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# Editorial: Rise of Low-Cost Sensors and Citizen Science in Air Quality Studies

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**Editorial on the Research Topic**

**Rise of Low-Cost Sensors and Citizen Science in Air Quality Studies**

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## RATIONALE

Sensors, and especially low-cost sensors designed for air quality and environmental monitoring and measurements, will play a central role in the environmental monitoring in future. The aim is that in the 21st century, the citizens, urban communities, researchers, and politicians will be active actors in different fields of environmental sciences and will take advantage of new technologies, such as the internet, social networks, communications in general. This trend together with free access resources in the management and processing of environmental information generated by sensors will allow citizens to understand, participate and commit to improving the environment and creating citizen science in air quality. The previously expressed is the democratization of environmental information, that allows citizens to understand the close and indivisible relationship that exists between air pollution and health as well as climate change.

The last decade has been characterized by intense activity around low-cost sensors. Both in Europe and in the United States, intensive work has been done on the creation of guides and protocols for the correct use of low-cost sensors for trace gases, particulate matter, radiation, temperature, relative humidity, among others. The European Committee for Standardization (CEN) is developing a technical specification that will describe general principles for evaluation of sensor system performance for monitoring of gaseous compounds (CEN/TC 264/WG 42), and the US-EPA is providing guidelines in their Air Sensor Guidebook. Remarkable and much needed is the work being done at the Air Quality Sensor Performance Evaluation Center belonging to the South Coast Air Quality Management District, which generates important information on the performance of low-cost sensors for air quality. Similar activities are carried out also at the Joint Research Center, European Commission. In addition, scientific community has been active in testing the sensors performance. Furthermore, large number of new companies providing sensors for environmental analysis has been established. Advanced international networks, such as the CAMS-Net, bring together universities, research centers, environmental authorities, city administrators, the private sector, and citizen groups interested in working for a common good. As this is a multidisciplinary network, it can obtain environmental information and process it in real time and deliver solutions to improve air quality. A pioneer project in IoT, which delivered real-time air quality information from areas never monitored, is the Map Sensor Community low-cost sensor network with global coverage, which in its program trained countless participants from emerging countries, that do not have economic resources to have networks with equivalent or referential instrumentation.

When it is analyzed what happens with the citizen interest in the implementation of low-cost sensors, it will find that it is enormous, and it can be the measurement of noise and atmospheric pollutants generated by vehicular traffic, in a residential neighborhood (Airflux), with presence of restaurants, where an alarm is created, at the request of its inhabitants, who receive a signal on their cell phones when the noise standard is exceeded (68 db for 15 min).

Another successful project is the Breathe network in the city of London, where hundreds of sensors were installed, financed by the Mayor of London and the participation of Imperial College, who is in charge of the installation, supervision, information management and training of all the participants and the interested community.

## CONTRIBUTIONS TO THE TOPIC

Measurements with sensors have already provided important research results. In Helsinki, the added benefits of a supplementary air quality sensor network were tested by installing over 30 air quality sensors to monitor the spatial and temporal variation of several gaseous and particulate parameters. The study found that the sensors can provide important additional data related to local emission sources such as traffic, wood combustion and construction sites. In addition, the long-range transported pollution episode was nicely detected by all sensors regardless of their location. In addition, portable low-cost sensors carried by citizens have been tested in Helsinki. Data about air quality during the measurements and of citizens personal exposure was made available to the participants.

Experiences from the use of low-cost sensor networks in several Gothenburg projects show a multitude of useful applications of these sensors, such as complementing standardized measurement networks, identifying patterns and hot spots, as well as in communication initiatives. However, it is of great importance that the intended use of the data is harmonized with the sensor data quality, to avoid that conclusions are drawn on the wrong basis. Collaboration with the city of Gothenburg have shown that incorporation of low-cost sensor data with the official environmental monitoring is currently not possible due to issues with data quality, maintenance, and monitoring needs, but that the use of low-cost sensors in citizen communication and dialogue can provide very useful information and enhance citizen engagement in environmental issues.

Low-cost sensors to measure $PM_{10}$ and $PM_{2.5}$ showed dependence both on the size and chemical composition of the particulate matter, as well as on the site where they were installed in Chile. Thus, if the particulate material had high levels of nitrate, sulfate, and silicon dioxide ($SiO_2$), they presented a low correlation with the $PM_{2.5}$ reference monitor, which was due to the principle of measurement of these sensors was optical since the dispersion coefficient depends on the particle size. If the $PM_{2.5}$ particulate matter had high concentration levels of organic carbon and black carbon, the correlation coefficient between the low-cost sensor and the reference monitor was high, which indicates that the particulate matter comes from the same source with a similar dispersion coefficient. For $PM_{10}$, the correlation coefficients between the low-cost sensors and the reference monitor were high if there were the concentrations of $SiO_2$, sulfate, nitrate were and low if there were high concentrations of these substances in the particulate material, which reveals the dependence that the low-cost sensors have with the selected place for the measurements.

An interesting experience was observed in the city of Birmingham, United Kingdom, where a low-cost wireless sensor network was implemented with $PM_1$, $PM_{2.5}$ and $PM_{10}$ sensors that provided high correlation coefficients when compared with the official network of the city.

The development of low-cost sensors that allow accurate measurement of solar ultraviolet radiation to better understand the formation of secondary particulate matter from the interaction of trace gases such as nitrogen oxides, volatile organic compounds, and ozone under the effects of radiation solar is highly anticipated. However, the experience gained with field measurements with three different sensors (ML8511, UVM30A and VEML6075) and the parameters used to determine the feasibility of their use indicate that the accuracy of the angular response is critical for the widespread use of these sensors. The information provided in this work is very relevant since it indicates what measures should be taken by the producers of ultraviolet radiation sensors to improve the accuracy of the angular response of these sensors, which will allow the creation of a platform with sensors to measure ozone, VOC, $NO_2$, and UV in real time in the near future.

An emerging use for low-cost sensors is the implementation of sensor networks in conjunction with official air quality networks to enable improved advanced air quality forecast models, which will be of great help to environmental authorities and policy makers. Furthermore, the sensors have been shown to be suitable for personal monitoring as well as monitoring of local sources, thus improving the local and personal mitigation of adverse impacts of air quality.

## AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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