A Study of Perceived Air Quality and Odours

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Abstract. Indoor air quality affects comfort, health and performance of buildings occupants. Chemical assessments and sensory assessments of indoor air quality contribute comprehensive knowledge on the state of the indoor environment. Fresh air without harmful pollutants is a prerequisite for a quality internal environment. This aim of the contribution is to emphasize the importance of ventilation intensity on the quality of the indoor environment. Chemical and sensory assessments of indoor air quality were done in the standard university classroom before and after the lesson. The impact of ventilation intensity on perceived air quality was studied. The experiment was performed for three levels of air exchange rate (0.50, 0.75 and 1.00 h⁻¹). Chemical evaluation involves monitoring the indoor air temperature, relative humidity, CO₂ and Total Volatile Organic Compounds (TVOC) concentrations. Sensory quality assessment is based on air acceptability, odour intensity and percentage of dissatisfied. Air acceptability raised and odour intensity decreased when ventilation intensity was increased. Perceived Air Quality (PAQ) is an important factor in assessing the indoor environment.

1. Introduction
People spend most of their lives indoors. It is clear that the indoor environment plays a significant role in terms of health, comfort and well-being of the occupants. Monitoring of the quality of the internal environment has been paying more and more attention in recent years [1, 2]. Temperature, relative humidity and air quality affect the user's sensory system using receptors and create the overall impression of perception of the quality of the indoor environment [3].

Each building and its indoor environment has its characteristic scent. The odours have the most powerful effects of all sensory sensations and have a particular psychological state. Odours cause positive or negative perceptions in humans, and they are linked to information stored in the subconscious. The perception of individual odometric substances and their complexes is highly individual. Odours influence cognitive processes and affect user's performance as well as personal moods, good or bad memories [4, 5].

The concentration of the pollutants is one of the main parameters determining air quality of the indoor environment. The quality of the indoor environment depends on the intensity of the ventilation. Sufficient ventilation is necessary to remove indoor-generated pollutants from the indoor environment and to reduce concentrations of harmful substances to acceptable levels. As an indicator of indoor air quality, carbon dioxide concentrations are commonly used. Its concentration in the indoor environment should be less than 1000 ppm (parts per million). Outdoor CO₂ concentrations are usually about 380-400 ppm. The main sources of carbon dioxide in buildings are people. The CO₂ production depends on gender, age, height, weight, musculature and activity. [6, 7]. Odours, especially volatile organic compounds (VOC), are one of the causes of Sick Building Syndrome (SBS). Volatile organic
compounds are emitted into the indoors from building materials, products and equipment, such as paints, carpets, PVC, solvent, adhesives and coatings. The symptoms of SBS include the development of asthma and allergies, burning, itching and watery eyes, stuffy nose or chronic rhinitis, drought and scratching in the respiratory tract, headache, fatigue during the day, depression, neurosis, insomnia or sleep disturbances and impaired concentration. Sick building syndrome is a recent phenomenon. There are a number of studies dealing with the Syndrome of Sick Buildings in the context of the quality of the indoor environment [8-12].

2. Research methodology
The standard classroom of the university (approximately \(6.5 \times 6.0 \times 3.5\) m) for chemical and sensory assessments was used. The walls and ceilings are fitted with a classic internal plaster with white paint. Flooring is PVC linoleum. Chemical measurements and sensory assessments were done for two states – before the lesson and after the lesson.

The chemical assessment is based on measurement of indoor air temperature, relative humidity (RH), and CO2 and TVOC concentration. The concentration of carbon dioxide was measured by using Flue Gas Analysers TESTO 330 situated in the breathing zone of sitting persons (1050 mm above the floor). The concentration of TVOC toluene was measured with apparatus ppbRAE 3000, which is a photoionization detector (PID) with UV lamp. The device has a measuring range from 1 ppb to 10000 ppm and measurement accuracy ±3%. Three-second response time allows real-time monitoring with this instrument. Ultra-fast electronic nose called zNose®, which is based on the combination of gas chromatography and the surface acoustic wave detector was used for sampling and analysis of individual VOCs. Manufacturer of this device specifies the standard deviation < 2%.

Sensory analysis is based on decisions and perceptions of human subjects as measuring instruments. A sensory panel of 25 subjects assessed odour intensity and perceived air quality. There was no restriction on distribution of gender Before the experiment, the principle of assessment was properly explained to panelists. The panelists evaluated the indoor air quality on two continuous scales – air acceptability (AA) and odour intensity (OI). Subsequently, the percentage of dissatisfied (PD) is derived. The air acceptability is evaluated on a five-point odour sensation scale: no odour (0), slight odour (1), moderate odour (2), strong odour (3), very strong odour (4) and overwhelming odour (5). The scale of the air acceptability is divided into two individual scales with end-point clearly acceptable (+1)/ just acceptable (0) and just unacceptable (0)/clearly unacceptable (-1). The panelists evaluated whether the indoor air quality is acceptable or unacceptable and he selects its rate (clearly or just). Both criteria are evaluated at the same time. The mean air acceptability can be converted to the percentage to dissatisfied (PD).

3. Results and discussions
The perceived air quality (PAQ) refers to air acceptability, odour intensity and percentage of dissatisfied were studied in this study. As well as chemical evaluation, the sensory evaluation is dependent on individual air change rate. The results of an experiment are presented for three levels of the air change rate are in Table 1 and Table 2 (0.50, 0.75 and 1.00 h\(^{-1}\)). Table 1 shows the results of chemical and sensory assessment before the lesson. Table 2 illustrates results for the indoor air quality after the lesson. The tables show indoor air temperature [°C], relative humidity [%], concentration of TVOC [μg/m\(^3\)], concentration of carbon dioxide [ppm], air acceptability (AA), odour intensity (OI), and percentage of dissatisfied (PD) [%].
Table 1. Results chemical and sensory assessments before the lesson

| n [h⁻¹] | Temp. [°C] | RH [%] | TVOC [μg/m³] | CO₂ [ppm] | AA [-] | OI [-] | PD [%] |
|---------|-------------|--------|--------------|-----------|--------|--------|--------|
| 0.50    | 22.3        | 40.8   | 350.2        | 356       | -0.25  | 2.1    | 70     |
| 0.75    | 23.8        | 40.2   | 275.25       | 372       | 0.10   | 1.5    | 50     |
| 1.00    | 24.6        | 39.9   | 195.3        | 387       | 0.45   | 1.3    | 20     |

Table 2. Results chemical and sensory assessments after the lesson

| n [h⁻¹] | Temp. [°C] | RH [%] | TVOC [μg/m³] | CO₂ [ppm] | AA [-] | OI [-] | PD [%] |
|---------|-------------|--------|--------------|-----------|--------|--------|--------|
| 0.50    | 24.8        | 55.5   | 350.2        | 2710      | -0.70  | 3.2    | 100    |
| 0.75    | 25.4        | 51.0   | 275.25       | 2054      | -0.55  | 2.4    | 100    |
| 1.00    | 26.7        | 46.5   | 195.3        | 1358      | -0.25  | 1.8    | 100    |

Mean values of air acceptability before the lesson range from -0.25 to 0.45 depending on the ventilation rate. Air acceptability is acceptable for air change rates 0.75 and 1.00 h⁻¹. In case of air exchange rate of 0.50 h⁻¹, the air in the classroom is unacceptable. Indoor air quality after the lesson is not acceptability for all cases of air change rate. The chemical assessment shows that the carbon dioxide concentration limits have been exceeded. Levels of CO₂ grow very quickly in an insufficiently ventilated classroom. According to Pettenkofer, the concentration of carbon dioxide should be below 0.1% (1,000 ppm = 1938 mg/m³) for comfort and well-being of the occupants. In the worst case, this value is exceeded twice. The greater the air change rate, the greater the air acceptability, see Figure 1.

![Figure 1. The relation between air change rate and air acceptability (AA)](image)

Mean votes of odour intensity before the lesson is the range of 1.3-2.1 which reflects slight odour (1). After the lesson, there is a clear increase in the respiration intensity for all monitored levels of ventilation intensity. The greater the air change rate, the lower the odour intensity see Figure 2.
The tables also show the percentage of dissatisfaction for all cases. The percentage of dissatisfied before the lesson was in the range 20 – 70%. Conversely, the percentage of dissatisfaction after the lesson is 100% for all three monitored levels of air change rate and it can be determined that the indoor environment is totally inappropriate for teaching students.

4. Conclusions
The aim of this study is to highlight the significance of the intensity of ventilation in the context of indoor air quality. The optimal quality of the indoor environment must be ensured especially in areas with the long-term residence of groups of people such as open-space offices, hospitals or schools. Chemical and sensory assessment of the indoor environment of existing buildings is an important source of essential information for the design and construction of new buildings. Lowering TVOC and CO₂ concentration is necessary to prevent the Sick Building Syndrome. The main aim of sustainable development is to ensure the optimum quality of the internal environment with minimum operational and investment costs.

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References
[1] I. Juhásová Šenitková, “Indoor air quality – buildings design,” MATEC Web of Conferences, vol. 93, 03001, 2017.
[2] T. Tomčík, and I. Šenitková, “Interior Materials Impact to Indoor Air Quality,” Adv. Sci. Lett., vol. 19, pp. 955-959, 2013.
[3] L. Fang, G. Clausen, and P. O. Fanger, “Impact of Temperature and Humidity on the Perception of Indoor Air Quality,” Indoor Air, vol. 8, pp. 80-90, 1998.
[4] I. Juhásová Šenitková, M. Kraus, and P. Nováková, Buildings and environment, 2018.
[5] S.A. Abdul-Wahab, Sick Building Syndrome: in Public Buildings and Workplaces, 2011.
[6] W. F. de Gids, and P. Wouters, “CO₂ as indicator for the indoor air quality – General principles,” Ventilation Information Paper, n. 33, 2010.

[7] A. Persily, “Evaluating building IAQ and ventilation with indoor carbon dioxide,” ASHRAE Transactions, vol. 103, issue pt 2, pp. 193-204, 1997.

[8] A.Norhidayah, L. Chia-Kuang, M.K.Azhar, and S.Nurulwahida, “Indoor Air Quality and Sick Building Syndrome in Three Selected Buildings,” Procedia Engineering, vol. 53, pp. 93-98, 2013.

[9] B. Crook, and N. C. Burton, “Indoor moulds, Sick Building Syndrome and building related illness,” Fungal Biology Reviews, vol. 24, issue 3-4, pp. 106-113, 2010.

[10] S. K- Wong, L. Wai-Chung Lai, D. Chi-Wing Ho, K.-W. Chau, C. Lo-Kuen Lam, and C. Hung-Fai Ng, “Sick building syndrome and perceived indoor environmental quality: A survey of apartment buildings in Hong Kong,” Habitat International, vol. 33, issue 4, pp. 463-471, 2009.

[11] K. W. D.Cheong, W. J. Yu, K.W. Tham, S. C. Sekhar, and R. Kosonen, “A study of perceived air quality and sick building syndrome in a field environment chamber served by displacement ventilation system in the tropics,” Building and Environment, vol. 41, issue 11, pp. 1530-1539, 2006.

[12] S. Gupta, M. Khare, and R. Goyal, “Sick building syndrome—A case study in a multistory centrally air-conditioned building in the Delhi City,” Building and Environment, vol. 42, issue 8, pp. 2797-2809, 2007