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## Disentangling the complex interactions in dwellings between tenant behaviour, indoor environmental qualities, public health and heating energy demands

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## Ongoing work:

### Disentangling the complex interactions in dwellings between tenant behaviour, indoor environmental qualities, public health and heating energy demands

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The conference ISESISIAQ2019 with the theme “The built, natural, and social environments: impacts on exposures, health and well-being” was hosted jointly by The International Societies of Exposure Science (ISES) and Indoor Air Quality and Climate (ISIAQ) in Kaunas, Lithuania, August 18 – 22, 2019. The conference attracted around 450 delegates from countries all over the world.

The PEIRE project at Lund University and Malmö University organised, together with the Danish research project ReVALUE and BE-READY from Aarhus University, a symposium within the conference titled “Holistic view on the interaction between residents and indoor air quality in dwellings”. The symposium comprised 10 presentations, of which 8 came from the Swedish-Danish projects, and two plenary discussions. Around 50 of the conference delegates attend the symposium.

#### **Approaching a holistic understanding**

The symposium took its starting point in the concept of meta-theory [1]. Studies of the interaction, or rather the transaction, between the physical environment and humans require theories and methods from both the physical/technical domains and the social science/psychological/medical sphere. Any cross-disciplinary cooperation should take into account that definitions, language, practices, methods and desired outcomes are likely to differ between the research fields involved, and that time and joint effort is required in order to identify such differences and find common ground, conceptually as well as socially. A meta-theoretical approach could reveal differences and commonalities between disciplines by making assumptions explicit, and identifying common patterns as well as missing perspectives. From this, triangulation methods across disciplinary borders and conceptual frameworks for organising empirical findings could be developed.

#### **Measurements of human behaviour and the indoor environment**

Within the Swedish PEIRE-project, indoor environmental quality and occupant behaviour in ten typical rental apartments built in the 1970s were extensively measured before and after a major renovation. Behaviour was measured with traditional methods such as interviews and self-report instruments, but also with technical, sensor-based tools in a Behaviour Measurement System (BMS). This system could, for example, detect airing and cooking patterns [2]. Combined with measurements of airborne particles and CO<sub>2</sub>, it is clear that residents’ activities contribute largely to the variation of indoor air quality [3]. Therefore, even though the renovation had a positive effect on the removal of ultrafine particles as a result of increased air extraction, differences between tenants’

behaviour, in terms of cooking and lighting candles, influenced the magnitude of this effect. In addition, individual differences in how tenants regulated the air inlet, i.e. windows and vents, were of importance for the air flows in the apartments, resulting in different air quality in different rooms [4]. The renovation, that included reducing the heat transfer through the building envelope by partly changing windows and walls, had, as expected, a positive effect on the heat distribution in the measured dwellings so that the temperature at different levels above the floor were less divergent [5]. Some apartments on the 1<sup>st</sup> and 2<sup>nd</sup> floors were perceived as too warm after the renovation, also confirmed by temperature measurements [6]. The temperatures in the apartments on the 3<sup>rd</sup> floor, however, became cooler the year after the renovation, possibly due to an insufficient balancing of the heating system. This indicates that adjustments of the heating system in relation to the other taken renovation measures are essential in order to achieve the right comfort temperature. The balancing of the heating system may take more time than planned which have implications not only when planning scientific measurements campaigns. The adjustment and balancing phase seem to be crucial and should be emphasised for planning of renovation to ensure provision of best possible conditions for tenants as soon as possible after the renovation.

### **Public health consequences**

People spend the majority of their lives indoors in varying environmental quality, leaving them exposed to harmful substances and conditions affecting their health and comfort. A large part of this time, around 16 hours per day, is spent at home, why the quality of these environments is of outmost importance. People living in rental housing do not have major influence on the build environment, even though it is their homes and they are the ones living and breathing there. Therefor two large Danish research projects called ReVALUE and BE-READY have a focus on health symptoms related to the built environment in multifamily social housing areas undergoing energy renovation. The objective is also to identify added values in the build environment to perform as arguments of more extensive building renovation than mere energy renovation [7].

### **Energy efficiency results**

Measures undertaken by a renovation should lead to increased energy efficiency. This was also the case in the housing block in which the PEIRE project took place; the energy demand in the dwellings was calculated to decrease 30kWh/m<sup>2</sup> per year [8]. However, the mechanical ventilation system required the tenants to regulate the air inflow by vents and windows to achieve a healthy indoor air quality. There was large individual differences between tenants in how they perceived their indoor environmental quality and what they meant by comfort. Simulations showed that these individual differences could lead to differences in vent and window opening behaviours that result in differences in energy demand at the same magnitude as the renovation in itself.

### **Discussion**

The presentations at the symposium, together with comments from the audience, raised questions for the continuing work. In both the Swedish and the Danish studies, indoor environmental qualities and human behaviour were measured with an array of methods. Questions from the audience mainly concerned separate methods from a single-discipline perspective, despite encouragement from the moderator to focus on the holistic perspective. From our point of view, it is of more importance to ask which of these measurements actually provide a state of the art and contribute to the holistic understanding [7]. Is it even desirable to include everything, or it is possible to find key parameters that can be indicators? And how should we in the end understand and present what is going on?

Moving forward, there is a clear need to further analyse retrieved data and look for associations and contradictions. In parallel, it is important to start a process where theories from the comprised disciplines consist basis for new ways to organise our knowledge [1]. This will entail a constant comparison approach in which theoretical concepts are tested in empirical findings and adjusted, and tested in data again, until a satisfactory understanding is reached.

**Presentations from the Swedish–Danish group (presenters in bold). The abstract book of the conference in which the full abstracts are found can be down-loaded from:**

**<http://isesisiaq2019.org/abstracts/>**

1. **Kristian Stålné**, Eja Pedersen, Jonas Borell, Yujing Li: Indoor environments as complex systems and the need for metatheories
2. Jonas Borell, **Günter Alce**: Measuring the occupant behaviour aspect of indoor air in apartments
3. **Yuliya Omelekhina**, E. Pedersen, B. Nordquist, P. Wallentén, P. T. Nilsson, A. Wierzbicka: Influence of the renovation on ultrafine particle concentrations in occupied Swedish residences
4. **Petter Wallentén**, Birgitta Nordquist, Lars-Erik Harderup: Measurement of how users affect air flows between rooms in renovated apartments with exhaust ventilation.
5. **Karin Lundgren-Kownacki**, A. Halder, J. Petersson, K. Kuklane, A. Wierzbicka, E. Pedersen, C. Gao: Does a building renovation improve the indoor thermal comfort? - A thermal environment evaluation before and after renovation
6. Philip Petersson, **Petter Wallentén, Birgitta Nordquist**, Lars-Erik Harderup: Measured and perceived thermal comfort in apartments, before and after renovation.
7. **Charlotte Gabel**, Grethe Elholm, Steffen Petersen, Mia Kruse Rasmussen, Torben Sigsgaard: Correlation between technical indoor air and tenants' perception of their indoor air, health and habits - Results from a Danish multiple site interdisciplinary cross-sectional study
8. Robert Magnusson, Niklas Sellin, **Birgitta Nordquist**, Petter Wallentén, Lars-Erik Harderup: Calculations of how users affects energy use and indoor environment by interaction with the ventilation system in apartments with exhaust ventilation systems.

Presentations from other contributors:

**Dusan Licina**: Indoor air quality and occupant satisfaction in BREEAM and WELL certified buildings: A case study.

**Gediminas Mainelis**: Investigation of indoor exposures and indoor air quality in multi-apartment buildings using three different data streams

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