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Evaluation of Indoor Air Quality by High School Students

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Summary:
To increase environmental awareness of high school students, age 12 to 18, four experiments were developed to investigate indoor air quality (IAQ) and demonstrate influencing factors. Students learn about the functionality of different gas and PM sensors and carry out measurements of different pollutants or materials used in everyday life. They also experience the influence of human breath on IAQ.

Keywords: air quality, environmental awareness, volatile organic compounds, particulate matter, CO_2

Introduction

Air pollution is the single largest environmental health risk in Europe with over 400.000 deaths per year in 2018 [1]. According to the World Health Organization (WHO) air pollution is a major cause for heart diseases and strokes, as well as lung diseases and Alzheimer's [2]. Air quality (AQ) monitoring is important to avoid health risks, especially in the interior, because people spend up to 90% of their time indoors [3]. Despite increasing environmental awareness in recent years, the concept of AQ and especially Indoor Air Quality (IAQ) is often rather diffuse and abstract, especially for teenagers. Indoor air pollutants are usually invisible and odourless, and therefore not detectable with human senses, hence deterioration of IAQ is often not noticed. To create awareness about IAQ, the outreach project "SUSmobil" wants to teach students, age 12 to 18, about air quality and how (I)AQ is determined with low-cost sensors [4]. For this purpose several experiments ("stations") were developed, each of which focuses on different AQ parameters, e.g. particulate matter (PM), volatile organic compounds (VOCs) as well as CO_2 and the sum parameter total VOC (tVOC) as indicators for IAQ.

Experimental Setup

Students work with a circuit board containing three different sensor types to evaluate IAQ, fig. 1. The board is equipped with (1) an infrared absorption sensor to detect CO_2, which also measures temperature and relative humidity, (2) a laser scattering sensor for PM, and (3) a metal oxide semiconductor (MOS) gas sensor to detect VOCs. All sensors are controlled by a microcontroller and the data is displayed with a specially developed software. Students perform four experiments, so called "stations", during which they learn about different aspects of IAQ.

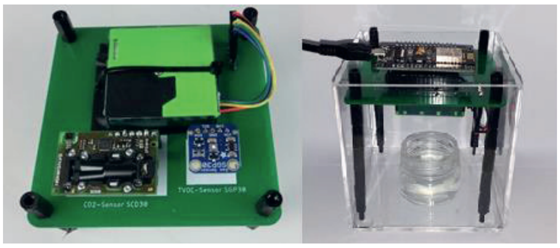

Fig. 1. Left: Circuit Board with three sensors to evaluate IAQ. Right: Investigation of diluted ethanol.

Station 1 – Sensor Test

In the first station, the students familiarize themselves with the software by checking the functionality of the sensors. The students have to think about their own test methods for testing the sensors and write down their procedure. For example, a sudden increase of CO_2 and VOC concentrations is observed when blowing on the board. The PM sensor can be tested by simply rubbing a paper napkin near the sensor.

Station 2 – VOC

The second station is divided into two parts both addressing VOCs. First, the students' nose competes against the gas sensor. The students are tasked to order five different dilutions of ethanol according to their concentration. Three of the five concentrations are below the human odour threshold, whereas the VOC sensor can discriminate all of them, fig. 1 (right). This experiment creates awareness for the need for objective measurements of air pollution.

The second part deals with VOC emissions of everyday products like paints, markers, glues and floors. For every category two examples with high and low emissions, respectively, were chosen. The students classify the samples on a scale from 0 (“undetectable”) to 6 (“extremely strong”) according to the odour intensity. Then the VOC sensor measures the VOC emission of the samples. Typical results are shown in fig. 2.

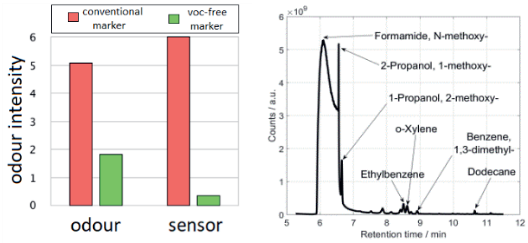

Fig. 2. Left: Odour intensity of two different markers according to the human nose and a VOC sensor from 0 (“undetectable”) to 6 (“extremely strong”). Right: GC-MS reference measurement of the head-space composition of conventional markers.

Both assessments are compared with the actual headspace composition of each material, determined by the reference method GC-MS (gas chromatography–mass spectrometry). The hugely different VOC emissions from objects with the same purpose demonstrate that consumers should consider health aspects, i.e. by taking notice of ecolabels like the “Blue Angel”.

Station 3 – Simulated Interior

The third station deals with IAQ in general. In a first experiment, students learn the function principle of infrared absorption sensors for CO_2.

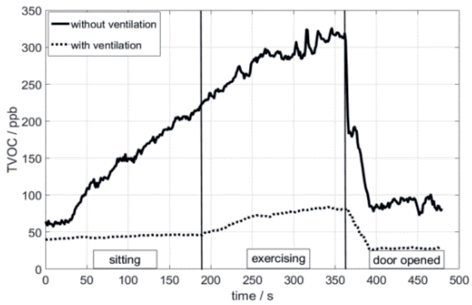

Fig. 3. VOC concentrations over time in the walk-in chamber with (dotted) and without (solid) ventilation.

To simulate an indoor environment, a walk-in chamber was constructed, which can be ventilated by fans. The students track the course of AQ parameters like temperature, humidity, CO_2 and VOCs in the chamber while sitting and doing physical exercises, with and without ventilation. Typical results are shown in fig. 3. Within a few minutes, VOC and CO_2 concentrations reach high values without ventilation, whereas both stay low with ventilation. Students compare sensor results with their senses and, based on their measurements, extrapolate these results to a normal sized room. This experiment shows the importance of regular ventilation to ensure good IAQ.

Station 4 – Particulate Matter

Again, the function principle of a PM sensor is demonstrated in a first experiment. Then, the students investigate PM emissions during cleaning of blackboards with dry and wet sponges, cf. fig. 4.

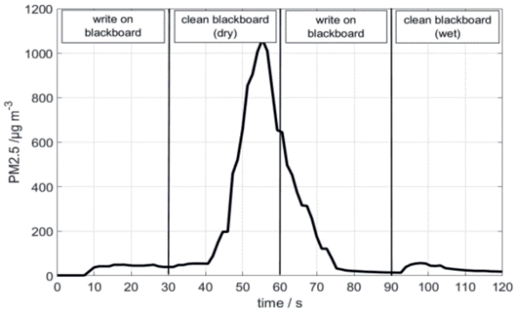

Fig. 4. PM emissions during writing on blackboards (0 – 30 s, 60 – 90 s) and during cleaning with dry (30 – 60 s) and wet (90 – 120 s) sponges, respectively.

Students spend considerable time in classrooms where chalk and blackboards are used. Each dry wiping of the blackboard generates large amounts of PM, whereas the emission of PM remains low when wiping wet. This experiment sensitizes to everyday sources of PM.

Conclusion

In order to convey a multifaceted picture of the subject of environmental metrology, the students perform various experiments addressing different AQ aspects. Students receive information about harmful and environmentally relevant gases and pollutants as well as sources and limit values according to the WHO. Experiments with gas and particle sensors raise environmental awareness and show simple ways to maintain or improve indoor air quality.

Acknowledgment

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