Unraveling Environmental Issues in the Soil-Plant System with X-Rays: Opportunities and Challenges

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Soil is a very complex environmental compartment where minerals, organic matter, (micro)organisms, plants, water and air are intimately connected at the micro/nano-scale. The fate of environmental pollutants (organic and inorganic) in soil is strongly influenced by many processes, both biotic and abiotic, taking place in this matrix. In particular, potentially toxic elements (PTE) tend to accumulate in soil and can be transferred from the solid phases to water, air and biota, especially plants, and then along the food chain, up to humans.
To study the processes occurring in soil and affecting the fate of PTE, analytical methods able to disentangle soil complexity at the micro/nano scale are needed. In this context, X-rays are electromagnetic radiations with a wavelength in the order of magnitude of atoms size (between 10^{-11} and 10^{-8} m) and therefore can provide many useful information about the composition and structure of matter. In addition, their high penetration capacity allows to investigate different type of materials almost without sample treatment, thus reducing the risks of artifacts and errors. Different types of X-rays-based analytical techniques are nowadays available to support environmental scientists dealing with PTE pollution in soil and plants. Beside both qualitative and quantitative bulk analytical capabilities, 2D and 3D chemical and structural imaging implementations make X-ray methods extremely appealing analytical tools in all fields of research, including environmental sciences (Terzano et al., 2019).
In this lecture, the most recent innovations in X-ray analysis will be reviewed and applications to the fate of PTE in the soil-plant system will be presented. X-ray-based methods available both at synchrotron radiation facilities and in the laboratory will be considered, as well as portable instruments to be used directly in the field. The advantages and limitations of these techniques will be discussed with a special focus on the combination of these methods. Challenges in instrument development and sample preparation will be also highlighted.

References

Terzano, R. et al. (2019) 'Recent advances in analysis of trace elements in environmental samples by X-ray based techniques (IUPAC Technical Report)', Pure & Applied Chemistry, 91, p.1029-1063. doi:10.1515/pac-2018-0605.