Urban Climate 14 (2015) 475–485

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim

System to control indoor air quality in energy efficient buildings

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ARTICLE INFO

Article history:
Received 12 December 2013
Revised 8 October 2014
Accepted 26 October 2014

Keywords:
Indoor air quality
Air preconditioning unit
Fluidic platform
Gas conductometric sensor
Benzene
Zinc oxide

ABSTRACT

The objective of the work described in this paper is to develop a device to monitor air quality in indoor environments integrating three conductometric gas sensors based on thin film and nano-structured metal oxide semiconductors (SnO_2, NiO and ZnO). The sensors are incorporated into a single robust, reliable and cheap detection platform, which includes air pre-conditioning and electronics. The main aim of the device is to integrate with HVAC (Heat Ventilation and Air Conditioning) in an energy-efficient way whilst maintaining a high air quality standard within the building. Due to the lack of common EU legislation, the target gases and detection limits have been set after reviewing the literature and the recommendations of different agencies in Europe and the US, focusing on indoor Volatile Organic Compounds (VOCs).

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http://dx.doi.org/10.1016/j.uclim.2014.10.009
2212-0955/

1. Introduction

Minimizing heating and cooling requirements is crucial to improve a building's energy efficiency. Therefore, most energy efficient climate control systems minimize the fresh air going into the building by recirculating most of the air. However, this can reduce air quality (Fisk et al., 2009; Sundell et al., 2011), which has become a public health concern in many countries.

The World Health Organization (WHO) WHO, 2005 recognized indoor-air pollution is the 8th most important factor for health and responsible for 2.7% of the global burden of diseases. Indoor air quality (IAQ) has become an important issue since the development of double glazing in the 1970's and buildings becoming increasingly energy efficient and thus better sealed: the concentration of contaminants may build up in an enclosed space and so the risks to health may be greater. This fact is particularly significant because Europeans spend on average 80–90% of their time indoors (Bruinen de Bruin et al., 2008; Sarigiannis et al., 2011). Volatile Organic Compounds (VOCs) and inorganic gases can contribute to poor IAQ and have been linked to symptoms of Sick Building Syndrome, an ambiguous term describing a wide range of symptoms related to a particular building (Redlich, 1997).

Benzene and formaldehyde are two VOCs found among the five indoor-originated compounds considered the most hazardous, according to the results of the INDEX EU project on indoor air quality assessment (Koistinen et al., 2008). Benzene is one of the 20 most relevant toxic chemicals produced in the US. It is a VOC used in the manufacturing of petroleum-derived products such as plastics, resins, nylon and synthetic-fibre manufacturing, among others. It also comes from some natural sources, such as volcanic emissions and wildfires, and it is closely related to some human activities such as tobacco consumption or gasoline combustion. Regarding its health effect, it is carcinogenic (according to the WHO there is no known exposure threshold to benzene exposure) (WHO, 2010) and it may also be the cause of other diseases such as plastic anaemia, acute leukaemia, and bone marrow abnormalities (in accordance with the Agency for Toxic Substances and Disease Registry-ATSDR) (ATSDR, 2013). As a reference, the OSHA states a STEL (Short Term Exposure Limit) of 5 ppm and an action level of 500 ppb.

Formaldehyde is also produced in high volume worldwide: more than 46 billion pounds per year. It is a great concern for example in China, the largest producer and consumer in the world (Tang et al., 2009). It is used in a wide range of products around the house such as cosmetics, cleaning products, varnishes, pressed wood or glues (Kelly et al., 1999). It is also required in rubber manufacture, and in many hospitals and laboratories to preserve tissue specimens. As for its effects on health, exposure to formaldehyde produces irritation of the eyes, nose and throat, at concentrations as low as 0.4–1 parts per million (ppm). Formaldehyde has been classified as a human carcinogen, because it causes nasopharyngeal cancer, pulmonary damage and probably leukaemia (Golden, 2011). The OSHA STEL for formaldehyde is 100 ppb with an action level of 500 ppb. Nevertheless, if we look at the long term exposure limits for both compounds in different standards and recommendations, the detection limits go to tens of ppb or even below 10 ppb. This fact evidences the need for very sensitive devices.

Many organisations and nations are now recognizing the need to balance ventilation, energy efficiency and IAQ (Agency, 2013; Tham, 2013), the main objective of this work is to provide a low-cost and high-sensitivity integrated device to measure IAQ that can be either used as an independent monitoring system or can be linked to the HVAC system. This aim will be achieved through the integration of sensors onto a common detection platform.

2. System description and experimental

The system consists of a set of three conductometric sensors for Volatile Organic Compound (VOC) detection and a fluidic preconditioning and handling system, with shared air intake and electronics. The fluidic platform has two main objectives: the control of the air flow and the control of the humidity reaching the sensors. The use of three different sensors will permit a more selective detection of the target toxic gases by using the procedures employed for electronic noses in the final device, which will also include the signal processing electronics.