Indoor Environment Quality as a multi-level, multi-factor, multi-disciplinary and multi-stakeholder issue

A condensed version of the inaugural speech "Understanding the indoor environment" spoken on May 22, 2013 at the occasion of her acceptance of the position of full professor of Indoor Environment at the Faculty of Architecture of the Delft University of Technology.

Prof.dr.ir. P.M. Bluyssen
© TUDelft, photo by Job Jansweijer

PHILOMENA M. BLUYSSEN
Prof. dr. ir. MBA
P.M.Bluysen@tudelft.nl

Key words: indoor environment, indoor environmental quality, thermal comfort, indoor air quality, indoor climate

Introduction

How to achieve a healthy indoor environment has been an issue among architects, engineers and scientists for centuries. However, it was not until the early decades of the twentieth century that the first relations between parameters describing heat, lighting and sound in buildings and human needs were established. For most of the time, science has relied on the optimisation of single factors such as thermal comfort or air quality. The realisation that the indoor environment is more than the sum of its parts, and that its assessment has to start from human beings rather than benchmarks, has only been gaining ground in recent years. The understanding of that indoor environment has only just begun.

The indoor environment can be described by the environmental factors or (external) stressors indoor air quality, thermal comfort, acoustical quality and visual or lighting quality (**Figure 1**). These various factors have slowly become incorporated within the building process through environmental design. However, aesthetic quality and spatial and ergonomical quality are also part of the indoor environment. In fact, historically these parameters received the most attention when designing a building. The chair "Indoor environment" merely focuses on the environmental parameters, without downgrading the dimensions and aesthetics of shapes and spaces.

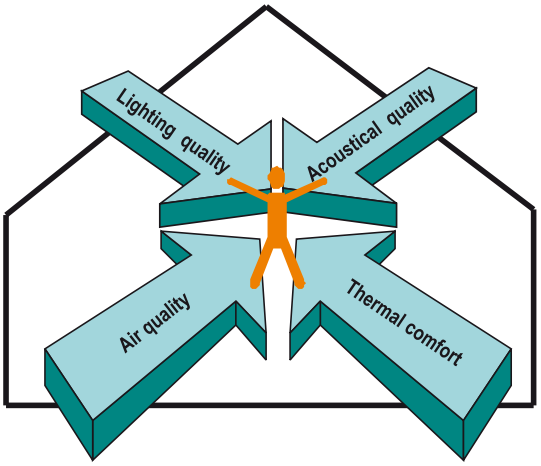

Figure 1. What is indoor environment quality? (Bluyssen, 2009: figure 3.1).

Facts and gaps

Most people are aware of the importance of the outdoor environment, especially in relation to climate change issues but also related more directly to our health, the effects of indoor environment quality are not that common knowledge. What most people also don't realize is that there are many diseases and disorders related to that indoor environment. In the last decade or so we are confronted with new diseases and disorders related to indoor environmental quality such as mental illnesses (Houtman et al., 2008), obesity (Bonnefoy et al. 2004) and illnesses that take longer to manifest, among which cardiovascular and chronic respiratory diseases and cancer (Lewtas, 2007; Fisk et al. 2007). If you look at the scientific outcomes it seems that staying indoors is not good for our health, even though the conditions seem comfortable enough (according to the standards we apply, according to the control strategies we have taken).

Why do we have still do not have this under control? Even after more than 100 years of R&D. To my opinion there are at least two major gaps contributing to an explanation for this situation.

Gap1

Starting with the first one: a gap or lack of knowledge shown by the discrepancy between standards and end-users wishes and needs! Even though standards are met, complaints and symptoms occur. Why and how do people respond, and which indicators can be used is thus an important question to answer. The health and comfort indicators we are today familiar with can be divided in three groups of indicators:

- The occupant or end-user: such as sick leave, productivity, number of symptoms or complaints, health adjusted life indicators or specific building related illnesses.
- The dose or environmental parameter: concentrations of certain pollutants, temperature and lighting intensity.
- The building and its components: certain characteristics of a building and its components, such as possibility for mould growth and even labelling of buildings or its components.

Of these groups of indicators, the dose related indicators, are used most frequently in guidelines and standards. But the dose-response mechanisms are not straightforward. Ventilation rate is a good example of this. Based on either CO_2 as an indicator for bioeffluents or on certain emissions of building materials, minimum ventilation rates have been discussed and are still being discussed for almost two hundred years now (**Figure 2**).

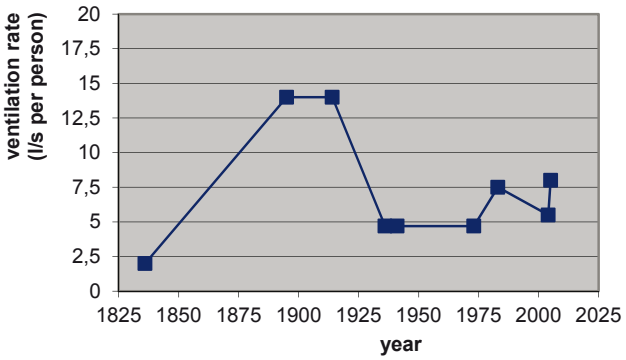

Figure 2. The recommended minimum ventilation rate over the years (Bluyssen, 2009: figure 5.2).

Also with thermal comfort discussions are prominent present. Another model, based on field studies of people in daily life, slowly begins to win ground (de Dear and Brager, 2002): the adaptive comfort model, in which the context and preferences of the occupant are considered to be important. And then even more recently it was suggested that thermal neutral conditions do not have to be necessarily healthy (Marken Lichtenbelt et al. 2009).

While current guidelines are focused on providing sufficient task lighting, research on biological lighting demands has revealed that the dosing of natural light is important for health purposes. The amount of light that enters the eye affects our bio-rhythm: under influence of light, the hypothalamus signals to the pineal body to produce melatonin, a hormone that makes us want to sleep. If exposed to light during night, the production of the anti-oxidant melatonin is immediately stopped, alertness and core body temperature is increased and sleep is distorted (Duffy and Czeisler, 2009).

And last but not least, noise has been associated with direct and indirect stress reactions. Annoyance is an important aspect in this mechanism (Babisch, 2002). It seems that noise effects do not only occur at high sound levels, but also at relatively low environmental sound levels, when certain activities such as concentration, relaxation or sleep are disturbed.

Diving into the literature of several fields of research, it can be found that the relations between the stressors, the stress mechanisms the human body has to cope with those stressors and the identified diseases and disorders, are very complex. It seems that interactions occur at human level, which can partly explain

the complexity. Additionally, interactions at parameter level can be seen that need to be considered, for example chemical interactions between pollutants in the air and microbiological growth at indoor surfaces, and interactions with the outdoor environment such as noise from outdoors, fine dust and biological lighting. And then we are also dealing with interactions between elements of the buildings and between the building and the environment. Interactions occur at different levels and in different ways.

Gap2

The second gap is related to the use of knowledge. The discrepancy seen between what end-users want/need and what they get, points not only to a lack of knowledge but also to an inefficient or wrong use of existing knowledge. The question 'How can existing knowledge be applied efficiently during the whole life cycle of a building' seems therefore just as important to answer in order get more insight in this complexity.

Answers should be found in the way communication takes place in the building process, lead by the different stakes of the stakeholders involved. The dynamic process of designing, constructing and managing the indoor environment, involves many stakeholders, such as the investor, owner, the end-user, the contractor, sub-contractors, local authorities and pressure groups. If those stakeholders do not understand each other, problems can occur. But answers can also be found in the fragmented structure of the buildings sector, leading to lack of coherency and slow take-up of innovation. In other words, the general awareness of what indoor environmental quality is, how you can improve it and who should or can undertake actions, is poor.

Drivers

In addition to the gaps presented we can also see that the drivers for health and comfort in the indoor environment are different from 100 years ago, leading to an increase in complexity. We see (**Figure 3**):

- Climate change resulting in serious energy-efficient measures for the built environment that can certainly have an effect on health and comfort of the indoor environment.
- Change from family-oriented to multifunctional and divers society.
- Individualization/Ageing population leading to other/new needs and demands.
- New products and materials leading new emissions and other behaviour.

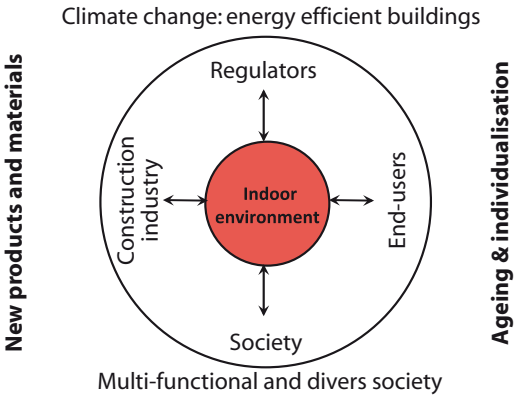

Figure 3. Drivers are different from 100 years ago (Bluyssen, 2013: figure 8.3).

Keeping to our old ways of assessing things, will therefore certainly not be enough. We need to adapt our current assessment and designing methods as well.

Needs

To cope with these gaps and changes we need first of all a different view on Indoor Environmental Quality (IEQ). The current view only considers single-dose relationships. With the exception of health-threatening stimuli, the complexity and number of indoor environmental parameters as well as lack of knowledge make a performance assessment using only threshold levels for single parameters difficult and even meaningless. We need a view in which for different scenarios, possible problems, interactions, people and effects are all taken into account. Focusing on situations rather than single components (**Figure 4**).

How we evaluate and respond to our environment does not only depend on the external stressors involved (physical and psycho-social), but also on personal factors

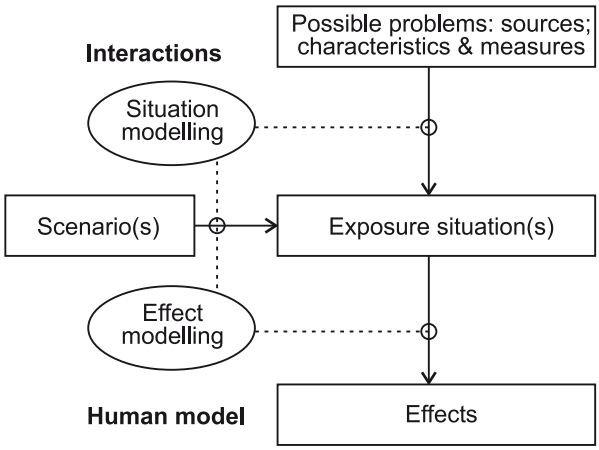

Figure 4. A different view on indoor environment quality (Bluyssen, 2013: figure 7.1).

and processes that occur over time, influenced by past events and episodes. They all determine the way external stressors are handled at the moment or over time. And they are all important to consider when an attempt is made to pinpoint the effects caused by different stressors (or combination of stressors). This means that besides a different view on IEQ it is important to consider other assessment methods and indicators.

The challenge of today lies in the accomplishment of sustainable and low-energy built environment and at the same time a healthy and comfortable built environment. This emerging fact, requires a multidisciplinary interactive top-down approach to facilitate the (re)design, construction, maintenance and operation of an indoor environment, in which the architect as well as the other stakeholders fulfil a new or different role. The architect as the integrating engineer who is able to optimise all components of a building along with the overall demands and needs, whether this is related to health, comfort or sustainability issues.

Ambition

My ambition is to establish an integrated research & education programme on Understanding and managing the indoor environment, in which is dealt with all the needs presented, in due time. A programme for future architects that can help them to fulfil the required multi-disciplinary coordinating role in the building industry on the one hand and the creation of truly sustainable buildings during the whole life-cycle on the other. Two books have been written to support this creation of awareness and will be made available for the educational programme at bachelor and/or masters level (Bluyssen, 2009 and 2013). The development of an integrated approach towards risk assessment of indoor environment quality, based on the assumption that the indoor environment is more than the sum of its parts, and that its assessment has to start from human beings rather than benchmarks (of single-dose relationships), will form the basis to realize this ambition.

Closure

I strongly believe a multi-disciplinary approach is needed in the building industry to create sustainable buildings. At national, European and world-wide level, it is acknowledged that a healthy and comfortable indoor environment is important for the quality of life, now and in the future. The architect will need to have a more than ever coordinating role in this approach as the overall systems engineer, with a basic multi-disciplinary knowledge and integrating capabilities. This new role requires a multi-disciplinary educational program with strong cooperation within and outside of the university, with organisations such as REHVA which is an excellent vehicle for bringing theory and practice together. ■

References

Babisch, W. (2002) The noise/stress concept, risk assessment and research needs, Noise and Health, 4: 1-11.

Bluyssen, P.M. (2009) The Indoor Environment Handbook: How to make buildings healthy and comfortable, Earthscan, London, UK.

Bluyssen, P.M. (2013) The healthy indoor environment: How to assess occuppants' wellbeing in buildings, Taylor & Francis, forthcoming by Earthscan from Routledge.

Bonnefoy, X.R., Annesi-Maesona, I., Aznar, L.M., Braubachi, M., Croxford, B., et al. (2004) Review of evidence on housing and health, background document for the Fourth Ministerial Conference on Environment and Health, Copenhagen.

De Dear R. and Brager, G. (2002) Thermal comfort in naturally ventilated buildings: revisions to ASHRAE standard 55, Energy and Buildings 34 (6).

Duffy, J.F and Czeisler, C.A. (2009) Effect of light on human circadian physiology, Sleep Med Clin. 4: 165-77.

Fisk, W.J., Lei-Gomez Q., M.J. Mendell (2007) Meta-analysis of the associations of respiratory health effects with dampness and mold in homes, Indoor Air, 17(40), 284-296.

Houtman, I., Douwes, M., de Jong, T., et al. (2008) New forms of physical and psychological health risks at work, European Parliament, Policy department Economic and scientific policy, IP/A/EMPF/ST/2007-19, PE 408.569, Brussels, Belgium.

Lewtas, J. (2007) Air pollution combustion emissions: Characterization of causative agents and mechanisms associated with cancer, reproductive, and cardiovascular effects: The Sources and Potential Hazards of Mutagens in Complex Environmental Matrices - Part II. Mutation Research/Reviews in Mutation Research 636, 95-133.

Marken Lichtenbelt, van W.D., Vanhommerig, J.W., Smulders, N.M., Drossaerts, B.S., Kemerink, G.J., Bouvy, N.D., Schrauwen, P., Teule, G.J.J. (2009) Cold-activated brown adipose tissue in healthy men, The New England Journal of Medicine, 360: 1500-8.