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Potential of hybrid sensing technology to monitor soil ecosystems

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To study and monitor environments, a plethora of sensors in last decades have been proposed and claimed to be as the most specific, sensitive, reliable, durable, affordable or whatever. However, they rarely take into account probable interactions of compounds of interest with other substances (i.e. molecules, matrices, surfaces, etc.) occurring in the environments where the analytes are present (although some corrections due to a few interfering compounds have been sometimes carried out), then, generating misinterpretations of results (e.g. overestimation or underestimation) or incorrect evaluation of effects (e.g. about toxicity and disease diagnoses). Another quite rare evaluation in the detection of analytes in environments concerns the partition of substances of interest into different phases, as well as adsorption/desorption and absorption/release events, thus often leading to misinterpretations of results. That issue is of outmost importance in complex multiphasic environments, such as soil, where these phenomena commonly occur.

An improvement in sensor applications to environmental monitoring, as concerns the competition and interference of other compounds in measurements, has been the development of electronic noses. The electronic nose (E-nose) is a sensing technology, where the presence of arrays of several suitable but unspecific sensors for volatiles and gases can deal with this problem, since the different features of sensors, despite overlapping responses to different compounds, are then evaluated in post-measurement data processing analyses (namely multivariate analyses) and integrated into a chemical image reproducing the fingerprint of the sample headspace or atmosphere (i.e. the odour), such as occurs in the olfactory system of mammalians. E-noses in the last decade have been extensively used to monitor volatile and gaseous analytes and odours in several contexts and environments.

In the last 5 years, a very few groups have applied this technology in studies on soil science to detect and monitor the presence of natural or anthropogenic compounds (i.e. nutrients and pollutants), soil processes (i.e. pollutant degradation and metabolic activity) and soil quality assessment (through the use of suitable metabolic indices), on the basis of volatiles and gases detection, and some devices have been set up on purpose. The E-nose approach, can be remarkably useful in the study of soil environments, because it may supply a holistic image of the entire soil ecosystem under study, with respect to very specific, accurate and sensitive but partial measurements that other sophisticated techniques commonly provide, taking into account both biotic and abiotic processes, as well as interactions between different populations and communities of living organisms.

Very recently, a different approach has been developed in pollutant monitoring, in order to relate the quantification and behaviour of contaminants in soil (e.g. solubility, volatility, phase partitioning, adsorption and desorption, etc.) to the relative environmental conditions, by measuring chemical (pH) and physical (temperature and moisture) parameters, which can affect such processes, while contemporarily detecting pollutants in soil atmosphere. According to this approach, an E-nose-like multi-parametric hybrid probe has been set up, where several types of sensors have been included, some of them in an array for pollutant detection and some others peculiar to different features concerning the site-specific environmental conditions where those compounds are present. Such a kind of device can permit, through the additional support of suitable algorithms and statistical analyses, the quantification and monitoring of toxic substances taking into account their behaviour in their specific environmental conditions, then providing more reliable quantification of substances and supplying a more sound interpretation of results, which can be useful in decision making processes.