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► **To cite this version:**

Luiz Miranda, Caroline Duc, David Umba, Marie Verrielle, Sabine Crunaire, et al.. Indoor air quality indices confronted to sensors measurement from field campaign. *Heathy Buildings* 2023, Jun 2023, AACHEN, Germany. hal-04221431

HAL Id: hal-04221431

<https://hal.science/hal-04221431v1>

Submitted on 11 Dec 2024

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Indoor air quality indices confronted to sensors measurement from field campaign.

Luiz Miranda ^{a,d}, Caroline DUC ^a, David Umba ^{a,d}, Marie Verrielle ^a, Sabine Crunaire ^a, Bernadette Dorizzi ^b, Jérôme Boudy ^b, Jugurta Montalvão ^c, Nathalie Redon ^a,

^a IMT Nord Europe, Institut Mines-Télécom, Univ. Lille, Centre for Energy and Environment, F-59000 Lille, France;

^b Samovar, Télécom SudParis, Institut Polytechnique de Paris, 91120 Palaiseau, France ;

^c Universidade Federal de Sergipe, Centro de Ciências Exatas e Tecnologia, Departamento de Engenharia Elétrica, São Cristóvão - SE, 49100-000, Brazil.

^d ADEME - l'Agence de la transition écologique, 49000 Angers, France.

Abstract. Risk of exposure to indoor pollutants can be assessed using Indoor Air Quality (IAQ) indices designed to be used with precise laboratory equipment. These indices quantify and give a rating of the environment's IAQ (good, moderate or bad, for example). The popularization of sensors for air pollution saw these sensors' measurements being applied directly to indices' formulas in order to obtain IAQ ratings. Here we investigate whether this is a valid approach. To do so, we compared 5 IAQ indices calculated using sensor's readings in three French residencies with good, moderate and bad IAQ characteristics with three copies of the same set of sensors (one for each house), using average time in each level of IAQ, most influential pollutant and average agreement rate as parameters for the comparison. Results show that in the extreme cases, very good or very bad IAQ, the indices' outputs mostly agree, but, in the moderate case, they completely disagree. These results may indicate that the application of sensors' measurements directly to IAQ indices is not a valid approach, but with a pre-calibration step, proper quality control and the proper adaptations of each IAQ index, sensors may be applicable.

Background. To evaluate risk of exposure in indoor environments, guidelines are often developed by governmental institutions, such as ANSES for France (Anses, 2021), Health Canada for Canada (Canada, 2018) and the WHO (World Health Organization, 2010) for most of the world. These guidelines come from the study of health effects caused by individual pollutants and often result into threshold values of concentration for each of the studied substances. Based on these values, a few indoor air quality (IAQ) indices were developed to qualitatively measure IAQ and to better present this information to the citizen (Cony Renaud Salis et al., 2017; Picard et al., 2020). These indices and guideline values were originally intended to be measured using a variety of different laboratory techniques, often described in their corresponding papers. The recent popularization of micro-sensors for air pollution measurements saw many physicochemical variables of IAQ measured in very different ways (Loh et al., 2017). Sampling times were shortened and portability was increased, but low accuracy and reliability are still problems when using these sensors. Despite these shortcomings, many studies have been published in which sensor data was directly applied to IAQ indices (Saini et al., 2020).

Aims. In this study, we investigate whether the use of sensors in premade IAQ indices is a valid approach to the qualitative measure of IAQ.

Methods. To answer this, we have confronted 5 IAQ indices to real world data extracted from a field campaign in three French residencies, that were classified as households with good, moderate and bad IAQ characteristics based on family composition, ventilation, family habits, building location and environment typology. The dataset was collected using three copies of

the same indoor air monitoring system (one for each house) previously metrologically characterized in laboratory. The selected indices were: (i-1) IAQI, an adaptation of the Air Quality Index (AQI) from the US EPA with the breakout values presented in (Saad et al., 2017); (i-2) a modified version of the IAQI using either the French (when available) or the WHO guidelines; (i-3) BILGA (Cohas, 1996); (i-4) TAIL (Wargocki et al., 2021); and (i-5) CERBAIR, an index designed for a participative science project (IMT Nord-Europe, 2022). The indices' outputs were truncated into three regions referent to good, moderate and bad air quality, to allow a fair comparison between them. We focused on measuring only, CO₂, TVOC and PM_{2.5} as these variables were measurable with the selected system. The parameters used to evaluate the comparison were: percentage of time in each level of air quality (figure 1), most influential pollutant for each index and the agreement rate between indices.

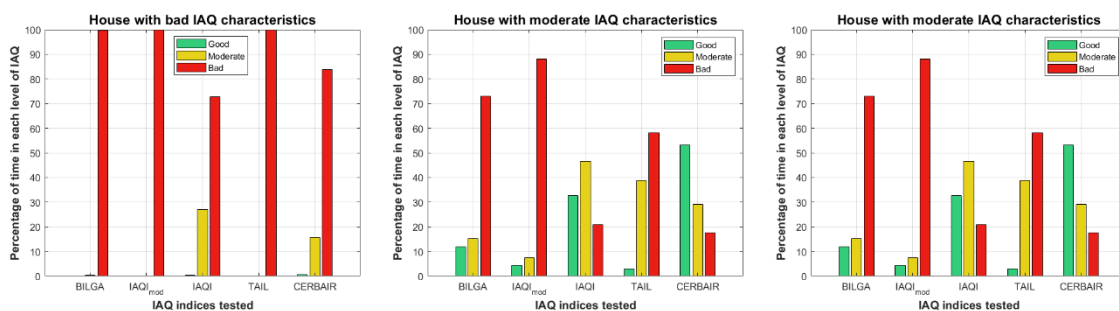
Results. For the household with good IAQ, all indices agreed that the IAQ was good most of the time, although index i-4 spent more than 30 % of time at moderate IAQ, the average agreement rate was 69.4 % with a standard deviation of 11.1 percentage points. The most influential pollutant results were divided between CO₂ (i-4 and i-5) and PM_{2.5} (i-1, i-2 and i-3). For the moderate IAQ house, there was no agreement on the state of IAQ, one index spent most of the time in good IAQ (i-5), one in moderate IAQ (i-1) and three in bad IAQ (i-2, i-3 and i-4), although i-4 spent almost 40 % in moderate IAQ. The average agreement rate was the lowest, 45.2 % with standard deviation of 22.7 percentage points and there was no agreement on the most influential pollutant, where one considered CO₂ (i-5), one considered TVOC (i-4), two considered PM_{2.5} (i-2 and i-3) and i-1 had similar influence from all three pollutants (33 % for CO₂, 28 % for TVOC and 39 % for PM_{2.5}). Finally, for the house with bad IAQ, there was an overall agreement that the IAQ was bad. The average agreement rate was 85.6 % with a standard deviation of 11.1 percentage points. The main consensus was that TVOC was the main pollutant for all indices.

Conclusions. An investigation to determine if sensor data can be directly applied to IAQ indices was achieved. Results were obtained on data extracted from a field campaign in three French households. Five indices characterized the IAQ in these households and their outputs were compared. Results have shown that indices can detect and agree on extreme levels of IAQ, that is, very bad or very good. They cannot, however, detect moderate levels of IAQ, as they completely disagree on what level of hazard is presented and what pollutants is the most influential. These results may indicate that sensors are not fitted to be used directly with existing IAQ. Their lack of precision and stability over time provide an unreliable reading of the environment (Caron et al., 2016; Dennler et al., 2022). However, these sensors can be calibrated to operate in a suitable range for these moderate intervals. With a pre-calibration step, proper quality control and the proper adaptations of each IAQ index, sensors may be applicable.

Keywords. Indoor air quality indices, micro-sensors, indices comparison.

Figure 1

Time in each level of IAQ for household with bad, moderate and good IAQ characteristics



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