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Indoor air quality impacts into life cycle assessments of buildings and building

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Abstract. Human exposure to indoor pollutant concentrations is receiving increasing interest in Life Cycle Assessment (LCA). Products used during construction and operation of a building can contribute to Indoor Air Quality (IAQ) problems that affect occupants' well-being. However, IAQ is conventionally not addressed in the life cycle assessments (LCAs) of buildings and building related products even though IAQ leads to one of the areas of protection under LCA - human health impacts. In this study, we proposed an overall framework for integrating IAQ into LCA using the standard steps of LCA. The framework focused on IAQ and LCA modeling from two categories of building related products: i) passive products that realize their function through initial installation and have long-term decayed emissions, and ii) active equipment that realize their function and cause emissions through daily operation. Dynamic and static life cycle inventory modeling approaches were proposed for passive products and active equipment, respectively. This study demonstrates the appropriateness and significance of integrating indoor environments into LCA, which ensures a more holistic account of all exposure environments and allows for a better accountability of health impacts.

Keywords: Indoor air quality, life cycle assessment of buildings and building.

Introduction

This document is one of a series of International Standards intended for use in the design of buildings and heating, ventilation and air conditioning systems. This series of International Standards specifies the methods of deriving design criteria for new buildings and systems and the retrofit of existing buildings for acceptable indoor environment. The indoor environment includes thermal, acoustic and lighting conditions, and indoor air quality (IAQ).

This International Standard covers methods of expressing IAQ and incorporating the goal of achieving good IAQ into the design process.

This International Standard recognizes that local laws, directives and regulations always apply and this document allows a compliance path which is consistent with such requirements.

The framework is established by the general principle documents.

This document does not prescribe a specific method but rather refers to existing methods in published standards and guidance, as referenced in this document. The referenced methods can be used to specify ventilation rates and other design requirements. The methods have in common the fact that they are based on a consideration of human health and/or comfort requirements. Therefore, the aim of the methods is to control indoor air pollutants to concentration levels below which, under the prevailing hygro-thermal conditions, the pollutants do not have the potential to :

— cause a significant risk of adverse health effects,

— adversely affect the comfort of the majority of occupants.

The pollutants considered include human bioeffluents, which have often been the principal consideration for IAQ and ventilation, but also all groups and sources of pollutants that can reasonably be anticipated to occur in the building being designed. The pollutants to be considered can, depending on the sources present, include

- volatile organic compounds (VOCs) and other organics, such as formaldehyde,
- environmental tobacco smoke (ETS),
- radon,
- other inorganic gases, such as ozone, carbon monoxide and oxides of nitrogen,
- viable particles, including viruses, bacteria and fungal spores,
- non-viable biological pollutants, such as particles of mites or fungi and their metabolic products,
- non-viable particles, such as dusts and fibers.

2 Scope

This International Standard is intended: to specify methods to express the quality of indoor air suitable for human occupancy, to allow several acceptable target levels of IAQ, depending on local requirements, constraints and expectations.

This International Standard applies to

- the design of new buildings and their systems and the retrofit of existing buildings and systems,
- indoor environments where the major concern is that of human occupants,
- buildings having any combination of mechanical and natural ventilation,
- commercial and institutional buildings.

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.ISO 16813, Building environment design ;Indoor environment; General principles.

The law on the improvement of indoor air quality in closed places accessible to the public comes into force on 11 December 2022.This law constitutes a framework that must be supplemented by royal decrees. It does not therefore create direct obligations for the sectors affected by its application. These obligations and their implementation schedule will be specified in the coming months. The law establishes two reference level, indicative of indoor air quality, which are targets that each operator should aim to achieve when making investments to improve indoor air quality.

Reference level A:

- the concentration of CO_2 in a room is less than 900 ppm (which means that CO_2 represents 0.09% of the volume of the air considered), or

-t he minimum ventilation and air purification flow rate is 40 m^3 per hour per person, including at least 25 m^3 per hour per person of ventilation with outside air.

Reference level B:

- the concentration of CO_2 in a room is less than 1,200 ppm (which means that CO_2 represents 0.12% of the volume of the air considered), orthe minimum ventilation flow rate with outside air is 25 m^3 per hour per person.

4 Methods

We first review potential human health impacts associated with the substances in building materials and the methods used to mitigate these impacts, also identifying several of the most important online data resources. A brief overview of the necessary steps for characterizing use stage chemical exposures and health impacts for building materials is then provided. Finally, we propose a systematic approach to integrate the use stage exposures and health impacts into building material LCA and describe its components, and then present a case study illustrating the application of the proposed approach to two representative chemicals: formaldehyde and methylene diphenyl diisocyanate (MDI) in particleboard products. Our proposed approach builds on the coupled near-field and far-field framework proposed by Environ Int 94:508–518, 2016, which is based on the product intake fraction (PiF) metric , The proposed approach consists of three major components: characterization of product usage and chemical content, human exposures, and toxicity, for which available methods and data sources are reviewed and research gaps are identified. The case study illustrates the difference in dominant exposure pathways between formaldehyde and MDI and also highlights the impact of timing and use duration (e.g., the initial 50 days of the use stage vs. the remaining 15 years) on the exposures and health impacts for the building occupants.

Conclusions

When approaching IAQ problems, efforts should be oriented on finding solutions that take into account several parameters and can therefore be useful to solve or avoid multiple issues. Attention should be given to the importance of reducing contaminants at the source (including the choice of non-emissive materials, increasing air tightness, and insulation), improving ventilation and, when relevant, purifying or treating the indoor environment. The integrated IAQ management approach that is presented here should be considered by decision makers, managers, public health players, and occupants that are wishing to maintain good IAQ in the context of climate change. The proposed approach thus provides the methodological basis for integrating into LCA the human health impacts associated with chemical exposures during the use stage of building materials. Data and modeling gaps which currently prohibit the application of the proposed systematic approach are discussed, including the need for chemical composition data, exposure models, and toxicity data. Research areas that are not currently focused on are also discussed, such as worker exposures and complex materials. Finally, future directions for integrating the use stage impacts of building materials into decision making in a tiered approach are discussed.

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