerheads in this regard.

To specifically assess the aerosolisation rate of bacteria, in particular of the opportunistic water pathogen Legionella pneumophila, during showering controlled experiments were run with one atomization showerhead and one continuous-flow, first inside a glove box, second inside a shower stall. The bioaerosols were sampled with a Coriolis® air sampler and the total number of viable (cultivable and noncultivable) bacteria was determined by flow cytometry and culture. We found that the rate of viable and cultivable Legionella aerosolized from the water jet was similar between the two showerheads: the viable fraction represents 0.02% of the overall bacteria present in water, while the cultivable fraction corresponds to only 0.0005%. The two showerhead models emitted a similar ratio of airborne Legionella viable and cultivable per volume of water used. Similar results were obtained with naturally contaminated hoses tested in shower stall. Therefore, the risk of exposure to Legionella is not expected to increase significantly with the new generation of water-efficient showerheads.

Tuesday, 13.06.2023 15:54-15:57 Room C Carbon

Residential indoor-outdoor PM measurements worldwide published between 1990 and 2019

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US EPA, United States of America

ID: 1263 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: particulate matter, residential, indoor-outdoor, infiltration, indoor sources

INTRODUCTION: Although no systematic record exists for particulate matter (PM) measurements in indoor air comparable to that for ambient air, numerous studies have documented measurements in research projects over many years. Their results offer insights on levels of PM indoors and relationships with outdoor PM levels, for multiple public health applications.

METHODS: We compiled literature on residential indoor PM measurement worldwide published between 1990-2019. Data on PM (all size fractions) measured indoors and, when available with paired outdoor measurements, was extracted, excluding measurements from homes using solid fuels. Lognormal regressions were performed with paired indoor-outdoor sample means, weighted by total sampling time in each study.

RESULTS: Statistics on 965 sets of paired indoor-outdoor measurements were obtained from a subset of 198 studies, representing 1.4 million hours of sampling in 7480 homes. Most regression models showed a significant effect of outdoor PM on indoor concentrations in all size fractions, variable by region. In global models, outdoor air contributed 86% ± 5% of its PM2.5 concentration to indoor air in homes, 63% ± 4% for PM10, 74% ± 15% for $PM^2.5 -10$, 55% ± 4% for PM1, and 79% ± 14% for UFP. Intercepts, approximating indoor source contributions, showed similar values for PM2.5 (2 to 11 μg/m³) in North America and Western Europe, and higher values in East Asia. Explained variance ranged considerably.

CONCLUSIONS: Outdoor air concentrations of PM were consistently a major driver of indoor concentrations, for all regions and size fractions, but insufficient as sole predictors of indoor exposures.

Tuesday, 13.06.2023 15:57-16:00 Room C Carbon

Particulate matter concentration and distribution in occupational settings: case study of Portuguese fire stations

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ID: 1442 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: indoor air, PM, firehouses, exposure

Firefighters are at increased risk for adverse health exposures. Though exposures and the respective impacts due to the fire combats are extremely relevant, large part of the working shifts are within the fire stations, where workers can be on a daily basis exposed to a variety of air pollutants, including particulate matter (PM), i.e., a known carcinogen. Thus this work aimed to assess the levels of particulate matter (PM) and particle size distribution at fire stations and to investigate the possible influencing parameters.

The sampling was conducted in summer 2021 in the north of Portugal at seven fire houses in Bragança district. Particle mass concentrations and size distributions in different functional spaces (rest areas, truck bays, etc.) were monitored using Dustrak™ Aerosol Monitor (model 8532, TSI Inc., Shoreview, USA; N0.3-20) and aerosol spectrometer (model 1.108, GRIMM Aerosol Technik GmbH & Co. KG, Ainring, Germany); the latter with concurrent monitoring of fifteen channels (particles range from 230 nm to 20 um).

The results showed that across all fire houses, indoor PM^2.5 and PM10 means ranged between 6.6 and 13.9 ug/m^3 and from 18.8–36.6 ug/m^3 respectively. These results showed that PM levels were well below the limits set by Portuguese legislation for public spaces (25 and 50 ug/m^3 for PM^2.5 and PM10, respectively; Decreto-Lei 118/2013). In living quarters, the indoor PM presented trimodal particle mass distribution, where particles of 0.230-0.300 um were the dominant of PM1 (4-8% of PM10) whereas size fractions of 2.0-3.0 um (9-15 % of PM10) and 5.0-7.5um (20-29% of PM10) dominated the other two distribution modes. In trucks bays. the observed mean values also fulfilled the legislative thresholds (2.3–7.7 ug/m^3 for PM^2.5, 15.8–26.9 ug/m^3 for PM10). Particles of 0.3-0.5 um constituted 72% of PM1, the contribution of 2.5-5 um fraction was 37% vs. 44 % for particles with diameter of 5-10 um, most likely resulting from resuspend dust.

Whereas all indoor PM concentrations were relatively low, the chronic exposures, even in small quantities, require further assessment to determine the respective health risks. In addition, assessment of and co-exposure to other pollutants in these settings would be precious.

Session 17 Tuesday Silver - Multi-domain environments

Time:
Tuesday, 13.06.2023 15:00-16:15

Room: Ag Silver

Chair:
Bandurski, Karol
Politechnika Poznańska

Co-Chair:
André, Maíra
Federal University of Santa Catarina

Tuesday, 13.06.2023 15:00-15:15 Room Ag Silver

Does the outside view affect the thermal perception? A preliminary study.

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Technical University of Denmark, Department of Environmental and Ressource Engineering, Denmark

ID: 1245 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: thermal assessment, visual assessment, window view, living lab.

While knowledge of thermal and visual interactions brings valuable information to create better indoor environments, available findings indicate the need for further research, especially in naturally lit indoor environments. This study, part of an extensive and ongoing experimental campaign, aims to explore whether different outside views affect thermal perception. The experiments are being conducted in two temperature-controlled standard office rooms equipped with instruments to measure air and globe temperature, air velocity, relative humidity, vertical and horizontal illuminance, correlated color temperature and light spectral composition, and CO2 concentration. The rooms are lit naturally with no use of artificial light sources. In a mixed design, 48 participants (50% females) are divided into eight blocks, each with 6 participants. Each subject is exposed to two urban window views. Half of the subjects are exposed to a cool temperature (19 °C) and the other half to a warm temperature (30 °C). Therefore, the within-subjects factor is the window view, while the between-subjects factor is the indoor temperature. For the whole experiment, the order of exposition was balanced. During the experimental sessions, subjects will complete paper-based questionnaires and performance tests. Analyses will include descriptive statistics and statistical modeling considering indoor environmental parameters (e.g., temperature and view out) as predictors and subjective responses (thermal and visual sensation, preference, comfort, and acceptability) as outcomes. The experiments are ongoing and are expected to be finished in mid-November. We expect to understand better the interaction between visual and thermal domains. The resulting knowledge will be meaningful in two dimensions. First, it will highlight urban design's impact on indoor environmental quality and contribute to its better design to promote occupants' wellbeing. Second, it will contribute to the discussion about integrating standards that address environmental domains separately.

Tuesday, 13.06.2023 15:15-15:30 Room Ag Silver

A critical appraisal of recent research in multi-domain indoor-environmental exposure.

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1: TU Graz, Austria; 2: Aalborg University, Denmark

ID: 1172 Full paper
Topics: 08. Psychology, psychophysics, performance & productivity
Keywords: Indoor environmental quality, multi-domain exposure, building desing and operation

The insufficient availability of evidence-based guidance in practical treatment of multi-domain exposure situations in indoor environments has motivated multiple efforts to conceive and conduct studies on the combined effects of multiple factors on occupants' perception and evaluation of indoor-environmental quality. However, the research strategies that are being currently considered and in part implemented for this purpose may be subject to certain simplifications and misconceptions that would limit their ultimate conclusiveness and utility. The present discussion intends to highlight a number of such issues and encourage thus efforts toward a more robust framework for conducting research and developing standards regarding multi-domain exposure patterns in indoor environments and their implications for occupants' health and comfort.

Tuesday, 13.06.2023 15:30-15:45 Room Ag Silver

Multi-domain sensor's location and frequency of measurements: a preliminary investigation for living laboratory developments

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ID: 1177 Full paper
Topics: 11. All other IEQ, ergonomics & health topics
Keywords: Indoor environmental quality, multi-domain, sensors, measurement quality, sensor location

Living laboratories are emerging as a new paradigm for studying human-building interactions beyond traditional laboratory and field studies. Living laboratories allow the measurement of several indoor environmental quality (IEQ) conditions simultaneously. To this end, sensors able to measure multiple IEQ conditions simultaneously, such as visual, thermal, acoustic, and air quality (i.e., multi-domain sensors), can be used. When installing and setting up multi-domain sensors in buildings, their location and frequency of measurements must be carefully chosen to gather the conditions that better represent the ones experienced by the occupants. This information is rarely detailed in experimental studies, and only general guidelines have been published for single-domain instrumentation. To fill this gap, this study investigates the influence of the location and frequency of measurements on the environmental measures of multi-domain sensors. The experiment, run in single and shared offices, involves the measurement of various IEQ conditions with commercial-grade devices. Results show small variations across the selected locations around the occupant, except for illuminance measurements. The results can be used by researchers interested in setting up a living laboratory or by building professionals, property owners, or building occupants interested in monitoring the buildings they design, manage, own, or occupy.

Tuesday, 13.06.2023 15:45-15:48 Room Ag Silver

An international Round Robin Test in test rooms: an opportunity to move forward together to understand in detail human environmental perception

Pigliautile, Ilaria (1); Jacoby Cureau, Roberta (2); Martins Gnecco, Veronica (2); Barna, Edit (3); Belussi, Lorenzo (4); Chinazzo, Giorgia (5); Danza, Ludovico (4); Deme Belafi, Zsofi (3); Deng, Zhipeng (6); Dong, Bing (6); Karimian, Hamidreza (7); Vince

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ID: 1201 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: Round Robin test, test room, multi-domain comfort, contextual, Hue-Heat Hypothesis

Test room experiments allow to study human-building interactions under controlled environmental boundaries. Differences in experimental design, methods, and contextual variables specific to the location and test room features, result in experimental outcomes that are difficult to generalize and compare. This paper presents an international Round Robin Test activity consisting in the replication of the same procedure in different test rooms worldwide to capture contextual variables effects on human-centric studies and to deepen multi-domain human comfort topics. The campaign focused on the hue-heat hypothesis and investigated the effect of coloured electric-light on human thermal responses (both perceptual and

physiological) with the aim of (i) analysing the existence of cross-effects between visual and thermal comfort domains and (ii) correlating physiological signals variations to different testing conditions. Overall, 76 subjects were involved in four laboratories during a summer campaign. Each subject was exposed to a controlled and fixed thermal environment while varying three lighting conditions throughout a single test. No significant crossed effects were verified. The same procedure will be repeated in winter to account for seasonal variability and identify new research questions in the framework of this promising cooperation that will be extended to a broader network of facilities.

Tuesday, 13.06.2023 15:48-15:51 Room Ag Silver

Correlated color temperature of light: Cross-modal effects on thermal comfort in cold conditions

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1: Department of Nutrition and Movement Sciences, Maastricht University; 2: Department of the Built Environment, Eindhoven University of Technology; 3: Department of Industrial Engineering and Innovation Sciences, Eindhoven University of Technology

ID: 1141 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: thermal comfort, thermal sensation, hue-heat hypothesis, correlated color temperature

Background: The effects of the correlated color temperature (CCT) of light on thermal sensation and comfort have been tested repeatedly over the last few decades. Based on the hue-heat hypothesis, it is often assumed that yellowish light (low CCT) induces a warmer temperature sensation than bluish light (high CCT) does, and therefore, a low CCT is expected to improve thermal comfort in thermally cold conditions compared to high CCT. However, results are rather inconsistent and most previous studies only focused on short-term effects (<1 hour).

Method: The current study investigated, with a relatively long exposure (>2 hours), the effects of CCT on thermal comfort in mild cold conditions (17˚C). Sixteen participants (8 males and 8 females) completed two CCT scenarios during daytime in an office-like setting: 2700 K vs. 5700 K and 500 lux at the eye. Thermal perceptions and thermophysiological parameters were measured repeatedly.

Results: In contrast to the hue-heat hypothesis, thermal sensation was, on average, unaffected by CCT in mild cold conditions. Interestingly though, thermal comfort was increased by high CCT (5700 K) while perceived shivering (an indication of muscle tension) was decreased. Most physiological parameters (mean skin temperature, skin blood flow, heart rate measures, physical activity and substrate oxidations) were not significantly affected by CCT, but energy expenditure increased after a one-hour exposure to 5700 K and the average diastolic blood pressure was lower in 5700 K

throughout the 2 hours. A correlational analysis indicated that thermal comfort was negatively associated with perceived shivering.

Discussion: Together, the results did not support the hue-heat hypothesis. In contrast, with a relatively long exposure duration, the higher CCT improved thermal comfort in mild cold conditions, possibly via decreasing perceived shivering and/or eliciting some changes related to decreased perceived shivering.

Tuesday, 13.06.2023 15:51-15:54 Room Ag Silver

Challenges and Solutions to Integrated Workflows for Multidomain Simulations assessed through a Teaching Experiment

Lorenz, Clara-Larissa (1); Schweiker, Marcel (2); Frisch, Jérôme (1); van Treeck, Christoph (1)

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ID: 1257 Extended Abstract
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views, 05. Architecture, aesthetics, passive design, biophilia
Keywords: Multidomain simulation, Building performance, Daylight performance, Energy performance, Design challenges, Information exchange, Integrated design, Interoperability

Striving towards health-promoting and sustainable buildings, building performance can be assessed using a wide array of performance metrices, including daylight performance and metrics related to occupant comfort and wellbeing, building energy consumption, or the global warming potential. Depending on which performance metric is used to support design decision making, the design outcome may greatly vary. The challenges to evaluating compromises between performance metrices may further be heightened by design constraints relating to the location and orientation of the building, as well as acoustic and aesthetic requirements. Additionally, the efficiency of the feedback loop from simulations to the design process is largely dependent on solving technological barriers including interoperability, computational power, and integration with tools that facilitate design exploration. Thus, simulation-based approaches may benefit from integrated design workflows that feed from information exchange between project participants.

This proposed extended abstract aims to discuss approaches and challenges to multidomain simulation workflows. The basis for the discussion will be design examples and results from a questionnaire accompanying and retrospectively assessing the work of multi-disciplinary student groups asked to integrate multi-domain considerations across the design process. This basis enables a discussion from 1) a simulation-based and performance-measure-orientated standpoint, 2) a technological standpoint, and 3) an integrated-workflow-oriented standpoint. The last point, in particular, will be a focal point of the discussion in regard to the potential of transdisciplinary communication in design workflows for solution finding. This will add another layer to ongoing discussions on multidomain simulation workflows in terms of the requirement for interdisciplinary communication and responsibility distribution.

Session 18 Tuesday Oxygen - Soundscape, acoustics & noise

Time:
Tuesday, 13.06.2023 15:00-16:15

Room: O2 Oxygen

Chair:
Fels, Janina
RWTH Aachen University

Co-Chair:
Hamida, Amneh
Delft University of Technology

Tuesday, 13.06.2023 15:00-15:15 Room O2 Oxygen

Students' experiences of the sound environment at their home study places

Hamida, Amneh; Eijkelenboom, Annemarie; Bluyssen, Philomena M.

Chair Indoor Environment, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands

ID: 1298 Extended Abstract
Topics: 04. Noise, acoustics, and soundscape control
Keywords: Indoor environmental quality (IEQ); sound environment; study places; sound perception; sound sources; students

Students are exposed to various environmental stimuli at their home study places. However, different students have different preferences in terms of indoor environmental quality (IEQ) aspects and psychosocial aspects of those study places. Moreover, different students are different pertaining to their sound environment experiences at their home study places. A previous study on students' preferences of their study places, resulted in nine profiles based on their IEQ and psychosocial preferences This present study aims at exploring how different students with different profiles experience the sound environment of their study places. To achieve this aim, a mixed method approach applied including in-depth interviews with students (bachelor's students at the Faculty of Architecture and the Built Environment, TU Delft) as well as sound level measurements of the sound environment at students' home study places. The in-depth interviews include opening questions about the student's motivations for choosing a specific place as a study place, the student's study-related activities in study places, and the main tools and technologies that the student has/uses at the study place. Also, the in-depth interview includes key questions that aim at exploring in depth how the student experiences the sound environment in terms of the kind of sound sources that the student is exposed to chronically, the student's perception of these sounds, and sounds that support the student while studying, the effect of sounds on student's health, and student's coping methods for the sounds perceived as unpleasant in their study places. Furthermore, there are a couple of closing questions that are pertaining to what the student would change in the study place to have an optimal sound environment. This study reports on a pilot test performed to develop this mixed method approach.

Tuesday, 13.06.2023 15:15-15:30 Room O2 Oxygen

Play me a river: Can nature sounds during microbreaks improve attention restoration and stress recovery in office environments?

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ID: 1254 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia, 08. Psychology, psychophysics, performance & productivity
Keywords: nature sounds, micobreaks, attention recovery, stress recovery, performance

Increasing digitization and urbanization has led people to spend more and more time inside buildings and, potentially, lose touch with nature. From the perspective of work efficiency, this may be problematic because nature stimuli are assumed to benefit cognitive performance and lower stress. Possible solutions could include enhancing indoor work environments with nature stimuli in terms of visual, auditory, and olfactory architectural or room interior elements. The goal of this study was to assess whether an exposure to nature sounds during microbreaks can improve attention restoration and stress recovery compared to exposure to office noise or silence. We conducted a laboratory experiment (n = 75) with a 3x2 mixed-factorial design, including the between-subject factor sound condition (office noise, silence, and nature sounds; the latter consisting of water sound and bird chirps) and the within-subject factor time of measurement (i.e., pre-break and post-break). Sounds were presented to the participants via headphones at 55 dB LAeq. The experiment began with a 15 min cognitive working phase (stress phase) while being exposed to office noise. Afterward, there was a 40 min testing phase in which participants performed an (also strenuous) attention task in office noise. The testing phase was interrupted by a 6 min microbreak, presented in one of the three sound conditions (office noise, silence, nature sounds). During the microbreak, participants' task was to simply relax and listen, before they performed the attention task again. Subjective assessments of attention restoration and stress recovery were collected just before the microbreak and at the very end of the attention task. Data analysis is still in progress but will soon be finished. We expect that exposure to nature sounds during microbreaks will significantly improve attention restoration and stress recovery compared to office noise and, perhaps, also to silence.

These results will provide insights on whether auditory exposure to nature stimuli can contribute to a more pleasant and healthier work environment.

Tuesday, 13.06.2023 15:30-15:45 Room O2 Oxygen

Soundscape Assessment at a University Campus in Detmold, Germany

Balderrama, Alvaro (1,2); Erol, Aylin (3); Götz, Johanna (4); Luna-Navarro, Alessandra (1); Kang, Jian (5); Arztmann, Daniel (2); Knaack, Ulrich (1)

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ID: 1466 Full paper
Topics: 04. Noise, acoustics, and soundscape control, 05. Architecture, aesthetics, passive design, biophilia
Keywords: Soundscape, soundwalk, acoustic environment, context, perception, ISO 12913

People in cities are often exposed to complex mixtures of sounds, some originating from nature along with some created by human activities like traffic noise, sounds of industrial machinery, or music. This research aimed to study how the acoustic environment of a university campus is perceived by people. The procedures for soundscape data collection and analysis were based on the ISO 12913 series. 30 volunteers divided into four groups participated in a “soundwalk” at the campus of the architecture school in Detmold, Germany, filling out questionnaires while sound measurements and recordings were being taken. After the soundwalk, the data from the questionnaires, sound measurements, recordings, pictures and videos were analyzed. The findings suggest that people’s perception of sound is susceptible to the context, as participants seemed to shift their preference according to the ongoing activities that drew attention, such as a construction site, sounds from children playing, music and groups of people. The results provide new evidence and insights about the acoustic environment and the soundscape of the university campus and can inform stakeholders to improve environmental quality.

Tuesday, 13.06.2023 15:45-16:00 Room O2 Oxygen

Indoor soundscape in classrooms: a case study

Pellegatti, Matteo (1,2); Visentin, Chiara (1); Torresin, Simone (2); Prodi, Nicola (1)

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ID: 1189 Extended Abstract
Topics: 04. Noise, acoustics, and soundscape control
Keywords: Soundscape, Indoor Soundscape, Schools, Classroom acoustics

Soundscape research has recently been applied in enclosed built environments to characterise and design living and working spaces from a perceptual point of view. In this context, the types of sounds that make up the acoustic environment seem to be foundational in shaping the acoustic quality of a place and determining people's affective response to it. While traditionally research on classroom acoustics has focused on the impacts of "noise" on students' and teachers' performance, research is called on the investigation of a potential role of wanted "sounds" in fostering positive emotions that may in turn lead to positive cognitive outcomes. To do this, however, it is essential to know what factors might impact soundscape assessments and which sound stimuli are favoured by students.

Drawing on soundscape research, a survey was designed and conducted to investigate real and ideal classroom soundscapes. Two hundred and forty students (grades III to VII) from five different schools in Ferrara (Italy) participated in the study. The schools were chosen to represent three different urban contexts. One school was in the town centre in a noisy area, two schools were in quieter town areas, and the remaining two were in the outskirts. The real soundscape was evaluated by rating the intensity, pleasantness and arousal of the classroom sound environment, as well as the frequency and pleasantness of specific types of sound (e.g., traffic noise, classroom chatter). As for the ideal classroom soundscape, pupils were asked to rate how frequently they would like to hear specific sounds during their schooldays. A nine-point self-assessment manikin scale (SAM) was used for all the evaluations. Furthermore, the children were asked to self-rate their noise sensitivity through the Weinstein Noise Sensitivity Scale. Finally, the acoustic parameters of the classroom (background noise levels and reverberation time) were measured in unoccupied conditions.

Data analyses provided insight on pupils' perception of the classroom sound environment (most frequent and pleasant sounds) and informed on the most desired sounds.

Moreover, two regression models were built to explore how pleasantness and arousal of the classroom soundscape are affected by the classroom acoustic parameters, the individual characteristics (school grade, noise sensitivity, gender), the rate of the intensity of the soundscapes, and the frequency with which specific sounds are heard.

Results will be useful to inform future research investigating the role of positive sounds (e.g., natural sounds from green urban areas) on student learning performance.

Tuesday, 13.06.2023 16:00-16:03 Room O2 Oxygen

Impact of ventilation-related sounds in classrooms: a review

Pellegatti, Matteo (1,2); Torresin, Simone (2); Visentin, Chiara (1); Babich, Franceso (2); Prodi, Nicola (1)

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ID: 1204 Extended Abstract
Topics: 04. Noise, acoustics, and soundscape control
Keywords: Sound, Ventilation, Student, Learning, Comfort

During the Covid 19 pandemic, particular attention was paid to the improvement of ventilation in enclosed spaces to prevent the spread of the virus. In the case of schools, guidelines suggested increasing the air change per hour. The adopted strategies were mainly twofold: either increasing the window opening time in naturally ventilated buildings or the external air flow rates for mechanically ventilated ones. Both solutions revealed not only effective against the spread of the virus but also in reducing CO2 concentration.

Since high CO2 rates impact students' learning, it is mandatory to ensure an adequate air change rate; however, this may lead students to a higher exposure of louder and more frequent sound events which in turn may affect learning and comfort.

In order to clarify how sound events related to natural and mechanical ventilation might affect speech perception, performance, and comfort of students in classrooms, a literature review was accomplished. Concerning mechanical ventilation, aeraulic noise was considered while, with regard to natural ventilation, natural sounds (e.g., bird songs and water sounds), traffic noise (e.g., aircraft, road, railway noise), construction and anthropic noise were included. Only studies dealing with field campaigns inside classrooms or similarly equipped laboratories were considered. Comfort studies were deemed eligible when investigating the assessment of pleasantness, annoyance, and disturbance or the overall acoustic comfort.

The most commonly employed tasks to evaluate students' performances were literacy and mathematical ones, as well as attention and memory ones. While much of the literature so far has focused on the negative impact of 'noise' on students, research is missing on the potential positive effect of 'sounds' that can be transmitted into the school environment through opening windows in the presence of a high-quality urban environment.

The results of the present review assessment will be helpful to better understand the effect of sounds related to natural and mechanical ventilation on students' comfort and learning as well as to motivate new research on the negative and positive impacts of ventilation strategies and rates on the classroom soundscape.

Session 24 Tuesday Carbon - Indicators, weighting, schemes & standards

Time:
Tuesday, 13.06.2023 16:45-18:15

Room: C Carbon

Chair:
Seduikyte, Lina
KTU

Co-Chair:
Olesen, Bjarne Wilkens
Intl. Center for Indoor Environment and Energy, Technical University of Denmark

Tuesday, 13.06.2023 16:45-17:00 Room C Carbon

Whole building algorithm for indoor air quality classification based on measured CO2 data

Aljas, Hans Kristjan; Parts, Tuule Mall; Thalfeldt, Martin

TalTech, Estonia

ID: 1431 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: indoor climate class, EN 16798-1:2019, indoor air quality, monitoring, algorithms

This study presents a practical method for assessing a building's indoor climate quality based on CO2 data. Poor indoor climate quality can have negative effects on productivity and increases the risk of airborne diseases. The method pre-processes, combines, and classifies measured CO2 data to output a single indoor climate class (IDCC) for the whole building or each room separately. The IDCC can be used to evaluate a building's HVAC system performance and identify buildings in need of auditing or renovation. The method is based on European guidelines, but additional computational specifications and data pre-processing algorithms were employed, including data repair, CO2 baseline correction, and occupancy detection. The method was evaluated on CO2 data from 56 zones of a renovated school building. The study found that poorly estimated occupancy times could lead to overly optimistic IDCC classification. The CO2 baseline correction algorithm demonstrated potential to raise or lower a single zone's IDCC. A minimum data availability requirement was proposed for weekly or monthly calculation subgroups with limited data to avoid disproportionate effects on the yearly IDCC. Occupant feedback should be used to validate the choice of classification criteria and the calculated IDCC's, and further analysis for thermal comfort is necessary.

Tuesday, 13.06.2023 17:00-17:15 Room C Carbon

Integration of Human Comfort Indicators in a Holistic Framework of Next-Generation Energy Performance Certificates

Seduikyte, Lina (1); Kalamaris, Thanos (2); Morsink-Georgali, Phoebe-Zoe (3); Konatzii, Panagiota (3); Chatzipanagiotidou, Panagiota (4); Katsaros, Nikolaos (4); Stavros, Koltsios (4); Ioannidis, Dimosthenis (4); Stasiulienė, Laura (1); Spūdys, Paulius (1

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ID: 1112 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: EPC, human comfort, KPIs, IAQ, thermal comfort, CO2, D^2EPC

The building sector constitutes the major energy-intensive domain, with 40% of Europe’s final energy demand. Indoor environmental conditions play a major role in the quality of life, yet the quality assessment is not well-known to the general public. Recent developments in the Internet of Things domain can help in the evaluation of indoor conditions and lead the building sector into the Industry 4.0 era. Moreover, the introduction of new key performance indicators can raise the awareness of relevant stakeholders and lead to more energy-efficient homes providing enhanced human comfort conditions. This study aimed to identify human comfort and well-being key performance indicators which could be included in the next-generation energy performance certificates and extract insights on the occupants’ comfort in the two pilot buildings with the minimum available information via a non-intrusive (to the occupants) procedure. The proposed set of human comfort and well-being indicators deals with the aspects of thermal comfort, visual comfort and indoor air quality. Only quantitative key performance indicators were considered within the study, as their calculation is based on acquired data from the pilots’; the internet of things infrastructure.

Tuesday, 13.06.2023 17:15-17:30 Room C Carbon

Impact of different indoor environmental weighting schemes on office architectural design decisions in different climates

Fathi, Arefeh Sadat; O'Brien, William

Carleton University, Canada

ID: 1217 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia
Keywords: Indoor environmental quality, weighting schemes, Building design elements, Parametric modeling

Increasing time spent indoors has resulted in a growing focus on improving indoor environmental quality (IEQ) at the early design stage. One of the challenges for the designer at this level is to prioritize IEQ components namely thermal comfort, visual comfort, acoustic comfort, and air quality, to make a holistic evaluation. There are lots of studies and certification schemes that suggest different weights for IEQ. However, the existing evidence still does not provide clear guidance on how to choose the proper weight when the information is limited. This study analyses the effect of different weighting schemes on commercial building design elements to have high overall comfort. To achieve this goal, first, existing IEQ weighting schemes are summarized and compared. Then, parametric modeling is developed to quantify IEQ domains with several design parameters that influenced IEQ criteria in various climate regions. Next, the different weighting schemes are applied and the aggregated score for indoor comfort is generated. Finally, the optimal designs according to each scheme were identified and compared. The results indicate the weighting scheme effect on selected high-performance designs is not considerable even in different climates, and the more important decision is to consider all four domains of comfort simultaneously.

Tuesday, 13.06.2023 17:30-17:33 Room C Carbon

In search of a blueprint for indoor-environmental quality standards

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1: Aalborg University, Denmark; 2: TU Graz, Austria

ID: 1241 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: Indoor-environmental quality, standards, building design and operation

Starting from a critical assessment of common indoor-environmental quality (IEQ) standards, this paper explores strategies that could improve their effectiveness and consistency. Thereby, it is assumed that IEQ standards should ideally display five key attributes, namely sound scientific basis, practical relevance for the stakeholders, compliance guidance provision, general usability, and developmental transparency. The study of common IEQ standards reveals a considerable level of diversity in terms of structure, character, and content. This highlights the need for a more harmonized approach to and a well-formed structural blueprint for the formulation of more effective and usable IEQ standards. The paper entails reflections on some of the necessary conditions for the development of such a blueprint.

Tuesday, 13.06.2023 17:33-17:36 Room C Carbon

Heat Stress Indicators in Certification Schemes for the Built Environment

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ID: 1478 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: overheating, heat stress, indoor environmental quality, building certification schemes, resilience

Overheating issues in buildings have gained increased attention due to the growing frequency and severity of extreme weather events across the world due to climate change. Thus, there is a need for buildings to become resilient, being able to protect occupants from heat stress caused by heatwaves and power outages that could follow. Nowadays a variety of heat stress indicators are used to evaluate heat strain on people. This critical review study presents the comparison of different international building certification schemes with regards to their indoor heat stress indicators and assessment criteria. Six certifications are included, namely WELL, LEED, BREEAM, DGNB, RELi and HQM. The comparison concerns the relation between the indoor thermal comfort indices and the heat stress indices, and the implementation of different indicators including feasible scenarios and limits. These heat stress indicators were implemented to compare in the existing measurement data. In conclusion, LEED and RELi demonstrated the most comprehensive considerations of indoor heat stress evaluations among these certifications. An analysis on the acquired indicators on the extracted indoor environmental data of a naturally ventilated building showed that the potential of heat stress risks increased when PMV was over 1.

Tuesday, 13.06.2023 17:36-17:39 Room C Carbon

Indoor air quality indices confronted to sensors measurement from field campaign

Miranda, Luiz (1,4); Duc, Caroline (1); Umba, David (1); Verriele, Marie (1); Crunaire, Sabine (1); Dorizzi, Bernadette (2); Boudy, Jérôme (2); Montalvão, Jugurta (3); Redon, Nathalie (1)

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ID: 1157 Extended Abstract
Topics: 07. Occupant behavior & controls, 09. Public health, occupational & environmental health
Keywords: Indoor air quality index, sensors, AQI, TAIL, CERBAIR

We don't have a universal indoor air quality (IAQ) index. But should we have one? According to some researchers, a uniformly accepted and publicly accessible IAQ index is not only unhelpful but also impossible to implement. The various national legislation or guidelines from different regions towards air pollutants, the lack of political interest and the difficulty of taking all the key pollutants into consideration are the main reasons. Despite this pessimistic view, the Air Quality Index (AQI) developed by the USA in 1999, for ambient air quality, is used by some of the largest countries in the world by making just a few adjustments, such as adding relevant pollutants or changing the considered exposure time to specific pollutants, to fit their needs. This index is often the one chosen as the IAQ indicex in many studies, especially the ones using miniaturized gas sensors. Is this the closest we have to a universal indoor air quality index? After all, it is a versatile index that requires few adaptations to provide a qualitative indication of IAQ. Maybe, but how does it perform when compared to others IAQ indices? To answer this question, AQI is applied, along with four others IAQ indices (a modified version of AQI, BILGA, TAIL and CERBAIR), to a dataset collected from a field campaign of IAQ assessment in French residences. The dataset contains data from three different homes collected using three sensor modules with the same configuration. Modules are previously metrologically qualified in laboratory. Because some of the indices tested consider just a few pollutants, only CO2, TVOC and PM².5 were considered for this comparison. The indices that required insertion of threshold values for their pollutants, such as the AQI itself, had these values extracted from French guidelines, when available, and from WHO guidelines, when not. The outputs from the IAQ indices were truncated into three regions referent to good, moderate and bad air quality, to allow for a comparison as fair as possible between the indices. As for parameters to evaluate the comparison, the selected ones were: (i) percentage of time in each level of air quality, (ii) most influential pollutant for each index and (iii) the histogram of the measurements compared to the indices' thresholds. Results show similar behaviors between most of the IAQ indices tested, including AQI, indicating that, although adapted from the ambient air quality, it is a promising index for IAQ.

Tuesday, 13.06.2023 17:39-17:42 Room C Carbon

The need for occupant-related and building-related indicators next to dose-related indicators in our guidelines for indoor environmental quality

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ID: 1240 Extended Abstract
Topics: 07. Occupant behavior & controls, 09. Public health, occupational & environmental health
Keywords: Indoor environmental quality, new guidelines, new indicators

Research has shown that, even though the indoor environmental conditions seem to comply with current guidelines and those conditions seem ‘comfortable’ enough, staying indoors is not good for our health. Reasons for this discrepancy might be the fact that these guidelines are based on single-dose response relationships to prevent negative effects, and that the criteria are determined for an average adult person, ignoring interactions occurring between stressors at human as well as environmental level. The fact that we are dealing with individuals in different scenarios (e.g. homes, offices, schools) and situations (e.g. sitting behind a desk, listening to the teacher, cooking, sleeping,) is ignored.

Session 19 Tuesday Silver - Air filtration & IAQ

Time:
Tuesday, 13.06.2023 16:45-18:15

Room: Ag Silver

Chair:
RAILLARD, Cécile
Nantes Université / IMT Atlantique /GEPEA UMR CNRS 6144

Co-Chair:
Mattsson, Johan
cTrap Ltd.

Tuesday, 13.06.2023 16:45-17:00 Room Ag Silver

INGENIOUS: Understanding the sources, tranformations and fates of indoor air pollutants

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ID: 1344 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: INCHEM-Py, Modelling, Emissions, Cooking, Cleaning

The INGENIOUS project is the first comprehensive mapping exercise of the main sources, transformations and fate of air pollutants in typical UK residences. Building on an extensive cohort study, "Born in Bradford", the project aims to use measurement and modelling in both laboratory and real home settings to fully analyse human exposure to indoor air pollutants; identify consequent health impacts in diverse populations; discover the social and behavioural factors that control pollutant distribution; and to design novel amelioration strategies and interventions.

Presented here are the initial stages of this project in which experimental measurements of complex emissions from typical polluting activities indoors, such as cooking and cleaning, were measured in a controlled laboratory chamber. Using INCHEM-Py (the INdoor CHEMical model in Python) these measured values were analysed to distinguish if a pollutant, such as formaldehyde, was directly created from the activity as a primary pollutant, or as a secondary pollutant resulting from reactions of terpenes with ozone. The pathways from primary to secondary pollutants have been identified and mapped through INCHEM-Py to show the important routes and intermediary species depending on the temporal variation of emissions. For example, during a cooking event the aldehyde emissions peak while warming oil and adding spices increases terpenes. As these species are produced at different times and in different quantities they effect the radical budget at different rates. Therefore these interations change which reaction pathways are dominant at different times.

Emission rates of primary pollutants were calculated from the measured results allowing activity chemical emission profiles to be input into the INCHEM-Py model with varying model parameters, such as air exchange and photolysis. Important parameters have been identified giving clear direction for potential intervention methods.

Tuesday, 13.06.2023 17:00-17:15 Room Ag Silver

Performance Assessment of Nanofiber Air Filters Modified with Optimal Metal-Organic Framework Loading for Indoor Air Quality Control

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ID: 1226 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor air quality, metal-organic frameworks, particulate matter, electrospinning, filtration efficiency

Metal-organic frameworks (MOFs) have become a commonly used additive in electrospun nanofiber filters for improving particle filtration efficiency. This study hypothesized that there is an optimal number of MOFs that can be integrated into electrospun nanofiber filters to achieve maximum particle removal efficiency while minimizing the corresponding MOF synthesis time. To test the hypothesis, this study systematically explored the influence of the time-dependent in-situ growing process of zeolitic imidazolate framework-67 (ZIF-67), a typical type of MOF, on the filtration performance of polyacrylonitrile (PAN) electrospun nanofibers. The results show that the surface morphology and chemical composition of the PAN/ZIF-67 hybrid nanofiber filters gradually changed with the reaction time. For PAN/ZIF-67 hybrid nanofiber filters with relatively low initial PM0.3-0.4 filtration efficiency, a reaction time of only 5 min was sufficient for the synthesis of the amount of ZIF-67 that maximized the PM0.3-0.4 filtration efficiency. However, for thick filters with high original PM0.3-0.4 filtration efficiency (> 90%), the integration of ZIF-67 is not necessary, because the efficiency enhancement would not be significant. In addition, the enhancement of filtration efficiency for ultrafine particles was positively correlated with the amount of incorporated ZIF-67. In summary, this study shortened the synthesis time of the in-situ incorporation of MOFs into electrospun nanofiber filters from over 10 hours (reported in the literature) to only 5 min.

Tuesday, 13.06.2023 17:15-17:30 Room Ag Silver

Advanced prediction of the vapor pressure of volatile and semi-volatile organic compounds using quantum chemistry

Salthammer, Tunga (1); Stahn, Marcel (2); Grimme, Stefan (2); Hohm, Uwe (3); Palm, Wolf-Ulrich (4)

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ID: 1145 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: vapor pressure, quantum chemistry, conformers, SVOCs, QSAR

The vapor pressure is a specific and temperature-dependent parameter that describes the volatility of a substance and thus its driving force for evaporation or sublimation into the gas phase. In environmental sciences the vapor pressure of a liquid or a sub-cooled liquid is a fundamental molecular property for calculating the partitioning and the dynamics of organic pollutants in aerosols.

Depending on the magnitude of the vapor pressure, there are different methods for its experimental determination. However, these are usually associated with a corresponding amount of effort and become less accurate as the vapor pressure decreases. Therefore, algorithms were developed that are usually based on quantitative structure-activity relationships (QSAR). The quantum mechanical (QM) approach presented here follows an alternative, much less empirical strategy, where the change in Gibbs free energy for the transition from the condensed to the gas phase is obtained from conformer ensembles computed for each phase separately. The results of this automatic, so-called CRENSO workflow are compared with experimentally reliably determined vapor pressures for a large set of environmentally relevant compounds. In addition, comparisons are made with the single structure-based COSMO-RS QM approach, linear-free-energy relationships (LFER) as well as results from the SPARC program. We show that our workflow is superior to conventional prediction models and provides reliable vapor pressures for liquids and sub-cooled liquids over a wide vapor pressure range. The improvement is due in particular to the fact that each molecule is calculated individually, while the results of QSAR and LFER calculations depend significantly on the calibration compounds.

Our work focuses on flexible organic compounds with low vapor pressures, for which both the theoretical methodology and the data are currently insufficient. After setting a baseline by comparing our computationally obtained values to reliable reference data from the literature, we also investigate newly emerging, environmentally relevant compounds like plasticizers, biocides and pharmaceuticals, for which no reliable vapor pressure data are available.

Tuesday, 13.06.2023 17:30-17:45 Room Ag Silver

Indoor CO2 Direct Air Capture (iCO2 DAC): indoor air pollutants as renewable carbon source

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ID: 1121 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Indoor air quality, CO2 capture, renewable energy, biofuels, microbial electrosynthesis technologies

This work aims to assess the coupling of CO2-DAC and microbial electrosynthesis technologies to produce carbon-neutral commodity chemicals. Specifically, this study simulated the installation of CO2-DAC technologies in three different scenarios: (i) high school classroom, (ii) office room, and (iii) underground transport cabin. For each scenario, MES cells were designed based on the state-of-art performance parameters reported in the literature for converting CO2 to either methane or ethanol). The produced biofuels were compared as green fuels for heating the environments, assuming an external temperature of 10 ºC and a target temperature of 20 ºC. An economic analysis was carried out based on the current market price of electric energy to assess the feasibility of this visionary technology. Methane prevailed as the most viable solution, resulting in a substantially lower reactor footprint and power consumption than those calculated for CO2 conversion to ethanol. It was estimated that the methane produced can be used for heating the indoors at an electricity cost of 4.1-6.1 €/d per room, which is considerably lower if compared to the non-household EU average electricity cost of 180 €/MWh

Tuesday, 13.06.2023 17:45-17:48 Room Ag Silver

Simulation models for material emissions and indoor air quality

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ID: 1128 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: Chamber tests, model rooms, airborne pollutants, interdependencies, modelling

The relevance of material emissions indoors is considered by testing protocols regarding the health-related assessment of building product emissions. Corresponding tests provide important information on the type and concentration of released compounds and are therefore a substantial basis for decision-making. However, they do not allow any estimation of the indoor air quality to be expected in real built environments. Even though the EN 16516 specifies a reference room with a defined emission scenario, it is highlighted that this room serves just as a model and does not represent a real indoor environment. Thus, there is a need to obtain further knowledge concerning the relationship between material emissions and resulting indoor air quality in order to contribute to a stronger emphasis of health protection in planning processes.

Within a three-years-research project, materials for flooring, ceiling and inner and outer wall constructions applied in real German buildings have been subjected to emission testing as i) single materials, ii) composite materials, iii) model rooms. The measurements were performed according to the German AgBB evaluation scheme (AgBB, 2021). Active air sampling was performed to cover a large spectrum of (very) volatile organic compounds (VVOCs/VOCs) by using different analytical techniques.

In order to answer the question whether indoor air quality in real indoor environments can be simulated using emission test results, a new simulation model based on simplified mass transfer model with semi-empirical approach is being developed. The model is designed to be suitable for routine operations that can be easily validated, and adjust parameters according to measured data. In the first step, the empirical model is applied to each single material to capture the best-fit parameters in the emission decay simulation. In a second step, the model is transferred to composite materials and subsequently applied to model rooms. Emission characteristics will be summarized by material type and substance group.

This research project will provide a valuable contribution to the understanding of real IAQ and important influencing factors by closing the knowledge gap regarding the relationship of material emissions and resulting indoor air quality. The results will be therefore of high importance for the scientific community and researchers, but also for planners, architects and all persons involved and responsible for construction projects.

Tuesday, 13.06.2023 17:48-17:51 Room Ag Silver

Direct Air Capturing in the Built Environment

Nehr, Sascha; Baus, Lukas

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ID: 1132 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Direct Air Capturing, Indoor Air Quality, energy-efficient ventilation, CO2-separation, HVAC

This study presents an approach for resolving the trade-off between energy-efficient building operation and the provision of hygienically harmless indoor air quality. A novel coupling of HVAC-systems (heating, ventilation and air conditioning systems) with DAC-technology (direct air capturing technology) is proposed to separate CO2 in the exhaust air of buildings and recirculate the CO2-depleted air back into the building. The corresponding potentials and limitations of the novel HVAC/DAC-coupling in recirculation mode are evaluated. For that purpose, CO2-loads in the feed and exhaust air of four buildings located in Germany were measured using calibrated non-dispersive infrared (NDIR) sensors with pyroelectric detection principle. Subsequent numerical model simulations resort to typical meteorological data as well as building operation parameters grouped in different scenarios. The measurement and simulation results were assessed with regard to: (i) the unique possibilities of a HVAC/DAC-coupling in recirculation mode for the improvement of indoor air quality, (ii) the energy saving potentials through reduced air conditioning requirements enabled by a HVAC/DAC-coupling in recirculation mode, and (iii) the potential allocation of CO2 separated from building exhaust air for energetic and/or material reutilization in decentralized systems. In conclusion, a HVAC/DAC-coupling in recirculation mode can not only reduce the energy demand of buildings but also facilitates access to unutilized CO2-resources transported in the built environment and additionally offers the potential to improve indoor air quality. However, a suitable DAC module for operation in indoor air is not yet commercially available. Therefore, different CO2-adsorbents were investigated that may offer the potential to further lower the investment costs and operating costs of a HVAC/DAC-coupling in recirculation mode.

Tuesday, 13.06.2023 17:51-17:54 Room Ag Silver

Air cleaner based on heterogenic catalysis to be used in emergency rescue service

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ID: 1153 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: air cleaning, heterogenic catalysis, rescue service, bioaerosol

Airborne aerosol transfer of SARS-CoV-2 pathogens was identified to be the main infection path of COVID-19. Consequently, elimination of this pathway can be expected to be an effective measure to prevent the spread of SARS-CoV-2 in indoor environments. For the elimination of viral pathogens by air filtration, today mainly HEPA filtration, electrical precipitators, or UV-C based photocatalytic devices are used. However, HEPA filters are at least throw-away products or have to be regenerated. However, organic compounds like disinfectants, fragrances, solvents or cleaning agents may occur in the air additionally to the target pathogens, implying the risk to produce unwanted by-products when using UV-C-based or electrical techniques. The aim of the joint research project described here is the development of an air cleaner running on heterogenous photocatalytic oxidation (PCO) with UV-A-radiation for the deactivation of COVID-19. To avoid expensive safety measures, which are necessary when working with original SARS-CoV-2 pathogens, surrogate bacteriophage MS2 are used for the performance of the corresponding experiments.

In this extended abtract first results will be reported from tests with the developed catalytical components and on the prototype of the catalytic module. Whereas methods for the characterisation of by-product formation are principally available and only have to be adapted to the specific application, methods to quantify the capability of pathogen deactivation have to be developed and verified. Tests are performed in stainless steal 4m³ and 30m³ emission test chambers. As a first step, quantification of bacteriophage MS2 by plague performing units (PFUs) at praxis relevant concentrations is set up. Additionally, a suitable process to dope bacteriophages into the chamber has to be defined. At least, the setup of a test procedure with components or modules and the complete analytical process will be reported.

By-product generation also has to be considered when using PCO technology. Consequently, components and demonstrators of the cleaning module are also thoroughly to be tested in this regard. If by-products can be identified, the relevant processes are characterised and countermeasures can be derived. At least, the reduction of bacteriophages MS2 by the PCO technology will be assessed and discussed with published results from HEPA filtration approaches. The expected results of the project will help to extend the application range to other micro-organisms, e.g. bacteria, and organic pollutants.

Tuesday, 13.06.2023 17:54-17:57 Room Ag Silver

The Development of Indoor-Outdoor Exchange in an Indoor Air Chemistry Model

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ID: 1233 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants
Keywords: indoor air quality, outdoor air quality, air exchange, modelling, indoor air chemistry model

Indoor air pollution and its impact on human health is an increasingly prominent area of research. Recent efforts have aimed to identify sources of air pollution indoors and how these influence indoor air chemistry. Such research is important as we spend approximately 90% of our time indoors, whether at home, at work, or commuting between the two. The ambient environment is a notable source of indoor air pollution. Chemical species which originate from outdoors, commonly from transportation and industrial settings, can ingress indoors and affect indoor air quality. Conversely, indoor air pollution can also affect the outdoor environment. For example, cooking and cleaning activities produce volatile organic compounds (VOCs), which can be transported outdoors and impact outdoor air quality under some circumstances. However, little is known about the details of these exchange processes at the interface between indoors and outdoors.

This study uses the INdoor CHEMical model for Python (INCHEM-Py) to explore these processes in detail. INCHEM-Py simulates indoor gas-phase chemistry by solving a system of coupled ordinary differential equations (ODEs) whilst considering terms for chemical reactions, photolysis, surface deposition chemistry, indoor emissions and indoor-outdoor exchange. The model has been developed to include a scheme which considers exchange of species within the indoor-outdoor interface through consideration of species residence time, diffusion and ventilation rates. In this way, we can track species that have been produced from cooking or cleaning indoors as they pass through openings in buildings and quantify their impacts on outdoor air concentrations. Such processes can be considered for a single building, or on a much larger city-scale. We also consider how the relative importance of these processes will change in the future, as outdoor air pollutant concentrations change as we increasingly adopt lower emission technologies, such as vehicle electrification, to meet net zero policies.

Tuesday, 13.06.2023 17:57-18:00 Room Ag Silver

Assessment of filtration & regeneration capabilities of a nonwoven activated carbon fabric (ACF)

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ID: 1406 Extended Abstract
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: air filtration, nonwoven ACFs, aerosol generation & sampling, thermal inactivation, CFD

Nonwoven activated carbon fabrics (ACF) are commonly used in gaseous pollutant removal like odours and COVs thanks to the nano-porous structure of the carbon fibres which fosters the adsorption and the heat released by joule effect when powered by an electrical current permitting desorption. The objective of this work was to measure the filtration efficiency of a nonwoven ACF regarding solid particles and a bacteriophage, and to evaluate its regeneration ability concerning thermal inactivation of the collected microorganisms.

The properties of the ACF media of 1 mm thickness (100 g/m²) were characterised in terms of thermoelectric, fibrous structure, porosity and air permeability. The filtration efficiency measurement was performed using two rectangular media samples of 60 cm² area which were installed symmetrically and in parallel on a frame and introduced inside a lab-scale ventilation duct of 3 m length and 15 cm × 15 cm cross area. Previously, an investigation of the airflow was carried out to validate the flow symmetry over the two samples and to optimize the sampling nozzle positioning avoiding the air flow disturbances caused by the frame singularity. The flow characterisation relies on a 3D CFD simulation done using ANSYS Fluent and by particle tracer of fluorescein ($d50$ = 0.18 µm) injected upstream of the AFCs media in the duct. Moreover, the combined particle and microorganism generation was performed using the MS2 virus (Emesvirus zinderi, 9.3 × 1011 pfu/ml) suspended in 10 g/l NaCl solution. The filtration efficiency was measured using optical particle counting (WELAS, Palas) for NaCl and cascade microbial impaction (ANDERSEN) for the virus.

The fractional filtration efficiencies were around 100% for the particles of 4 µm; 70 % for the particles of 1 µm; < 40 % for particles with diameters less than 0.5 µm. In contrast, the overall collection efficiency was 55 % surely because of the aerosol granulometry dominated by submicronic diameters. Nevertheless, the microbial filtration efficiency (51 ± 6 %) was similar to the overall particle efficiency, demonstrating the aggregation/adsorption of the MS2 on NaCl particles. Furthermore, 3 W power were applied to one of the samples rising its temperature to 80°C. After extraction and culture of the collected microorganism, the results demonstrated the total inactivation of the MS2 virus collected on the ACF subjected to 80°C, while the sample without heating demonstrated the presence of active CFU with a risk of growth and entrainment. Ultimately, this AFC has promising capabilities for combining gaseous/particle/microbial air treatment.

Session 20 Tuesday Oxygen - Building design & architecture

Time:
Tuesday, 13.06.2023 16:45-18:15

Room: O2 Oxygen

Chair:
Knudsen, Henrik N.
Aalborg University

Co-Chair:
Pilehchi Ha, Peiman
RWTH Uniklinik Aachen

Tuesday, 13.06.2023 16:45-17:00 Room O2 Oxygen

ZEB Test Cell Laboratory digital twins: assessing the textile SSF benefits in the Nordic region

Mokhtari, Niloufar (1); Ciampi, Giovanni (1); Spanodimitriou, Yorgos (1); Scorpio, Michelangelo (1); Nocente, Alessandro (2); Manni, Mattia (3); Lobaccaro, Gabriele (3); Sibilio, Sergio (1)

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ID: 1440 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 05. Architecture, aesthetics, passive design, biophilia
Keywords: energy saving, passive and lightweight solutions, second skin facades, textile materials, energy-efficient buildings

A significant part of global energy consumption is related to buildings, most of which is consumed through façades. To address this issue, the Second-Skin Facade system is considered one of the most effective solutions for new and existing buildings. Furthermore, the use of textiles for building skin has been growing, creating smart, flexible, and advanced envelopes. The performance of the Second-Skin Façade depends strongly on the boundary conditions, and its adoption in the Nordic climate is scarcely investigated. In this research, the digital twin of the ZEB Test Cell Laboratory in Trondheim (Norway) is developed using a dynamic simulation software, then calibrated and validated based on experimental data. This digital twin is used to conduct a comparative numerical analysis to assess the potential benefit of the textile Second-Skin Façade in the Nordic region. Seven simulation cases have been realized in total, varying the control logic through four operating states based on the global vertical solar irradiation and the indoor and outdoor air temperatures. The results show that the Second-Skin Façade adoption allows the reduction of the yearly average indoor air temperature by up to 3.5°C, lowering the energy needs for heating and cooling demands by up to 21.4%.

Tuesday, 13.06.2023 17:00-17:15 Room O2 Oxygen

Multiscale modeling and application of thermal properties in Polyurethane with phase change materials

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ID: 1385 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 05. Architecture, aesthetics, passive design, biophilia
Keywords: Polyurethane (PU), Phase Change Materials (PCMs), Thermal properties, Multi-scale modeling, Building energy.

Polyurethane (PU) is an ideal thermal insulation material due to its excellent thermal properties. The incorporation of Phase Change Materials (PCMs) capsules into Polyurethane (PU) has been shown to be effective in building envelopes. This design can significantly increase the stability of the indoor thermal environment and reduce the fluctuation of indoor air temperature. We develop a multiscale model of a PU-PCM foam composite and study the thermal conductivity of this material. Later, the design of materials can be optimized by obtaining thermal conductivity. We conduct a case study based on the performance of this optimized material to fully consider the thermal comfort of the occupants of a building envelope with the application of PU-PCMs composites in a single room. At the same time, we also predict the energy consumption of this case. All the outcomes show that this design is promising, enabling the passive design of building energy and significantly improving occupants' comfort.

Tuesday, 13.06.2023 17:15-17:30 Room O2 Oxygen

Comprehensive energy, technoeconomic and thermal comfort assessment of school premises in Cyprus and their proposed retrofit interventions.

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ID: 1118 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 05. Architecture, aesthetics, passive design, biophilia
Keywords: school premises, thermal comfort, energy performance, technoeconomic analysis, retrofit

Educational buildings comprise a significant portion of public buildings in Cyprus and most of them are characterized by poor energy performance and indoor environmental quality. Building retrofitting offers significant opportunities for enhancing energy efficiency, thermal comfort and achieving green development goals. This paper aims to evaluate the thermal and energy performance of school premises in Cyprus in the existing state as well as the energy-saving potential, affordability and thermal comfort performance of various passive building retrofit measures. The findings of the current research are based on an on-site investigation and software dynamic simulation (IES-VE) carried out in a representative and typical school building that is going to be upgraded to a lighthouse renovation project. Retrofitting approaches consider thermal insulation of the building envelope, introduction of shading systems, ventilation systems, ceiling fans and PVs and upgrades to the heating system. In order to evaluate the performance of these defined retrofit combinations, assessment indicators are proposed, including indoor thermal comfort, energy reduction rate, and life cycle costs. The results of the current research will benefit decision makers to determine the appropriate solutions for the holistic retrofitting of educational building stock to achieve better energy efficiency and comfort under the framework of green building development.

Tuesday, 13.06.2023 17:30-17:45 Room O2 Oxygen

Passive Cooling Measures in Reducing Interior Overheating of Multi-Unit Residential Buildings

Bartko, Michal; Laouadi, Abdelaziz; Lacasse, Michael

National Research Council Canada, Canada

ID: 1119 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 05. Architecture, aesthetics, passive design, biophilia
Keywords: Multi-Unit Residential Buildings, Resiliency, Interior Overheating, Passive Cooling Measures

Due to the effects of climate change, summer outdoor temperatures are rising, possibly resulting in overheating the buildings' interiors, and lead to health issues for building occupants. This paper describes the effects of overheating within multi-unit residential buildings (MURB), the effectiveness of the different cooling strategies and the overheating likelihood. An investigation was conducted using the EnergyPlus® simulation tool. The National Renewable Energy Laboratory (NREL) developed archetype for midrise-rise MURB, which was adapted for the purposes of our study. A model was configured for several passive cooling strategies, such as the effect of building envelope thermal mass, increased envelope R-values, shading, ventilation, and window glazing, resulting in 1728 simulated combinations. The effectiveness of the measures was evaluated for five summer months (May to September) for the climate data of Ottawa, Canada. Results confirmed interior overheating issues showing that: 1) During extreme heat events, the most effective passive measures was increased ventilation from opening windows during favorable climatic conditions and the use of exterior shading for the fenestration. 2) The high performance buildings had a tendency to overheat more than less well insulated buildings. 3) Suits on the ground floor overheated considerably less than those at the top storeys.

Tuesday, 13.06.2023 17:45-17:48 Room O2 Oxygen

Passive design for reducing carbon emissions of residential and commercial buildings in cold climate zone, China

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ID: 1239 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia, 06. Heating, ventilation, air conditioning & cooling
Keywords: Passive design; carbon emission reduction; building shape coefficient; passive volume ratio; residential and commercial buildings

In response to global warming, reducing carbon emissions in building sector is essential. From the sustainable development perspective, passive design is now receiving renewed attention for energy conservation while creating comfortable conditions inside buildings. By simulating building archetypes in Beijing, this paper studies the impacts of building shape factor (BSF) and passive volume ratio (PVR) on carbon emissions in building operations. In residential buildings, the increase of BSF will increase the emission from heating but decrease that from cooling, and altogether increase the total emissions. Strengthening the envelope insulation can reduce the emissions by 4.1-4.6%. In commercial buildings, operational carbon emissions increase with the increase of BSF. Natural ventilation and daylighting utilization can reduce the emissions by 11.6-16.1%. The larger the BSF, the larger the PVR, as well as the greater the carbon reduction effects of passive measures. In addition, for commercial buildings with the same shape, the carbon emissions increase with the increase of single-storey height. In the cold climate zone, BSF should be carefully considered in the building design, and PVR can be improved for full passive energy use to reduce carbon emissions

Tuesday, 13.06.2023 17:48-17:51 Room O2 Oxygen

A comparative study on the embodied carbon and operational carbon of a radiant cooling system and an all-air system

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ID: 1340 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia, 06. Heating, ventilation, air conditioning & cooling
Keywords: embodied carbon, operational carbon, thermally active building system (TABS), embedded surface system (ESS), radiant panel

Greenhouse gas emissions worldwide must be reduced to prevent the further acceleration of global warming. Therefore, there is an urgent need to reduce carbon emissions in the building sector. Radiant cooling systems have been proven to be an energy-efficient and resource-effective heating and cooling solution for buildings. These features of radiant cooling systems are expected to reduce building operational carbon emissions. The objective of this study was to quantify the effect of radiant cooling systems on building supply chain carbon emissions. The classification of whole life cycle stages of a building was based on EN 15978:2011. Dynamic building simulations were carried out to verify the effects of radiant cooling system on building operational carbon emissions. The studied radiant cooling system type was a Thermally Active Building System (TABS). A model with packaged variable air volume system (VAV) with reheat was simulated as a reference case for comparison. The building model was based on the medium office of the prototype building developed by the U.S. Department of Energy. The whole life carbon (A1-A3, B4, B6, C3, C4) was 8.4 kgCO2-eq/m²/year for the all-air system and slightly lower, 7.9 kgCO2-eq/m²/year for the TABS.

Tuesday, 13.06.2023 17:51-17:54 Room O2 Oxygen

Research on thermal performance index of resilient building envelopes based on RC network

Li, Zhengrong; Si, Yang

Tongji University, China, People's Republic of

ID: 1376 Full paper
Topics: 05. Architecture, aesthetics, passive design, biophilia
Keywords: Building resilience, envelope, disturbance, RC network

This study introduces the idea of resilience, and proposes a thermal resilience index that can accurately describe the ability of buildings to cope with indoor and outdoor disturbances. Firstly, based on the analysis of existing resilience concepts, a description of thermal resilient building is established for the context of this study. Then, based on the RC network method, a non-stationary room heat transfer model is established, and the influence of solar heat gain through the windows on the heat transfer process of the walls in the actual environment is considered, and the room integrated thermal resistance and integrated heat capacity indexes describing the overall room thermal resilience performance are proposed. Finally, based on the above indexes, simulations and field tests are conducted to verify the effectiveness of the indexes in describing the overall building (maximum difference within 3.67% MBE and 2.92% CVRMSE). The results show that the proposed new performance index can fully describe the envelope thermal resilience performance under the real conditions.

Tuesday, 13.06.2023 17:54-17:57 Room O2 Oxygen

Pilot trial on early-building design method considering trade-off of upfront and operational carbon.

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ID: 1269 Extended Abstract
Topics: 05. Architecture, aesthetics, passive design, biophilia
Keywords: Early building design, Upfront carbon, Operational carbon, Life cycle assessment

The Intergovernmental Panel on Climate Change (IPCC) with its Special Report on Global Warming of 1.5°C indicated that global CO2 emissions must be reduced to net zero by 2050. To achieve carbon neutrality in response to climate change, the government of Japan declared the goal of achieving a 46% reduction of CO2 emissions from 2013 levels by 2030. Buildings account for about one-third of Japan's total CO2 emissions, and non-residential buildings account for about 60% of this amount. Therefore, reducing CO2 emissions from non-residential buildings is an urgent task for realizing a decarbonized society in Japan.

To design low-carbon buildings, it is important to estimate CO2 emissions through various design studies. In particular, early design study is the most influential process because it determines the performance of buildings during their "cradle-to-grave" life cycle. For instance, changes in building aperture ratio mutually affect operational carbon through heating and cooling loads, and embodied carbon is related to the manufacturing of envelope materials. However, very few studies have evaluated life cycle performance from the early stages of building design, although many life cycle assessment (LCA) databases are available in Japan. In addition, few studies have presented LCAs, such as life cycle CO2 emissions assessments, in connection with parametric studies on 3D models in the early stages of design, when there is significant opportunity for changing building design.

This study presents a framework for sustainable early design strategies for life cycle CO2 for non-residential buildings in Japan. First, the reference embodied carbon is estimated using the Japanese Inventory Database for Process-based Life Cycle Assessment (IDEA, National Institute of Advanced Industrial Science and Technology) by implementing a standard 3D energy model (US Department of Energy prototype buildings). The reference operational carbon is estimated by energy simulation (EnergyPlus). Then, the embodied and operational carbon are calculated from various variables, such as the aperture ratio and core placement, as in case studies, and these are optimized as indicators to propose a lower-carbon building plan. This study aims to assist architects in proposing lower-carbon buildings in the early design stage while also identifying areas with high potential for CO2 emission reductions.

Parallel sessions

Wednesday

Session 21 Wednesday Carbon - Resilience & measurements

Time:
Wednesday, 14.06.2023 08:30-09:45

Room: C Carbon

Chair:
Loomans, Marcel
Eindhoven University of Technology

Co-Chair:
Manu, Sanyogita
University of British Columbia

Wednesday, 14.06.2023 08:30-08:45 Room C Carbon

Assessment of mechanical ventilation performance in Finnish daycare buildings

Lastovets, Natalia (1); Luoto, Anni (2); Sormunen, Piia (1,2); Elsayed, Mohamed (1); Mäkinen, Antti (3); Juvela, Jussi-Pekka (3); Uusitalo, Sakari (3); Sanmark, Enni (4)

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ID: 1426 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Indoor air quality, mechanical ventilation performance, daycare buildings, ventilation strategies

Ventilation performance is critical in daycare buildings since they are often designed for high occupancy density and longer occupant periods. During the past decades, broad research and detailed guidance on ventilation design to provide good indoor air quality have been developed in Finland. However, the Covid-19 pandemic revealed the significance of ventilation in preventing airborne transmission within enclosed spaces. Therefore, ventilation strategies are currently being reconsidered for the health emergency arising from the pandemic. Moreover, even in retrofitted educational buildings, the effect of the intervention showed some differences from what was expected at the design stage. Thus, ventilation performance analysis and detailed ventilation system inspection are required to provide healthy and safe indoor spaces.

This study presents measurement results for assessing mechanical ventilation performance and indoor air quality in several Finnish daycare buildings. Indoor air quality in daycare premises was evaluated by measuring CO2 and indoor temperature. In addition, the mechanical and electrical components of ventilation systems were expected using the Finnish guideline for inspecting ventilation systems. The study revealed differences between the expected and measured ventilation performances. The findings of this study will contribute to understanding ventilation performance and potential measures to improve indoor air quality for daycare premises.

Wednesday, 14.06.2023 08:45-09:00 Room C Carbon

A survey of indoor air quality conditions in bedrooms of Dutch daycare centers

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ID: 1312 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Indoor air quality, daycare center, ventilation

A daycare center (DCC) is the most important indoor environment for young children besides their homes, where they keep the habit of daytime sleeping. They are vulnerable and susceptible to the health effects of airborne contaminants. Therefore, it is essential to keep a healthy indoor sleeping environment for young children in daycare centers. However, only a few studies have analyzed indoor air quality (IAQ) in bedrooms of DCCs. This study aims to learn more about the IAQ of bedrooms of DCCs through a field survey and analyzing CO2 concentration data. The field survey was conducted to collect detailed information on occupants and bedroom design with the ventilation system. It is found that around 60% of the bedrooms do not meet the requirement of airflow rate according to Dutch Building Code. Also, ventilation systems in bedrooms are not designed according to room geometry, number of occupants, and their ages. As for the analysis of CO2 concentration, it is found that 39% of the bedrooms have reported CO2 concentration higher than 1000 ppm with a daily average time of 111 minutes. According to those findings, the status of the DCCs' IAQ is not satisfying and needs further improvement.

Wednesday, 14.06.2023 09:00-09:15 Room C Carbon

Evaluation of the performance of Low-Cost Monitors for their use in Fault Detection and Diagnosis

Gopalan, Srinivasan (1); Zheng, Hailin (1); Walker, Shalika (2); Kramer, Rick (1); Zeiler, Wim (1)

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ID: 1149 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Low-Cost Monitors, Indoor Air Quality Monitoring, Fault Detection and Diagnosis, Offices and Commercial Buildings

Fault Detection and Diagnosis (FDD) is a process that helps to identify anomalous behaviour caused by operational faults in HVAC systems. However, the lack of sufficiently spatial-granular sensor networks in buildings and their poor accuracy is hindering the widespread uptake of FDD tools. While installing additional Low-Cost Sensors (LCSs) and Low-Cost Monitors (LCMs) required for FDD could provide a viable solution, their performance needs to be evaluated and deemed adequate. The objective of this research is to test and rank multiple LCMs based on their suitability for use in FDD applications. The study was conducted in a controlled climate chamber to test multiple LCMs and evaluate their performance in measuring Temperature (T), Carbon dioxide (CO2), and Relative Humidity (RH) under varying conditions. Metrics corresponding to Precision, Linearity, Bias, and Error were calculated and a weighted rating based on the metrics' values for each LCM was obtained using the rating scale of the Smart Readiness Indicator (SRI) framework and the importance of the parameter for FDD. Based on the results, the top-performing monitors are recommended for installation to collect data for FDD applications.

Wednesday, 14.06.2023 09:15-09:18 Room C Carbon

Low cost-effective measurements for schools.

Mohammed, karzan (1); Krishnan, Vinayak (2); Zheng, Hailin (1); Walker, Shalika (2); Kramer, Rick P. (1); Zeiler, Wim (1)

1: Eindhoven University of Technology, The Netherlands; 2: Kropman Gebouwautomatisering

ID: 1173 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: Smart buildings, indoor air quality, indoor environmental quality, measurements.

Indoor Environmental Quality (IEQ) in schools is often found to be unsatisfactory and leads to complaints. Furthermore, a recent study conducted in school revealed large spatial differences in multiple metrics. Hence, a classroom is desirable to be divided into several zones for air quality evaluations with a fine spatial granular sensor network. Low-cost monitors (LCM) may be interesting for such sensor networks from a cost-perspective. For instance, the government of the Netherlands decided to supply low-cost CO2-monitors for all school classrooms to evaluate the CO2-levels. However, recent studies question the quality of low-cost sensors. Therefore, this study investigates the reliability of (LCM) in a case study school in the Netherlands. Two Sensor-networks were created consisting of one LCM and one research-grade instrument (RGI) at each measuring location in the classroom. Other than that, because of the limitation of using a variety of LCMs in the field study, a wide and comprehensive laboratory analysis was performed by comparing LCMs, including fourteen different brands/types and (RGIs). Measurements of PM and CO2 have been conducted under different creative activities emulating common emission scenarios. Based on the results, the possibility of using LCM in Sensor-networks in the indoor environment has been recommended.

Wednesday, 14.06.2023 09:18-09:21 Room C Carbon

Resiliency and Performance Evaluation Indicators of Personalized Environmental Control Systems (PECS)

Shinoda, Jun (1); Bogatu, Dragos-Ioan (1); Watanabe, Futa (2); Kaneko, Yosuke (2); Olesen, Bjarne W. (1); Kazanci, Ongun B. (1)

1: Technical University of Denmark; 2: Mitsubishi Electric Corporation

ID: 1182 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Thermal Comfort, Indoor Air Quality, Resiliency, Personalized System, Key Performance Indicators

A Personalized Environmental Control System (PECS) conditions the local environment around occupants. Depending on its functions (e.g., heating, cooling, ventilation), it allows individual control over indoor environmental quality (IEQ) parameters based on each occupant's own preference. This characteristic of PECS is expected to improve comfort and satisfaction, which could also lead to higher productivity. PECS also has the potential to reduce energy use, when they are effectively coupled with the heating, ventilation, and air-conditioning (HVAC) systems of the building. A personalized ventilation function that provides fresh and/or clean air can reduce occupant exposure to indoor pollutants. PECS could be a resilient solution both in terms of thermal comfort and indoor air quality during extreme events such as heat waves, power outages, outdoor air pollution, and pandemics. A new international project "IEA EBC Annex 87 – Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems" aims to develop a universal performance evaluation framework of PECS. As a first step towards this goal, an extensive literature review of performance indicators for PECS has been conducted in the present study. Commonly used indicators and possible indicators for resiliency evaluation have been presented and discussed.

Wednesday, 14.06.2023 09:21-09:24 Room C Carbon

Sustainable renovation solutions for Finnish apartment buildings

Wang, Yangmin (1); Hirvonen, Janne (1,2); Jokisalo, Juha (1,3); Kosonen, Risto (1,3,4)

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ID: 1289 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling
Keywords: Residential building, Energy renovation, Primary energy, CO2 emissions

To achieve carbon neutrality in Finland, it is necessary to improve energy efficiency of residential stock through renovation. The study evaluates the performance of several renovation technologies in a Finnish apartment building by simulation. The renovation technologies include roof and balcony walls' thermal insulation, vapour barrier, heat distribution pipes' thermal insulation, daylighting louvers, mechanical balanced ventilation systems with heat recovery, bi-facial photovoltaic panels and ground-source heat pump. IDA ICE was utilized to simulate the demo building model, serving as the reference for renovation technologies' simulations. The renovation technologies were divided into the passive, ventilation and generation packages, and then integrated into the reference model to examine their effect on primary energy, CO2 emissions and indoor climate. The biggest impact on CO2 emissions (31% reduction) was gained by installing ground-source heat pump, which converts significant coal-based district heating into low emission electricity. Converting the mechanical exhaust ventilation into mechanical balanced ventilation with heat recovery was another significant measure, reducing CO2 emissions by 21%. In contrast, the thermal insulation technologies possess lower emission reduction potential. However, the thermal insulation technologies and mechanical balanced ventilation systems slightly worsen overheating problem in summertime. Installing daylighting louvers significantly reduces summer indoor temperature.

Wednesday, 14.06.2023 09:24-09:27 Room C Carbon

Long-term performance analysis of a hybrid GSHP system for a large educational building in Finland

Xue, Tianchen (1); Jokisalo, Juha (1,3); Kosonen, Risto (1,3,4); Ju, Yuchen (1); Vuolle, Mika (2); Nadas, Viktoria (2); Marongiu, Federica (2)

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ID: 1364 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling
Keywords: Borehole free cooling, Ground source heat pump, Energy efficiency

Ground source heat pump (GSHP) system is widely used for heating or cooling in many countries. However, in cold regions, the GSHP system may face performance deterioration due to excessive underground thermal imbalance. Therefore, hybrid GSHP systems with auxiliary heat sources are proposed for overcoming this problem. This study investigated the long-term performance of a hybrid GSHP system assisted by district heating and a chiller for a large educational building in Finland. The studied building and the hybrid GSHP system were modelled in IDA ICE 4.8. Two simulation cases were designed and compared to investigate the effects of dimensioning GSHP heating capacity on the system performance and energy consumption. The result showed that by reducing the GSHP heating capacity, the brine temperature increased by 2.3 ℃ and the heat pump COP increased by 5 % compared to the reference case. The total electricity consumption in the case with the reduced GSHP heating capacity was reduced by 7 %, while in contrast the entire district heating consumption was increased by 50 %.

Session 22 Wednesday Silver - Modelling & human variability

Time:
Wednesday, 14.06.2023 08:30-09:45

Room: Ag Silver

Chair:
Vellei, Marika
La Rochelle University

Co-Chair:
Christoforou, Rania
University Hospital RWTH Aachen

Wednesday, 14.06.2023 08:30-08:45 Room Ag Silver

Effect of short-term thermal history on human physiological and psychological responses: A pilot study

Wu, Zhibin (1); Schiavon, Stefano (2); Wagner, Andreas (1)

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ID: 1425 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Short-term thermal history, Thermal sensation, Physiological response, Psychological response

The purpose of this study is to examine the effect of short-term outdoor thermal history on psychological and physiological responses of human in indoor environment. This study relies on a long-term field study in 4 split air-conditioned dormitory buildings. Total of 345 valid datasets were collected from 65 participants. Both thermal comfort responses and physiological responses were systematically investigated. According to the indoor staying time, the participants were clarified into two groups, STN30 (indoor staying time less than 30 min) and ST30 (indoor staying time more than 30 min). The study compares the thermal comfort responses and physiological responses of these two groups. Also, the relationship between thermal sensation and physiological is determined. There is no significant difference in the distribution of thermal responses and physiological responses with regard to outdoor short-term thermal history. The less the indoor staying time, the lower the neutral temperature (1.1℃), and the higher the acceptable percentage with cool-side temperature. The upper extremity skin temperatures are significantly related to thermal sensation. At the same indoor temperature, the less staying time, the higher upper extremity skin temperatures.

Wednesday, 14.06.2023 08:45-09:00 Room Ag Silver

Evaluation and comparison of the prediction accuracy of thermophysiological comfort models

Koczorek, Nicole; Derwein, Dennis; Rewitz, Kai; Müller, Dirk

RWTH Aachen University, Germany

ID: 1214 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: thermal comfort, thermophysiological comfort models, accuracy comparison, skin and core temperature simulation

Various thermophysiological comfort models were developed with different approaches and levels of detail. In this work, we investigate the prediction accuracy of five comfort models including the Berkeley model, the JOS-3 model, the NOODEL model, an adjusted version of the NOODEL model and the Gagge 2-node model, with respect to the mean skin temperature and core temperature. We compare the simulations to measured temperature profiles from subject studies respectively. We evaluate the accuracy with the Root Mean Square Error (RMSE) and compare the results in the categories temperature range, step change size, age and gender in order to investigate application areas and limits. The results have underlined the importance of multi-segment models for transient conditions. Regarding the mean skin temperature, the original NOODEL and the JOS-3 model have the highest prediction accuracy. The adjusted NOODEL model has improved the accuracy of the mean skin temperature for the calibrated categories. Regarding the core temperature, the Gagge model has the highest accuracy between 5- 28 °C with small step changes or steady state conditions. Additionally, the JOS-3 model has a high prediction accuracy between 28 - 48 °C. In summary, a model comparison only seems fully holistic with a standardized evaluation framework.

Wednesday, 14.06.2023 09:00-09:15 Room Ag Silver

Advancing a health-model linked smart control framework to improve occupant health and comfort in residences

Cooper, Elizabeth; Wang, Yan; Stamp, Samuel; Mumovic, Dejan

University College London, United Kingdom

ID: 1242 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 09. Public health, occupational & environmental health
Keywords: air purifier, health impact assessment, smart building controls, PM^2.5

The work described here builds upon previous work that proposed a smart control framework that combined portable air purifiers and automatic window control systems to reduce indoor PM^2.5 concentrations in residences whilst maintaining thermal comfort. The modelled changes inform health models for better estimations of the impacts to population health due to the implementation of controls that use both thermal conditions and contaminant concentrations as control targets. The IAQ modelling, which uses EnergyPlus to simulate both airflow and thermal conditions, includes different ambient pollution levels, and, importantly, different occupant behaviour profiles. The quantitative health impact assessment in this work predict survival patterns based on age-specific mortality figures and hazard ratios. The simulation results showed that dual control of portable home air purifiers and window openings has the potential to not only maintain thermal comfort but also achieve effective PM^2.5 removal even in cases of high indoor sources which, consequently, can lead to considerable health benefits at a relatively low energy cost.

Wednesday, 14.06.2023 09:15-09:18 Room Ag Silver

Validation of human thermo-physiology models for personalized predictions of thermal responses

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ID: 1388 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 11. All other IEQ, ergonomics & health topics
Keywords: Human thermal comfort, Human thermophysiology modelling, skin temperature

Current thermal comfort models used in practice do not consider physiological and psychological differences. Human thermo-physiology models (HTPM) are useful tools to assess human thermal comfort at local and overall levels in the human body. All published HTPM models claim a high level of agreement with experimental data; however, in most cases, the comparison was made with data from third-party experimentation. This paper presents an independent detailed evaluation of two sophisticated human thermo-physiology models, JOS3 and ThermoSEM, considering individual parameters (gender, height, weight, etc.) as input. Furthermore, both models are similar in heat transfer calculation but differ in thermoregulation control. For validation, we used data from our experimental study with male and female subjects sitting relaxed and standing sorting under different environmental conditions (22-28°C) in a climatic chamber. The measured core temperature and the skin temperature at 14 locations were used to evaluate the predicted values. The paper highlights the capabilities and limitations of HTPMs and, furthermore, discusses the application of HTPMs in the field of individualized thermal comfort. The results show that HTPMs are valuable tools for predicting individual local thermal response but in order to reach a better accuracy models needs more refinement on local thermal characteristics assumptions.

Wednesday, 14.06.2023 09:18-09:21 Room Ag Silver

Variability of human metabolism: sex, thermal exposure, season, and activity effect

Khovalyg, Dolaana

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ID: 1395 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 11. All other IEQ, ergonomics & health topics
Keywords: human metabolic rate, thermal comfort, personalized comfort

Metabolic heat is one of the main factors that influence the rate of heat exchange between the human body and the environment and defines the thermal sensation of individuals. Static metabolic rate values for an average person are prescribed in thermal environment-related standards and are widely used in thermal comfort research. This work question applicability of the standard values by demonstrating the variability of metabolic heat in 3 males and 3 females across a range of low-level activities, indoor temperatures, and seasons. To this aim, experiments were conducted with overnight fasted healthy human subjects in a climatic chamber at uniform indoor temperatures of 17 and 24oC in winter and 24 and 32oC in summer. Metabolic heat was measured using the indirect calorimeter Quark CPET (Cosmed). The results demonstrate that the magnitude of metabolic heat varies across sex at a different magnitude for cold and heat exposure. As the change is profound in males, it is smaller in females, and the phenotyping into "spenders" and "savers" could be established. Thus, the energy cost of activity seems to be dependent on the "Sex-Temperature (Season)-Activity" interaction that needs further investigation.

Wednesday, 14.06.2023 09:21-09:24 Room Ag Silver

Sex differences in metabolic rate at different activity levels

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ID: 1127 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: metabolism, individual differences, thermal comfort, design, sustainability

One of the main parameters that affect thermal comfort is the metabolic rate. However, it is by far the least studied one. Accurately determining the metabolic rate is still an expensive and time-consuming task, despite advances in technology. Currently, most thermal comfort assessments are carried out using tabulated values of metabolic rate as expressed in international standards such as ISO 7730, ISO 8996 and ASHRAE 55. The problem is that such metabolic rates were estimated for an average adult male, which may not adequately reflect the metabolic rate of other groups, for instance, females. Arguments have arisen that this potential difference in metabolic rate may explain reported individual differences in thermal perception. However, there is no strong evidence on the matter. This way, the main objective of this work is to analyse the metabolic rate of males and females with similar characteristics. The method consisted in performing experiments with human subjects in a climate chamber. Subjects were asked to wear clothes with insulation of 0.61 clo. The chamber temperature was controlled at 25ºC (relative humidity = 40%; air speed < 0.1 m/s) in order to provide a neutral sensation to subjects while seated in a chair. Subjects performed three different activities during the experiments: seated in a chair, cycling at light intensity and cycling at moderate intensity. The metabolic rates were measured through indirect calorimetry. The criteria for the subject's participation took into account the participant's age, gender, body composition, health condition and thermal history. In total, 24 subjects participated in the experiments (50% females). The metabolic rate for each subject was determined based on the measurements of oxygen consumption rate and carbon dioxide production rate, according to ISO 8996. A comparison between measured and standard metabolic rates was conducted. The measured metabolic rates were lower than standard values. Results have also shown significant

differences in metabolic rate between males and females – females presented lower metabolic rates, which may help to explain individual differences in thermal perception. The findings of this study may be useful, especially for the design and operation of personalised environmental control systems.

Wednesday, 14.06.2023 09:24-09:27 Room Ag Silver

Protective facemask-induced facial thermal stress and breathing burden during exercising in gyms

Zhong, Qilong; Song, Jiyun; Shi, Dachuan

Department of Mechanical Engineering, The University of Hong Kong, Pokfulam Road, Hong Kong SAR, China

ID: 1274 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness
Keywords: Thermal stress, breath comfort, indoor exercise, simulation

During the COVID-19 pandemic, 99% of infections occur at indoor environments such as gyms, restaurants, etc. Particularly, people in gyms are facing intensive challenges from both infection risks and extra heat and breathing burdens with the use of protective facemasks (PFMs) during intensive exercises. To evaluate the PFM-induced thermal stress and breathing comfort during exercising, the study aims to study the mechanisms of heat and air exchanges between human and environment under the intervention of PFMs via both experiments and computational fluid dynamics (CFD) simulations. In the experimental phase, the influence of human activity intensities (resting, walking, running at different slopes and speeds on treadmills), and types of PFMs (flat, fold, and cup) on thermal and breathing comfort were tested. An uncomfortable facial microenvironment covered by PFM was found with an increase of 10-11 °C and 40%-50% in air temperature and humidity, respectively, compared to air-conditioned room environment (21°C, 50%), together with high CO_2 concentration (1500 ppm), and low O_2 concentration (42000 ppm) during high-intensity exercises. In the CFD simulation phase, temperature and humidity of PFM dead space were calculated via ANSYS Fluent. Simulation results were compared against experimental data for validation and model sensitivity analyses were conducted to assess the impact of different factors (e.g., exhale temperature, exhale frequency, blood temperature, mask volume, mask resistance, mask leakage, etc.) on facial thermal stress and breathing burden. Our results could provide significant references for government policymaking, mask design, and public health.

Session 23 Wednesday Oxygen - HVAC & thermal comfort

Time:
Wednesday, 14.06.2023 08:30-09:45

Room: O2 Oxygen

Chair:
Rawal, Rajan
CEPT University

Co-Chair:
Burgholz, Tobias Maria
Heinz Trox Wissenschafts gGmbH

Wednesday, 14.06.2023 08:30-08:45 Room O2 Oxygen

Addressing overheating in Swiss apartments using controlled natural ventilation

Belias, Evangelos; Licina, Dusan

Human-Oriented Built Environment Lab, School of Architecture, Civil and Environmental Engineering, École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

ID: 1190 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: multifamily buildings, overheating, smart controls, renovated buildings

Increased occurrence of heatwaves in Western and Central Europe has led to more intense summer overheating in buildings with negative consequences for human health. Controlled natural ventilation (CNV) via automated windows has been used in various building types to address overheating with encouraging results. Yet, this technology has not been applied in apartments due to challenges related to reduced floor areas and floor-to-ceiling heights. To investigate the applicability of these systems in apartments, we installed automated windows in a highly solar-exposed apartment in Western Switzerland, which was regularly occupied. Continuous yearlong monitoring of indoor temperature, relative humidity, and CO2 and outdoor meteorological parameters before and after the installation of the automated window system in the building permitted comparisons to reveal the utility of the CNV in addressing overheating. The results unveiled that the CNV reduced the overheating hours according to the adaptive thermal comfort model by 23% for thermal comfort category I and by 11% for adaptive thermal comfort category II, eliminating the risk of overheating (overheating hours for thermal comfort category II <1% of occupied hours). The reduction of overheating did not compromise the indoor air quality, as the indoor CO2 concentrations remained lower than 1000 ppm for more than 99% of the time. Moreover, during the summer of 2022, the apartment with the CNV was 2 oC cooler than the identical apartment with manual window operation situated next to it. The results of this case study indicate that the CNV could be a reliable alternative to air-conditioning for Swiss apartment buildings.

Wednesday, 14.06.2023 08:45-09:00 Room O2 Oxygen

Building occupants-centered HVAC system management via integration of a multi-domain model of the human body for comfort assessment

Barone, Giovanni (1); Buonomano, Annamaria (1); Forzano, Cesare (1); Martins Gnecco, Veronica (2); Pigliautile, Ilaria (2); Pisello, Anna Laura (2); Russo, Giuseppe (1)

1: University of Naples Federico II, Italy; 2: University of Perugia, Italy

ID: 1400 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Thermal sensation; Wearable sensors; Physiological signals; Machine learning; Personal comfort model; Energy savings.

About 40% of the total energy consumption in the building sector is employed to heating, ventilation, and air conditioning systems necessary to ensure indoor air quality and thermal comfort for the occupants' well-being.The proposed model allows the dynamic evaluation of the impact of different physical and physiological parameters, human behaviour features, and environmental conditions on the multi-domain comfort of occupied indoor spaces. The reliability of the proposed multiphysics-based model has been validated by exploiting new dedicated measurements obtained during an experimental campaign conducted in a test room specifically built-up for studies on multidimensional comfort. The participants were physiologically monitored through wearables and exposed to controlled physical stimuli in the facility. Measured dynamic trends of the subjects' skin temperature and heart rate are combined with mean radiant temperature and indoor CO_2 concentration, and then related to the thermal sensation votes expressed by the same subject during the test. The final objective of this work is to evolve the developed model into an innovative and smart HVAC system control strategy, which manages and predicts optimal operating conditions for achieving both thermal comfort and energy savings.

Wednesday, 14.06.2023 09:00-09:15 Room O2 Oxygen

Two-wave intervention study to measure and improve ventilation in classrooms

Syndicus, Marc; Huang, Qirui; Frisch, Jérôme; van Treeck, Christoph

RWTH Aachen University, Germany

ID: 1154 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: CO2, Ventilation behavior, Covid-19, Classroom, School

This paper reports findings from a two-wave intervention study to monitor and improve natural ventilation in classrooms. Already installed single CO2 traffic lights were evaluated in terms of their representativity. Measurements took place during winter and the early summer in three classrooms of a middle school in Düren, Germany. During the second period, a mechanical exhaust ventilation system was installed in one of the three classrooms, and its performance was compared to a behavioral intervention (natural ventilation) as well as a third classroom (no intervention). Overall, the already installed traffic lights proved to be fairly representative when compared to five additional measurement locations. Infection risk was assessed with the "PIRA" tool. Although window opening was performed less in the room with the exhaust ventilation, the average CO2 concentration was still lower compared to the other two classrooms. The infection risk was 22.2 % lower than in another room, but only 1.4 % lower than expected when considering the results of the first wave. Achieving sufficient air exchange with natural ventilation alone proved difficult, especially in colder seasons. Generally, CO2 only slowly diffused overnight, carrying over stuffy air and potential infection risks.

Wednesday, 14.06.2023 09:15-09:18 Room O2 Oxygen

Predicting the Distribution of Room Temperature in Office Buildings Using Deep Learning: Verification of Improvements in Prediction Accuracy with Temperature and Position Sensors

KADOKAMI, Masaki (1); HAYASHI, Tatsuya (2); KADO, Keita (3); YOKOTA, Takefumi (4); OURA, Masamichi (5)

1: Graduate Student, Graduate School of Science and Eng., Chiba University; 2: Asoc Prof. School of Engineering, Chiba University, Dr. Eng.; 3: Asst Prof. School of Engineering, Chiba University, Dr. Eng.; 4: Nikken Sekkei Ltd., Dr. Eng; 5: Nikken Sekkei Ltd.

ID: 1232 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Deep Learning, Thermal Comfort, Room Temperature Distribution, Activity-based Working, Office Environment

This study aims to provide a healthy working environment by reducing the number of workers who experience thermal discomfort. By providing information on temperature distribution in activity-based working (ABW) offices, workers can select the optimal workspace to reduce discomfort caused by uneven temperatures. The study uses deep learning to predict temperature distribution in an office using indoor and outdoor environmental data. The results show that the combination of 8 perimeter locations plus motion sensors resulted in the smallest error. The correct response rates were 81.29% and 96.55% respectively, when a forecast error of ±0.5°C and ±1.0°C was allowed. These figures are practical considering the accuracy of the temperature sensors used for the measurements was ±1.0°C. In addition, the error for winter was about twice as high as the average for the entire period without modification, but the addition of outdoor temperature data significantly lowered the error. Therefore, the study suggests that the combination of perimeter locations and motion sensors, in addition to outdoor temperature data, is effective in predicting temperature distribution in an office and providing a healthy working environment for workers in ABW offices.

Wednesday, 14.06.2023 09:18-09:21 Room O2 Oxygen

Quantifying the Health Effects of Retrofit Intervention in Buildings: An Exploratory Review

André, Maíra (1,2); Dias, Marcelo (1); Brianti, Laisa (1); Dias, Ana Carolina (1); Nicolletti, Mariana (3); Gaudereto, Felipe (3); d'Obrenan, Honorine van den Broek (3); Berensson, Markus (3); Sarran, Lucile (4); Christoffersen, Jens (4)

1: Mitisi; 2: Federal University of Santa Catarina; 3: C40 Cities; 4: VELUX A/S

ID: 1325 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 09. Public health, occupational & environmental health
Keywords: Retrofit, Health Impact, Cost-benefit, city

Energy efficiency interventions in buildings are known to generate multiple benefits beyond energy cost savings. One of them is health improvement, however, this relationship is poorly mapped in literature. Most studies present results applicable to a particular building typology or climate. Therefore, the aim of this work is to compile existing indicators that allow to estimate the health impacts of most common retrofit interventions in different climates and building typologies. This study is part of a C40 Cities' project aimed at developing guidelines and indicators to drive local governmental interventions and decision-making for funding programs. To achieve that, more than 220 publications were screened, and 27 were selected for this review. Results show the stronger multipliers relate to air pollution concentration and heatwave. Increasing ventilation rates and filtration can decrease Sick Building Syndrome (SBS) symptoms, pollutant-related mortality, as well as improve learning rates and lower absenteeism at schools. By reducing solar heating gains, the odds of heat-related mortality and circulatory diseases decrease. The financial aspects of health are also covered. More studies are needed for hospitals, other cold and warm climate illnesses, and energy poverty.

Wednesday, 14.06.2023 09:21-09:24 Room O2 Oxygen

Operational Improvements for Energy Efficiency and Thermal Comfort in a Zero-Energy Government Building in Japan.

Nakanishi, Ryo (1); Ukai, Masanari (1); Kanie, Shino (4); Iihara, Kosuke (5); Itoh, Anri (2); Maruyama, Jun (2); Kobayashi, Hikaru (3); Tanabe, Shin-ichi (1)

1: Department of Architecture, Waseda University, Japan; 2: MHS Planners, Architects & Engineers Ltd; 3: Department of Architecture and Building Science, Tohoku University, Miyagi, Japan; 4: Tokyo Electric Power Company Holdings, Inc. (Former Graduate Student, Waseda University), M.Eng.; 5: Obayashi Corporation (Former Graduate Student, Waseda University), M.Eng.

ID: 1352 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Zero-energy building, Local government building, Operational Improvement, Energy Efficiency, Thermal comfort

Kaisei Town Hall was the first government building be certified as a net-zero-energy building, as evaluated by building housing energy-efficiency labeling system certification at the design stage. In this study, we propose a method of operation for zero-energy government buildings that takes into account office workers' thermal comfort as well as the need for increased energy efficiency. Operational improvements were made based on summer measurements, such as comfort and temperature, questionnaire results, and analysis of the Building Energy Management System data. The indoor temperature was lowered using an air-conditioning system with photovoltaic power generation during the daytime on weekends. Consequently, the Predicted Mean Vote remained stable during office hours and was within the comfort range. Increased power generation and higher photovoltaic availability can be achieved by operating the heat source equipment during daytime on weekends and at sunrise on weekdays. In summer, air-cooled heat-pump chillers have a higher system coefficient of performance than geothermal water-cooled heat-pump chillers. Therefore, it is possible to save energy by prioritizing the use of air-cooled heat-pump chillers in the summer.

Wednesday, 14.06.2023 09:24-09:27 Room O2 Oxygen

Energy implications of implementing adaptive thermal comfort models: A case study of a nursing home

Verges, Roger; Forcada, Núria

Department of Project and Construction Engineering (DPCE), Group of Construction Research and Innovation (GRIC), Universitat Polit`ecnica de Catalunya. (UPC), Colom, 11, Ed. TR5, 08222, Terrassa, Barcelona, Spain

ID: 1250 Extended Abstract
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: thermal comfort, eldery, energy efficency, adaptive thermal comfort.

Buildings account for about 40% of the global energy consumption and contribute over 30% of the CO2 emissions. A significant proportion of the increase in energy use is due to the spread of the HVAC installations in response to the growing demand for better thermal comfort within the built environment. In general, in developed countries HVAC is the largest energy end-use, accounting for about half of the total energy consumption in buildings especially non-domestic buildings.

Indoor environmental conditions are strongly related to thermal comfort which has a direct implication in building energy efficiency. The increase in life expectancy and the particular indoor conditions requirements of elderly, make nursing homes and their Heating, Ventilation and Air Conditioning (HVAC) systems to be designed and operated with different setpoint temperatures, thus provoking higher energy consumption. However, previous studies have developed adaptive thermal comfort models specifically for elderly. Adaptive comfort theory considers that the optimal indoor operative temperature for occupants who can interact with the building and its devices relates primarily to the outdoor environmental conditions.

This research presents a case study of a nursing home in Spain to analyse the energy implications on the application of adaptive thermal comfort models for elderly during the heating and cooling periods.

The results of this research will be used to define good practices to design and operate nursing homes under the same climate and building characteristics.

The results of the research can also be used to design or manage other buildings occupied by elderly such day centres, rehabilitation centres, active adult communities, independent living communities, assisted living residences or retirement villages.

Session 25 Wednesday Silver - Ventilation & thermal control

Time:
Wednesday, 14.06.2023 10:00-11:15

Room: Ag Silver

Chair:
Leivo, Virpi
Tampere University

Co-Chair:
Huang, Qirui
RWTH Aachen - Lehrstuhl für Energieeffizientes Bauen (e3D)

Wednesday, 14.06.2023 10:00-10:15 Room Ag Silver

Natural Ventilation System for Office Buildings with Perforated Metal Ducts on Ceiling

Yamanaka, Toshio (1); Kobayashi, Tomohiro (1); Momoi, Yoshihisa (2); Choi, Narae (3); Tanaka, Hiroaki (4); Fujii, Takuro (4); Mori, Masatoshi (4); Wakasa, Miho (4)

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ID: 1480 Full paper
Topics: 06. Heating, ventilation, air conditioning & cooling
Keywords: Natural Ventilation, Perforated Metal Duct on Ceiling (PMDC), Network Model, Gauss-Seidel Method, Ventilation Shaft

In order to distribute the cool outdoor air evenly in the large office room Perforated Metal Duct on Ceiling (PMDC) are proposed as Natural Ventilation system for large office buildings. The bottoms of the ducts are composed of perforated metal plates and outside air should be designed to make the velocity distribution uniform. The authors developed the duct airflow model to predict supply air flow rate distribution and its results were compared with CFD for validation. From the comparison betweenthen, the pressure loss coefficient of the duct surface was identified, and the distribution of opening ratio of PMDC was obtained by means of duct airflow. In addition, the result was compared with the CFD result for validation.

At last, the authors proposed to adopt PMDC with two vertical ventilation shafts in a high-rise office building. The waste heat from cogeneration system is generated in the ventilation shafts in order to enhance buoyancy-driven ventilation. To estimate this effect, the overall flow network model for the whole building was resolved by Gauss-Seidel iteration method, and an appropriate distribution ratio of waste heat in the ventilation ducts were made clear using this overall network model.

Wednesday, 14.06.2023 10:15-10:30 Room Ag Silver

Resilient cooling strategies: a preliminary study of an all-air system application

Carnieletto, Laura (1,2); Corazza, Laura (1); Bogatu, Dragos-Ioan (3); Shinoda, Jun (3); Kazanci, Ongun Berk (3); De Carli, Michele (1); W. Olesen, Bjarne (3)

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ID: 1387 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Resilient cooling, heatwave, power outage, all-air system, thermal comfort

Resilient cooling is the ability of a building-plant system to withstand and recover after a disruptive event. In particular, heatwaves and power outages have been considered in this study as perturbations of a building-plant system. The present work investigated the operation of an all-air HVAC system combined with two air to water heat pumps in Copenhagen, Denmark. TRNSYS simulations considered both current and future outdoor climatic conditions, both in mid and long term, to evaluate building's energy use. The results showed that during heatwaves operative temperatures higher than 28 °C were registered, but only for 5 to 20% of the occupied time in the worst scenario. The variation was due to the cooling load, which increased as the heatwave increased in length and intensity. Nevertheless, the energy use did not considerably increase with values between 33 to 39 kWh/(m² y) but the system resulted to be non-resilient in most of the cases that combine heatwaves with power outages.

Wednesday, 14.06.2023 10:30-10:45 Room Ag Silver

Development of a Rule-based Control for Hybrid Ventilation Systems and Evaluation by Field Test

Jiang, Jun; Wu, Yue; Rewitz, Kai; Müller, Dirk

RWTH Aachen University, E.ON Energy Research Center, Institute for Energy Efficient Buildings and Indoor Climate

ID: 1168 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: hybrid ventilation, rule-based control, multivariable control system, field test

Hybrid ventilation systems use natural and mechanical ventilation to provide a comfortable indoor environment and minimize energy consumption. In this study, a rule-based control strategy was experimentally developed for a hybrid ventilation system and evaluated by field tests on a facade test bench. The test bench consists of four test rooms with identical office sizes but different windows. In each room, two thermal manikins were set up with ejection nozzles for carbon dioxide (CO2) to simulate the occupants. All windows in the room were able to be tilt opened automatically. For each room, four facade ventilators supplied and extracted the air individually. Temperature and CO2 sensors were installed in each room to determine thermal comfort and indoor air quality (IAQ). Measurements were carried out on different days with various ambient temperature ranges from 5 to 25 °C. The control strategy was evaluated by three categories: predicted mean vote (PMV) and draught rate (DR) for local thermal comfort, CO2 concentration for IAQ, and heating/cooling/ventilation duration for energy saving potential. The evaluation shows that the rule-based control of a hybrid ventilation system, with a limited number of sensors, can ensure good IAQ and thermal comfort with low energy consumption under changing weather conditions.

Wednesday, 14.06.2023 10:45-10:48 Room Ag Silver

Effectiveness of a novel hybrid ventilation system in enhancing the air quality in highly occupied spaces.

Karam, Jennifer; Ghali, Kamel; Ghaddar, Nesreen

American University of Beirut, Lebanon (Lebanese Republic)

ID: 1170 Full paper
Topics: 01. Indoor air quality, particles, aerosols, chemical pollutants, 06. Heating, ventilation, air conditioning & cooling
Keywords: ultraviolet germicidal irradiation, indoor air quality, cross-contamination, classroom, pulsating jet ventilation

This work studies the cleaning effectiveness of a combined system consisting of a pulsating jet ventilation (PJV) and upper room ultra-violet germicidal irradiation (UR-UVGI) lamps in classrooms. The supply flowrate of the PJV and the UV intensity of the lamps are varied in while ensuring air quality and thermal comfort. Their impact on preventing cross-infection is evaluated using the intake fraction (iF) index. The air quality was assessed based on the amount of exhaled CO_2 contained at the breathing level whereas thermal comfort was calculated using a transient, segmental thermal comfort model. A 3D computational fluid dynamic (CFD) model was developed to simulate the airflow field and the contaminants dispersion created by the PJV system. Furthermore, a user-defined function is implemented into CFD to predict the irradiation field created by the UV lamps. A parametric study was performed to obtain the cleaning range of each PJV+UV operating condition considering two infected student positions. It was found that the best infection prevention was obtained when the PJV was supplying at 250 l/s and the lamps operating at 32 W UV-power. In this operation, the maximum exposed student faced iF values between 1.77×10^{-4} and 3.00×10^{-4} according to the infected student position.

Wednesday, 14.06.2023 10:48-10:51 Room Ag Silver

Experimental study on thermal performance and feasibility of heat pump assisted hybrid desiccant cooling system under different load conditions

Liu, Shuo (1); Jang, Hyusan (2); Yeo, Myoung-Souk (3)

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ID: 1339 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: indoor humidity, various load pattern, dehumidification system, thermodynamic processes, thermal performance

Indoor humidity, as a factor that has a significant impact on the living environment and comfort, has become an important control target for modern novel air conditioning systems. The system that combined cooling equipment with solid desiccant wheels can provide an effective humidity control. This paper focus on a heat-pump assisted solid desiccant cooling system (HPDC) that heats the regeneration air by the condensing heat from the condenser. This research aims to conduce the thermal performance and internal air state change of the HPDC system under different indoor load conditions. The experiment result shows that the upstream located evaporator handles a part of dehumidification load. More than 65% of the system's latent cooling capacity is provided by the desiccant wheel. The HPDC system is able to control indoor humidity effectively without extra regeneration heat source under all conditions. The air temperature difference between the process inlet and outlet of desiccant wheel can reach up to 9oC under low SHR and high indoor sensible load conditions, which leads to the increase in indoor air temperature. The thermal imbalance problem between condensing heat demand for effective indoor humidity control and cooling capacity demand for effective indoor temperature control has been clarified.

Wednesday, 14.06.2023 10:51-10:54 Room Ag Silver

Analysis of the effectiveness of opening windows to control infection risk and thermal comfort in school classrooms taking into account climate change

Nateghi, Seyedkeivan; Grygierek, Krzysztof; Kaczmarczyk, Jan; Ferdyn-Grygierek, Joanna

Silesian University of Technology, Poland

ID: 1437 Full paper
Topics: 02. Thermal comfort, temperature, hygro-thermal, humidity, dampness, 06. Heating, ventilation, air conditioning & cooling
Keywords: Natural ventilation; window opening; climate change; indoor environment; Infection risk.

Natural ventilation via window openings is an efficient strategy to improve indoor environment quality and reduce infection risk. However, manual control of windows by occupants is not always effective for maintaining the indoor environment in appropriate condition. Moreover, climate change and global warming have made it difficult to control and predict the conditions. Designing a window controller based on selected objective functions and climate data can improve natural ventilation. In this study, a controller for window opening was developed to naturally ventilate a classroom with 30 occupants. The aim was to analyze the effectiveness of window controllers to control infection risk and the indoor environment under two climate data: present and projected for 2050. The results showed more window openings in cases related to 2050 rather than in the present case. Also, it was shown that in future climate data, optimization of the controller keeps the acceptable conditions for more than 80% of the time. Wearing masks is necessary to maintain the probability of infection risk, and using air cleaners in the classroom is recommended for the future. In future cases, energy demand was reduced by 17% compared to the optimum case of present climate data.

Session 26 Wednesday Oxygen - Lighting & visual environment

Time:
Wednesday, 14.06.2023 10:00-11:15

Room: O2 Oxygen

Chair:
Wienold, Jan
Ecole Polytechnique Fédérale de Lausanne

Co-Chair:
Vasquez, Natalia Giraldo
Technical University Of Denmark

Wednesday, 14.06.2023 10:00-10:15 Room O2 Oxygen

Boosting Productivity of Remote Workers with Biodynamic Lighting

SHARP, NINA (1); FANI, MAHYA (1); ALRAHYANI, MOHAMMED (1,2); YAGUE, NDEYE (1)

1: Arizona State University, United States of America; 2: Qassim University, Saudi Arabia

ID: 1180 Extended Abstract
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views, 08. Psychology, psychophysics, performance & productivity
Keywords: Dynamic lighting, Remote Workers, sleep quality, Alertness, Home-based Offices

The practice of working from home was widespread well before the 2020 Covid-19 pandemic; The Covid-19 pandemic pressed the fast-forward button on this trend. One of the biggest business concerns associated with working from home is how to maintain employees' productivity. Lighting has been proven as the main environmental element that significantly impacts office workers' health, sleep, mood, comfort, cognitive functions, and, consequently, productivity. One inadvertent issue of working from home is the reduction in daily light exposure. Offices are converted from bedrooms and basements which are often illuminated in the recommended 50 – 100 lux range, as opposed to the approximately 500 lux of most office environments. Exposure to dimmed lighting throughout the day and lack of contrast between the daytime and evening lighting could bring about negative effects on the health and productivity of home workers. This study examines the effectiveness of two lighting conditions, applied in real home-based offices, on alertness and cognitive performance of adults working from home. The first condition (L1) is a dynamic lighting scheme that mimics natural lighting by providing blue-enriched bright lighting in the morning (400 lux, 5000K) and yellowish dimmed lighting late in the afternoon (185 lux, 3000K). The other condition (L2) delivers a constant colour (4000 K) and brightness (300 lux) during working hours. Both conditions deliver a similar dosage of circadian lighting throughout the working hours; however, the "time factor" is ignored in the L2 condition. A counterbalanced crossover study is designed. Participants are ten full-time remote office workers, aged 40 to 65 years old, who showed no evidence of sleep disorders (Pittsburgh Sleep Quality Index [PSQI] score ≤ 5), extreme chronotype, and colour blindness. Participants are exposed to each condition for two consecutive weeks (4 weeks of intervention). Daytime cognitive performances and alertness are assessed during the baseline (week 1) and the second week of each intervention (Weeks 3 and

5). Findings show that exposure to both lighting conditions (biodynamic and placebo) improves vigilant attention, working memory, and alertness of home office workers during working hours. These findings exhibit evidence that lighting in home-based workplaces is a significant contributor to improving the cognitive performance and alertness of remote workers and consequently boosting their productivity.

Wednesday, 14.06.2023 10:15-10:30 Room O2 Oxygen

WINDOW VIEW QUALITY IN BUILDINGS: STATE OF ART AND FUTURE DEVELOPMENTS

Sabet, Parinaz; Ciampi, Giovani; Scorpio, Michelangelo; Sibilio, Sergio

Università degli studi della Campania Luigi Vanvitelli, Italy

ID: 1412 Full paper
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: user's wellness, daylight, visual perception, view out, building efficiency

Access to daylight and views of the outdoors are severely restricted in buildings due to the population rise and corresponding increase in density in metropolitan areas. Nowadays, a high-quality window view is essential in people's indoor lives. Due to access to windows and associated views, the literature review suggested focusing primarily on the view concept and only secondarily on daylight exposure. In addition, the result underlined that daylight generally presents ambient levels of interior daylight illumination. Papers, standards, and guidelines focused on the challenges in building performance with the evaluation of view quality were reviewed to determine: i) the principal aspects and elements affecting the view quality, ii) parameters and indexes used to assess window view, iii) set up used to perform investigations on view quality, as well as iv) methods followed to analyze window view from objective and subjective points of view. The results of this review aim to highlight state-of-the-art and critical needs in research, tools, and methodologies that, if satisfied, may enable a more effective estimation of the view quality in buildings. Finally, future challenges and developments related to view are provided.

Wednesday, 14.06.2023 10:30-10:45 Room O2 Oxygen

Study on the lighting requirements of indoor ornamental plants using a growth chamber

Sugano, Soma (1); Ishii, Masahisa (2); Tanabe, Shin-ichi (1)

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ID: 1220 Full paper
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views, 05. Architecture, aesthetics, passive design, biophilia
Keywords: Biophilic Design, Indoor greenery, Growth analysis, Photosynthesis, Daily Light Integral

Information regarding the light levels adequate for the growth of indoor ornamental plants is limited. The objectives of this study were: 1) To analyze the possibility of survival of ornamental plants under low-level lighting conditions, which simulates an indoor workplace environment lacking access to daylight 2) To analyze the impact of extending photoperiod or increasing the intensity of supplementary lighting on the growth of the plants. Three species of ornamental plants were grown in growth chambers for 191 days. Results showed sustained growth of the three plant species under lighting conditions of 0.22 mol/m²·d, which simulated the exposure to 500 lx of white LED lighting for 9 hours/day. This indicated that extra energy consumption through supplementary lighting might be unnecessary if plant species with sufficient shade tolerance are selected and placed appropriately in workplaces. In contrast, differences were noted in growth rate, appearance, and photosynthetic performance of the plants subjected to a light intensity of approximately 500 lx when compared to those subjected to 1500 lx. Under low light intensity, plants down-regulated their photosynthetic activity and suppressed growth. Increasing the intensity of light through supplementary lighting would prove efficient if occupants expect a faster growth rate of ornamental plants.

Wednesday, 14.06.2023 10:45-10:48 Room O2 Oxygen

Towards realistic lighted virtual environments in head-mounted displays: transfer functions effects on luminance representation

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ID: 1378 Full paper
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views
Keywords: Head Mounted Displays (HMD), Immersive Virtual Reality, Luminance Distribution, Experimental Measurements, Light Distribution

Immersive virtual reality can be considered one of the most promising technologic for developing lighting design to satisfy the standard requirements and users' satisfaction. In this process, the deep knowledge of the relation between the digital input values to the frame buffer that controls the software, and the head-mounted displays output is crucial in affecting the users' perception. This paper presents the preliminary results of a comparison between the luminance values in the Unreal Engine 4.27 and an HTC Vive Pro head-mounted display. A simple physical environment was modelled to find the relationship between the luminance values calculated by the software and those shown by the head-mounted display. The absolute luminance values and the luminance ratios were explored by varying the number of luminaires turned on and the luminous flux. In addition, the effect of the tone mapping operator on the luminance values shown by the head-mounted display was also investigated. Results highlight that: i) tone mapping does not influence luminance values obtained in the game engine, and ii) disabling tone mapping allows showing virtual scenes in the head-mounted display whose luminance values and luminance ratios are linearly correlated with those obtained in the Unreal Engine.

Wednesday, 14.06.2023 10:48-10:51 Room O2 Oxygen

Healthy View Review: A Study on Impacts of View to Outdoor on Human Health.

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ID: 1379 Extended Abstract
Topics: 03. Lighting, visual comfort, daylight, circadian lighting, views, 08. Psychology, psychophysics, performance & productivity
Keywords: Mental health, Physical health, Architecture, Well-being

Leading a productive life depends on providing a healthy environment. There has been recent research showing that views of the outdoors may have an adverse effect on the health of users of the built environment. Thus, it is necessary to review the research to improve the quality of future studies and assist researchers.

Analysing high-ranked journal articles published in recent years, this article attempts to determine how views affect physical, mental, social, and spiritual health.

A review of the literature found insufficient research on the impact of view on spiritual and social health. As for two other health dimensions, the findings indicate that view can improve stress, mental fatigue, sleep, satisfaction, well-being, attention, anxiety, depression, cognitive performance, memory, concertation, and creativity in mental health, as well as thermal comfort, healing, and avoiding illness in physical health.

A key goal of this project was to categorise the impacts of view studies on health and identify the gaps in this area to promote future research.

Wednesday, 14.06.2023 10:51-10:54 Room O2 Oxygen

Is there a Hierarchy in visual effects? A preliminary investigation on Occupant Preferences with Dynamic Façades

de la Barra Luegmayer, Pedro (1); Luna-Navarro, Alessandra (1); knaack, Ulrich (1); Prieto Hoces, Alejandro (2); Vásquez, Claudio (3)

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ID: 1467 Extended Abstract
Topics: 07. Occupant behavior & controls
Keywords: Dynamic façade, control strategy, laboratory experiment, preferences, occupant satisfaction

The automated operation of facades in buildings can positively impact indoor environmental quality (i.e. thermal regulation, acoustic control, air quality, and access to daylight and outside view) whilst reducing cooling, heating, and lighting energy demand. However, several studies have also pointed out that the automated operation of dynamic façades can be disruptive to occupants and a source of discomfort when it does not meet occupant requirements.

There are several factors that affect occupant requirements concerning façade operation. However, the hierarchy of importance with which individual occupants perceive these requirements is yet to be understood, and it could inform better user-centred controls of automated facades.

This study shows preliminary results from a measurement campaign with human volunteers aimed at capturing individual occupant hierarchy of preferences in relation to façade configuration and operation. The occupant hierarchy of preference was investigated in regard to (i) access to daylight, (ii) glare mitigation, (iii) privacy, and (iv) view access. Data from occupants' satisfaction with façade operation, considering personal factors, indoor environmental conditions, facade technologies, control scenarios and contextual conditions, were captured in a laboratory setting. These results can improve current façade automated controls to enhance indoor environmental quality, energy savings and occupant acceptance of automated operation facades.

Wednesday, 14.06.2023 10:54-10:57 Room O2 Oxygen

Urban forest views for stress level reduction

Llaguno-Munitxa, Maider; Edwards, Martin; Grade, Stephane; Agudo-Sierra, Elena; Letesson, Clement; Lacroix, Emilie

UCLOUVAIN, Belgium

ID: 1468 Extended Abstract
Topics: 08. Psychology, psychophysics, performance & productivity, 10. Community- and urban-scale challenges and solutions
Keywords: Urban Health, Urban Comfort, Urban Green Infrastructure, Stress Level Reduction, Immersive Media, Bio-environmental Sensing

Recent literature has reported that immersions in nature provide diverse health benefits amongst which it is to highlight the capacity for stress level reduction. However prior studies have mainly focused on parks and wild natural enclaves, and thus the role urban green infrastructure planning can play in stress level reduction is to be further understood. Aiming to fill this research gap, we propose novel research methodologies to on the one hand i) quantify the pedestrian level visual accessibility of urban green infrastructure, and on the other, ii) to develop a participant immersive experience to account for subjective and objective measures linked to green view accessibility. A novel methodology combining biometric and immersive media technologies and participant questionnaires has been proposed to evaluate the positive role urban forest views and its characteristics play in stress level reduction. Most significant positive effect has been observed for vertical urban green infrastructure elements, such as high trees or trees that are positioned in close proximity to the pedestrian.

Practical information

Banking

Although card payments are accepted in most occasions, there are places that accept only EC-cards or cash. Therefore, we advise you to carry cash with you. You can find several ATM machines in the city centre – however, withdrawing cash from your account might be subject to fees. An ATM is located next to Aachen Hauptbahnhof (the main station, right-hand side when leaving through main doors) and close to the location of the Welcome reception (Pontstraße 91-93, 52062 Aachen).

Currency

Germany is part of the many countries that use Euros.

Electricity

Electricity outlets in Germany take type C and F type 220/240V plugs.

Emergency Medical and first aid

Please contact the registration desk or any person from the organizing committee if you have an emergency, medical or first aid need. The University Hospital is 16 minutes away from the conference venue by taxi/car.

Emergency numbers

Police: 110

Fire & ambulance: 112

Language

The official language of the conference is English.

Lost and Found

If you lost something, please contact the registration desk first, send an email to:hbe2023@ukaachen.de or ask any person from the organizing committee. If you found something, please return it to the registration desk or give it to someone from the organizing committee.

Lunch

Daily lunch will be provided in the main hall and allows you to have a look at the posters and the sponsor presentation in the meantime. Please assure to wear your badge visibly. We tried to provide for special dietary requirements (clearly visible) as well, please ask the staff if you are uncertain. During the breaks, coffee/tea and/or refreshments are served.

Mobile Phone

Please switch them off or have them in 'silent' mode while present at any of the sessions during the conference.

No smoking

Smoking is prohibited in all public buildings, restaurants and cafes, including the trains and railway stations.

Parking

The venue has its own free parking space. However, for our environment, we suggest you to use public transport.

Refreshments

Refreshments (soft drinks, tea and coffee) are available for registered participants during the breaks.

Registration desk

The registration desk will be open on Monday June 12th, Tuesday June 13th and Wednesday June 14th between 07:30 and 10:00 at the conference venue (Das Liebig).

On Sunday, June 11th, a registration desk will be set up at the Welcome Reception venue (SuperC) between 18:00 and 21:00.

Fur urgent aspects, you can also call our conference office: +49 241 80 - 96652

Social media

We plan to use Twitter during the conference.

Speaker's room

A speaker's room is available near the registration desk to upload your PowerPoint file. However, we urge you to upload the presentation file before the start of the conference. This is obligatory for poster presentations (see the information provided to you by e-mail and the website). In case needed, you should upload your PowerPoint-file at least 4 hours before your presentation.

Tipping

Tipping generally is expected in restaurants and cafes. Most commonly you would round up your bill. Of course, if you experience good service you may tip more. For hotels tipping is not expected.

Transport options

We recommend you to use public transport for traveling around Aachen. Tickets for public transport will be provided for those who need them at the reception desk during registration. Detail information on route times and bus numbers are provided on the AVV app (website also available: https://avv.de/de - only in German) or on the DB app (website also available: www.Bahn.com/en - available in English and other languages).

In case, you purchased a day-pass via conftool, make sure to have a valid ID and your name badge with you.

Wifi / Internet access

Free Wifi is available. Access information will be available on-site.

Disclaimer

While we aim to ensure that all information provided is correct and the conference programme will take as scheduled, the Organization reserves the right to make changes at any time if this is deemed necessary.

Liability

The Organization will not be liable for any personal accident and/or loss or damage to the property of participants during the Conference. Participants should make their own arrangements with respect to personal insurance.

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