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Research Highlight

'Field Evaluation of Low-cost Electrochemical Air Quality Gas Sensors at Extreme Temperature and Relative Humidity Conditions'

Summary

Modern electrochemical gas sensors hold great potential for improving practices in Air Quality (AQ) monitoring as their low cost, ease of operation and compact design can enable dense observational networks and mobile measurements. Despite that, however, numerous studies have shown that the performance of these sensors depends on a number of factors (e.g., environmental conditions, sensor quality, maintenance and calibration, etc.), thereby adding significant uncertainties in the reported measurements and large discrepancies from those recorded by reference-grade instruments. In this work we investigate the performance of electrochemical sensors, provided by two manufacturers (namely Alphasense and Winsen), for measuring the concentrations of CO, NO_2, O_3 and SO_2. To achieve that we carried out collocated yearlong measurements with reference-grade instruments at a traffic AQ monitoring station in Nicosia, Cyprus, where temperatures ranged from ca. 0 °C in the winter, to almost 45 °C in the summer. The CO sensors exhibit the best performance among all the ones we tested, having minimal mean relative error (MRE) compared to reference instruments (ca. -5%), although a significant difference in their response was observed before and after the summer period. At the other end of the spectrum, the SO_2 sensors reported concentration values that were at least one order of magnitude higher than the respective reference measurements (with MREs being more than 1000% for Alphasense and almost 400% for Winsen throughout the entire measurement period), which can be justified by the fact that the concentrations of SO_2 at our measuring site were below their limit of detection. In general, variabilities in the environmental conditions (i.e., temperature and relative humidity) appear to affect significantly the performance of the sensors. When compared with reference instruments, the CO and NO_2 electrochemical sensors provide measurements that exhibit

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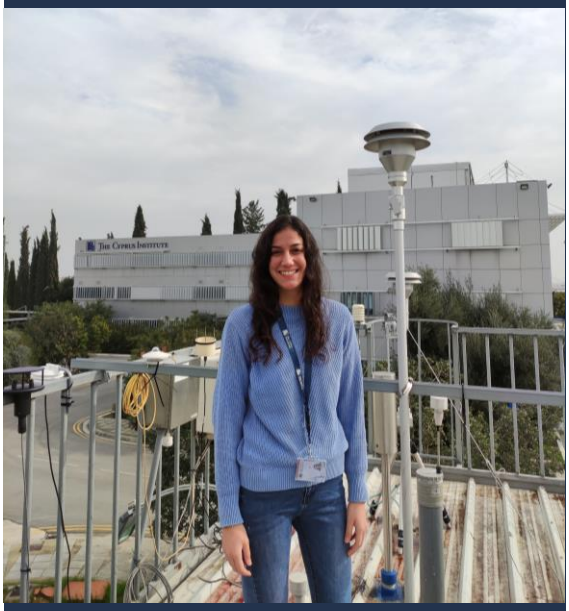
increasing errors and decreasing correlations as temperature increases (from below 10 to above 30 °C) and RH decreases (from > 75 to below 30%). Interestingly, the performance of the sensors was affected irreversibly during the hot summer period, exhibiting different response before and after that, and resulting to a signal deterioration that was more than twice as that reported by the manufacturers. With the exception of the Alphasense NO_2 sensor, all LCSs exhibited measurement uncertainties that were much higher, even at the beginning of our measurement period, compared to those required for qualifying the sensors for indicative air quality measurements according to the respective EC Directive. Overall, our results show that the response of all LCSs is strongly affected by the environmental conditions, warranting further investigations on how they are manufactured, calibrated and employed in the field.



Impact

The study highlighted the challenges and complexities associated with the field tests of Low-Cost Sensors (LCSs) for monitoring air quality. The wide variation in testing parameters such as location, environmental conditions, and duration of measurements, as observed in previous field tests, poses a significant hurdle for direct comparisons and in-depth analysis of LCS performance. The research emphasizes the need for systematic observations conducted at diverse locations and under different environmental conditions over extended periods. The focus of this work is on yearlong measurements of key gaseous pollutants using low-cost EC sensors manufactured by Alphasense and Winsen, comparing the results with those obtained from reference-grade instruments. The study takes place at a traffic station in Nicosia, Cyprus, characterized by highly variable gaseous concentrations influenced by both local and regional pollution sources, as well as extreme environmental conditions, including temperatures reaching up to 50 °C and humidity dropping below 10%. This unique setting offers valuable insights into the performance of LCSs under challenging and extreme circumstances, shedding light on their efficacy in real-world applications.

Reference

Papaconstantinou, R., Demosthenous, M., Bezantakos, S., Hadjigeorgiou, N., Costi, M., Stylianou, M., Symeou, E., Savvides, C., Biskos, G., Field Evaluation of Low-cost Electrochemical Air Quality Gas Sensors at Extreme Temperature and Relative Humidity Conditions, Atm. Meas. Tech., 16, 3313–3329, https://doi.org/10.5194/amt-16-3313-2023, 2023.

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