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Performances and limitations of electronic gas sensors to investigate an indoor air quality event

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ABSTRACT

Indoor air quality (IAQ) receives an increasing attention because of long-term occupancy of confined environments with high specific pollutant concentrations, especially volatile organic compounds, inducing a risk for human health. Standard air quality instruments are not adapted for long-term continuous real-time monitoring of these environments, and a promising alternative resides in using electronic gas sensors, which are miniature and low-cost devices capable to detect air pollutants, even at low concentrations.

The present study focuses on IAQ monitoring with electronic gas multi sensor systems, as well as with typical indoor air analyzers in a 40 m^3 experimental room. The suitability of electronic gas sensors to monitor pollution events in indoor environments, characterized by transient concentrations of VOCs, has been characterized by simultaneous injections of acetaldehyde, acetone, formaldehyde, toluene and *o*-xylene. The impact of a green wall structure in the room has been assessed by the reduction of residual pollutant and higher decay of injected oxygenated VOCs than in the empty room. It has been shown that electronic gas sensor response show a good correlation within the analyzer measurements, both for injected VOC concentrations and their decay. Indeed, these systems provide relevant information for air treatment control system and detection of indoor air quality events, in the case of simple gas matrixes, however realistic complex matrixes are poorly monitored by electronic gas sensors selected in this study. This limitation could be overcome by increasing the number of sensitive sensors to indoor air specific composition.

1. Introduction

People spend up to 90% of their lifetime indoor, where they are exposed to high concentrations of various air pollutants [1], emitted from building materials, furniture, consumer products, occupants and their activities, or transferred from outdoors, with recognized adverse effects on health [2]. Decreased productivity performances of students [3] and office workers [4] have also been linked to a poor indoor air quality (IAQ). Due to an increasing concern for energy saving, recent buildings are much more airtight than older buildings, potentially leading to an increased build-up of pollutants indoors. To improve indoor air quality, the reduction of pollutant sources and the use of an efficient ventilation system in buildings are basic strategies. Air treatment systems [5] may also be applied for air cleaning. The air purification technologies range from single techniques such as filters for suspended particles removal [6], adsorption of VOC on activated carbon filters [7], photocatalytic methods [8] or botanical purification for which pollutants from indoor air can be adsorbed or absorbed either on the plant leaves and/or their substrate [9,10], to hybrid techniques combining the above-mentioned processes [11,12].

To evaluate these air treatment systems, or, once they are installed, to trigger corrective actions in case of degraded IAQ, it is necessary to be able to monitor in real time the concentration of

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pollutants. On the one hand, standard indoor air quality assessment by passive samplers [13] requires long periods of sampling, usually several days, followed by delayed analysis in laboratory, which rules out real-time information. On the other hand, real time monitoring cannot also be conveniently done using the typical online gas or particle analyzers employed for outdoor measurements, because of (i) their bulkiness, (ii) the noise and vibration they generate, and (iii) the cost of such instruments that prevents their simultaneous and permanent deployment in many buildings or in many rooms of a given building.

An alternative to these conventional sampling and analysis techniques recently appeared under the form of microsensors [14]. Sensors are physical-, chemical- or biological- based devices that translate the pollutant concentrations into an electrical signal. Sensors can be classified according to their operating principle [15], for instance (i) metal-oxide semiconductor sensors (MOS) based on conductivity variation, (ii) amperometric sensors based on solid or liquid electrolytes, or (iii) optical sensors using fluorescence or absorption of light. Specific sensors can provide accurate information regarding a target compound, whereas non-specific sensors give a global response to one or several families of chemical species.

Electronic noses, i.e. arrays of several non-specific sensors and/or partially specific sensors for gas and odor detection, are able to identify pollution signatures, when used with an adequate pattern recognition algorithm [16]. The nature of each sensor and the number of sensors in the array are the most important features of electronic noses. Electronic noses were first introduced by Persaud and Dodd in 1982 [17] to classify odors. There is now a huge interest for electronic noses in various research fields, such as food industry [18], breath monitoring [19], olfactometry [20], outdoor pollution [21] and indoor air quality monitoring [22]. Especially in this last research field, the small size, low cost and ease of use of sensors are particularly interesting. However, most of the studies are focused on (i) the improvement of gas sensor selectivity and performances [23], (ii) the development of sensor networks and related data sharing protocols [24], or (iii) the mathematical analysis techniques [25]. The validity of the chemical sensor responses to specific compounds, which might be affected by (i) other species present in the air, (ii) temperature, and (iii) humidity [26] has been investigated in very few studies, under simulated atmospheres [27,28] or directly during field campaigns [29,30].

The aim of the present study is to assess the ability of sensors to monitor (i) the typical indoor air VOC concentrations and (ii) the evolution of indoor air quality, in the present case after simulating a brief VOC pollution event, mitigated by a green wall. For this purpose, experiments were carried out in a 40-m^3 experimental room, in which a green wall was installed. The IAQ in the experimental room was monitored using electronic gas sensors and classical indoor air gas analyzers, analyzing the response of the instruments to transient concentrations of volatile organic compound.

2. Experimental setup

2.1. Experimental room design

The IRINA (Innovative Room for Indoor Air studies) experimental room, located at Mines Douai, has been designed to perform real scale and representative indoor environment experiments. The surface area of the room (Fig. 1) is 12.5 m^2, the volume is 40 m^3. The walls and the ceiling are covered with aluminum foil and the floor is tiled in order to avoid material emissions inside the room and to minimize and control gas-surface interactions. The windows, located on the south side of the building allow the penetration of natural sunlight inside the room. Four multifunction transmitters KIMO C310 spread in the experimental room continuously monitor the temperature and the relative humidity (combined humidity and temperature probe SHSI) and the carbon dioxide concentration (CO_2 probe SCO_2). The temperature in the experimental room is regulated by a closed-cycle air-conditioning system. The air renewal rate of the room, periodically checked by injecting CO_2 and monitoring the exponential decay, is 0.30 ± 0.10 h^{-1}.

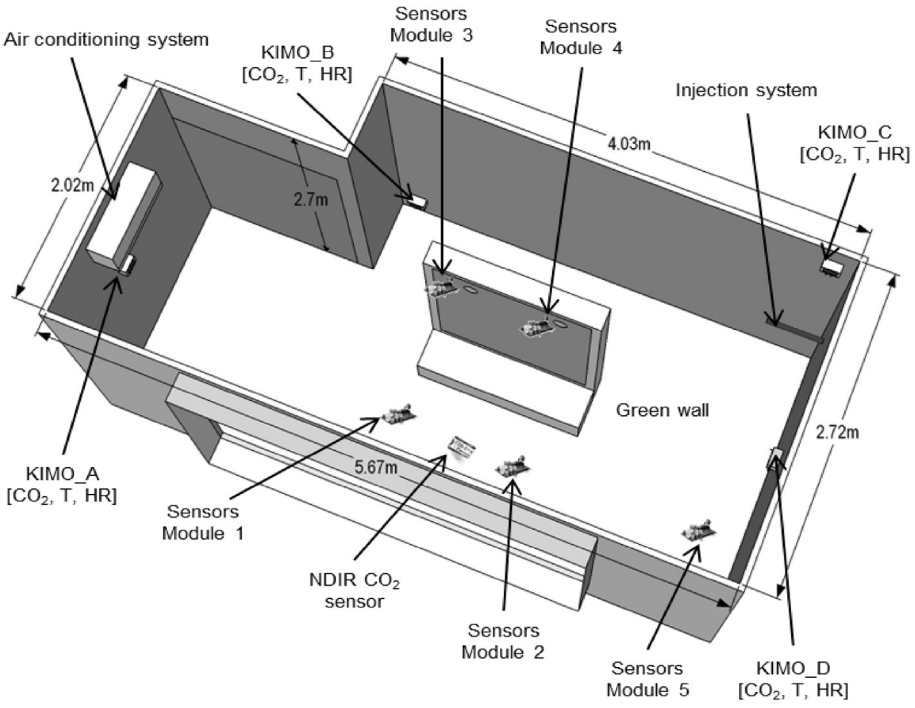

Fig. 1. Schematic view of the IRINA experimental room and green wall, with the position of KIMO probes and electronic gas sensors networks.