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Standards for evaluating indoor air

Chuck Yu[1]*and Derrick Crump[2]

[1]International Society of the Built Environment (ISBE), UK
Email: editorial@ibejournal.co.uk

[2]Institute of Environment and Health (IEH), Cranfield University, Bedfordshire, MK43 0AL
Email: d.crump@cranfield.ac.uk

*** Corresponding author:** Prof Chuck Yu

Contact Address: 29 The Nortons, Caldecotte. Milton Keynes MK7 8HQ, UK.

International Society of the Built Environment: www.isbeltd.com

Email: chuck.yu@isbeltd.com

Tel: +44 (0)1908 370887

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It is arguably an indication that an area of science has matured when a wide range of international standards are available to support application of knowledge and facilitate sharing of data around the globe. Measurements undertaken according to international standards ensure the data is obtained according to agreed best practice and that issues of quality and uncertainty have been considered. It allows comparability of studies for example to assess whether levels of a particular pollutant in buildings in Europe are higher or lower than say America of China. It can allow collation of data to form large data sets important for epidemiological studies and it may ensure that a product manufactured and tested in one country meets the specification of a client in a different country.

If we consider international standards for measurement of chemical, biological and physical parameters that impact indoor air quality then indoor air can be considered as a maturing science, though perhaps more for a young adult than someone in retirement. Few countries have legislative requirements for indoor air pollutants in non-occupational environments and this probably explains why their development has lagged behind standards relating to ambient (outdoor) air. Governments have funded development of standard methods for measuring air pollutants to check compliance with limit values, such as in Europe where the European Standards Organisation (CEN) receive mandates to develop standards for measuring pollutants such as nitrogen dioxide, benzene and PM_{10} particulates to support the Ambient Air Quality Directive. However increasingly national building codes may include criteria for air quality and the World Health Organisation [1] have recommended guidelines for a number of indoor pollutants in recognition of the important role of the indoor environment has for determining people's exposure to pollutants and thereby their impact on human health.

Development of international standards for measuring parameters determining indoor air quality is under the remit of technical committee ISO TC 146. The committee have now published 23 standards and a number of others are under development (Table 1). For measurement of individual pollutants there are a number of separate standards for describing the strategy of measurement and one or more procedures for measurement (e.g. active and diffusive methods). Most standards address measuring air quality parameters in buildings and one group is for evaluating chemical emissions from materials. It is notable that a series of new standards concerning air quality in new motor vehicles is under preparation by a joint working group involving ISO TC 146 and another committee concerned specifically with road vehicles. The approach being taken reflects both the experience of ISO TC 146 but also methods developed in the car industry by a number of manufacturers to ensure appropriate quality of in car materials with respect to chemical emissions, including measures to prevent fogging of windscreens through deposition of semi-volatile compounds (SVOCs) released by materials onto the glass in the vehicle cabin.

Table 1. ISO 16000 series of International Standards on measurement of indoor air quality parameters

Published standards	
ISO 16000-1:2004	Indoor air -- Part 1: General aspects of sampling strategy
ISO 16000-2:2004	Indoor air -- Part 2: Sampling strategy for formaldehyde
ISO 16000-3:2001	Indoor air -- Part 3: Determination of formaldehyde and other carbonyl compounds -- Active sampling method
ISO 16000-4:2004	Indoor air -- Part 4: Determination of formaldehyde -- Diffusive sampling method
ISO 16000-5:2007	Indoor air -- Part 5: Sampling strategy for volatile organic compounds (VOCs)
ISO 16000-6:2004	Indoor air -- Part 6: Determination of volatile organic compounds in indoor and test chamber air by active sampling on Tenax TA sorbent, thermal desorption and gas chromatography using MS/FID
ISO 16000-7:2007	Indoor air -- Part 7: Sampling strategy for determination of airborne asbestos fibre concentrations
ISO 16000-8:2007	Indoor air -- Part 8: Determination of local mean ages of air in buildings for characterizing ventilation conditions
ISO 16000-9:2006	Indoor air -- Part 9: Determination of the emission of volatile organic compounds from building products and furnishing -- Emission test chamber method
ISO 16000-10:2006	Indoor air -- Part 10: Determination of the emission of volatile organic compounds from building products and furnishing -- Emission test cell method
ISO 16000-11:2006	Indoor air -- Part 11: Determination of the emission of volatile organic compounds from building products and furnishing -- Sampling, storage of samples and preparation of test specimens
ISO 16000-12:2008	Indoor air -- Part 12: Sampling strategy for polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and polycyclic aromatic hydrocarbons (PAHs)
ISO 16000-13:2008	Indoor air -- Part 13: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) -- Collection on sorbent-backed filters
ISO 16000-14:2009	Indoor air -- Part 14: Determination of total (gas and particle-phase) polychlorinated dioxin-like biphenyls (PCBs) and polychlorinated dibenzo-p-dioxins/dibenzofurans (PCDDs/PCDFs) -- Extraction, clean-up and analysis by high-resolution gas chromatography and mass spectrometry
ISO 16000-15:2008	Indoor air -- Part 15: Sampling strategy for nitrogen dioxide (NO_2)
ISO 16000-16:2008	Indoor air -- Part 16: Detection and enumeration of moulds -- Sampling by filtration
ISO 16000-17:2008	Indoor air -- Part 17: Detection and enumeration of moulds -- Culture-based method

ISO 16000-23:2009	Indoor air -- Part 23: Performance test for evaluating the reduction of formaldehyde concentrations by sorptive building materials
ISO 16000-24:2009	Indoor air -- Part 24: Performance test for evaluating the reduction of volatile organic compound (except formaldehyde) concentrations by sorptive building materials
ISO 16017-1:2000	Indoor, ambient and workplace air -- Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography -- Part 1: Pumped sampling
ISO 16017-2:2003	Indoor, ambient and workplace air -- Sampling and analysis of volatile organic compounds by sorbent tube/thermal desorption/capillary gas chromatography -- Part 2: Diffusive sampling
Standards under development	
ISO 16000-18	Indoor air -- Part 18: Detection and enumeration of moulds -- Sampling by impaction
ISO/DIS 16000-19	Indoor air -- Part 19: Sampling strategy for moulds
ISO/NP 16000-21	Indoor air -- Part 21: Detection and enumeration of moulds -- Sampling from materials
ISO 16000-25	Indoor air -- Part 25: Determination of the emission of semi-volatile organic compounds by building products -- Micro-chamber method
ISO/DIS 16000-26	Indoor air -- Part 26: Sampling strategy for carbon dioxide (CO_2)
ISO/WD 16000-27	Indoor air -- Part 27: Determination of settled fibrous dust on surfaces by SEM (scanning electron microscopy) (direct method)
ISO/DIS 16000-28	Indoor air -- Part 28: Determination of odour emissions from building products using test chambers
ISO/NP 16000-29	Indoor air -- Part 29: Test methods for VOC detectors
ISO/NP 16000-30	Indoor air -- Part 30: Sensory testing of indoor air
ISO/WD 16000-31	Indoor air -- Part 31: Measurement of flame retardants and plasticizers based on organophosphorus compounds -- Phosphoric acid ester
ISO/NP 16000-32	Indoor air -- Part 32: Investigation of constructions on pollutants and other injurious factors -- Inspections
Joint working - Standards under development	
ISO/DIS 12219-1	Indoor air of road vehicles -- Part 1: Whole vehicle test chamber -- Specification and method for the determination of volatile organic compounds in cabin interiors
ISO/DIS 12219-2	Indoor air of road vehicles -- Part 2: Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and materials -- Bag method
ISO/DIS 12219-3	Indoor air of road vehicles -- Part 3: Screening method for the determination of the emissions of volatile organic compounds from vehicle interior parts and

	materials -- Micro-chamber method
ISO/CD 12219-4	Indoor air of road vehicles -- Part 4: Determination of the emissions of volatile organic compounds from car trim components -- Small chamber method
ISO/NP 12219-5	Indoor air of road vehicles -- Part 5: Screening method for the determination of emissions of volatile organic compounds (VOC) from car trim components

The international standards concerning VOC emissions from construction products along with the analytical methods for formaldehyde (ISO 16000-3) and VOCs (ISO 16000-6) are key base documents for the preparation of the proposed harmonised European standard for determining VOC emissions in support of the Construction Products Directive. This was described in some detail previously by Yu and Crump [2], and since that time the work within CEN has progressed so that the robustness testing of the draft standard is now underway. This will investigate and confirm the appropriate values for a number of test parameters, such as the required precision of the temperature and humidity conditions during the environmental chamber test. This demonstrates the important role that ISO standards can have for defining standards that are highly important for manufacturers and users of products.

An important aspect of standard preparation is to seek to prescribe procedures in sufficient detail to ensure the user can carry out the test effectively but not so precisely as to deter innovation whereby improved methods can be applied. Often this is achieved by providing informative notes and annexes giving details of how a certain requirement may be achieved and the mandatory (normative) requirement is expressed in performance (outcome) terms. A second element of adopting innovation is the regular review of standards to enable updating to include new improved methods.

An example of the importance of updating is current work to amend ISO 16000-6. This is a key standard for measuring VOCs in emissions chamber air (as well as the air of buildings, cars etc.) and thereby supports the development of standards for the CPD and also the labelling of construction products based on their emissions in a number of countries. There is increasing interest in the measurement of SVOCs as well as very volatile VOCs because of concerns about possible health effects of some compounds. The current standard is very focussed on the VOC range classically defined by WHO as compounds with boiling points between hexane and hexadecane. To help meet this need the proposed revised standard offers more detailed advice about the use of multi-sorbent tubes to extend the range of compounds that can be determined. It includes the use of quartz wool in front of Tenax to improve collection and recovery of SVOCs. Much of this extra information is ‘informative’ because additional performance information such as uncertainty of measurement is still required. These innovations have become possible because of improvements in the thermal desorption/gas chromatography and mass spectrometry systems (TD/GC/MS) that allow the determination of a wider boiling point range than possible with commercial systems that were available when the standard was first developed.

But our knowledge continues to expand and new developments are expected to lead to further amendments in years to come. For example Crump et. al. [3] discussed evidence for the trapping of ultrafine and fine particles as well as vapour by sorbent tubes used for thermal desorption analysis. Other workers report the effective trapping of particulates by sorbent tubes containing PDMS (polymethylsiloxane) and Tenax and subsequent analysis to determine polyaromatic hydrocarbons associated with both the vapour and particulate phase [4]. Given the increasing recognition of the role of particles, including ultrafines, as a cause of adverse health effects, there is a demand for cost effective methods appropriate for measuring chemicals associated with particles in indoor environments. Therefore there is a research need to improve understanding of the effectiveness of existing and new sorbents/ sorbent combinations appropriate for TD/GC/MS analysis that offers the possibility of high sensitivity, but with low volume sampling more suited to indoor environments rather than the high volume samplers traditionally used in outdoor environments. Should this approach prove to be as effective as initial research suggests, then this could enable more informative studies of indoor air quality and human exposure and possibly lead to future revision of ISO 16000-6 to further widen its application.

In summary therefore international standardisation is an effective means for scientists and other practitioners to share experience and identify best practice and when applied it can optimise comparability of data around the world. Such standards require a certain maturity in the subject and the indoor air sciences can be considered as having reached that stage. The evolution of this science is well documented through the series of tri annual conferences in the 'Indoor Air' series, the most recent (and 12th) being held in Austin, Texas, in June 2011. The more than 1,000 papers will take some time to be assimilated by the indoor science community but no doubt a number of findings will inform future standards development. For example the considerable number of papers on SVOCs in indoor air and house dust is indicative of current interest in this topic and the planned new work on flame retardants in air and dust in ISO (ISO 16000-31) reflects some of these developments.

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