E-Nose: a research object or an industrial device? An overview of open challenges

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During the last decade of the 20th century, the promising results obtained in various research fields have proven that the e-Nose technology can offer unique advantages related to the possibility to characterize odours in a wide variety of applications (i.e., food industry, biomedical field, environmental field, process control).

The final goal for e-Noses to be used in the industrial practice is – today as 40 years ago – to obtain accurate, reliable, and reproducible results over time. As a matter of facts, even though there are some commercial instruments on the market, long-term application still seems a distant goal. In fact, despite great progresses in instrumental odour sensing and e-Nose technology, the introduction of these instruments in the industrial practice for advanced applications related to odour characterization still poses some technological challenges. While e-Nose could be considered a flexible and multipurpose instrument because of the wide range of fields in which it can be employed, each e-Nose is currently developed and designed in order to make the instrument fit-for-purpose. Thus, even if e-Noses are nowadays employed in real-application in which their functioning demonstrated to be effective and useful, commercial e-Noses currently available on the market are "customized" meaning that their scalability on diverse industrial applications is still hampered.

In this context, this paper has the aim to scout and give an overview of some of the most relevant open challenges needed to be solved in order to turn e-Noses from customized research objects to largely applied device in the industrial practice, by discussing some examples from real applications.

One main critical aspect related to the use of e-Noses especially in the environmental field and in process control applications is related to the improvement of the instrument capability to quantify odours. The evaluation of odours concentration detected by e-Noses

still needs the development of robust regression models able to effectively take into account the diverse classes the odours belong to and the drawback of comparing e-Noses results with concentration values obtained by dynamic olfactometry, which is intrinsically characterized by high level of uncertainty. Moreover, a special attention in e-Noses calibration has to be directed to possible interfering substances that can be present in field experiments. Some substances can interfere with some sensors hampering a correct detection of odour profiles and intensity but, contemporarily, they do not prevent the human capability to detect odours in dynamic olfactometry tests. This may produce a bias in the correlation between the e-Nose detection and the sensorial one.

As for quantification, also for odours classification high accuracy levels need to be obtained guaranteeing high performances over time. For this reason, the worsening of sensor responses need to be faced with models for drift compensation in order to avoid the high costs of re-calibration, which still limit the widespread adoption of artificial olfaction systems in industrial setups.

Even though the drift correction could extend the sensors array life decreasing the periodically replacement of sensors in the array, it is needed to develop also suitable models for the so-called "calibration-transfer", in order to avoid that every time that a sensor is replaced in the array the whole calibration shall be repeated. In fact, one of the main drawbacks of this technology is related to the poor reproducibility in the sensors' fabrication meaning that the "same" sensors could not guarantee the same instrument performance. In order to overcome this limitation and to allow the spread on e-Nose technology at an industrial scale, such correction methods need to be applied to develop a technology reproducible for different systems and devices.

In conclusion, the need for overcoming those technical issues preventing the widespread diffusion of e-Nose at an industrial level is pushing the scientific research towards the development of innovative solutions capable to solve initially application-specific problems, and progressively providing general solutions.