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Editorial

Soil Pollution Assessment and Sustainable Remediation Strategies

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When the presence of a chemical in soil affects humans or other living organisms, producing undesired effects, that soil is considered polluted. Some of these chemicals are human made, like the organic xenobiotics, while others may have both natural and anthropogenic origin, like trace elements. Besides the usually known potentially toxic elements (e.g., metals and metalloids), persistent organic pollutants (POPs, e.g., polychlorinated biphenyls, dioxins and furans), polycyclic aromatic hydrocarbons (PAHs), and pesticides, some of which already classified as POPs and obsolete, soils are also threatened by emerging contaminants, such as nanoparticles, human and veterinary drugs, and microplastics. The knowledge about these pollutants is scarcer, meaning that it is very important to have more studies conducted on their concentrations, bioavailability, toxicity, and behaviour in the soil compartment.

These pollutants will not only affect the soil but, ultimately, will affect different resources and environmental compartments in different ways, which will represent a major risk. To control this risk, measures must be taken on the polluted soil, which can range from the isolation of the affected area to its full remediation. Of course, confinement and remediation actions are costly and, sometimes, the extension of the affected area makes the costs of the soil remediation difficult to bear and therefore not considered as a priority. Another factor that compromises the identification and intervention on contaminated soils is the fact that, in many countries, there is no specific legislation on contaminated soils, and there is an urgent need for soil health criteria and framework legal documents.

Nevertheless, science has moved on, developing solutions for the management of contaminated soils, controlling the risks, and promoting their remediation, using sustainable remediation practices. This is true for the biological methods of soil remediation, e.g., bioremediation and phytoremediation, which can be used singly or combined, allowing the immobilization, extraction, or degradation of different soil pollutants, contributing to the control of the risk of exposure, or to the soil decontamination, through the continuous reduction of pollutants concentration. These methods can be also classified as nature-based solutions, allowing the full-recovery of degraded environments and the full restoration of their ecosystem functions.

The Environments Special Issue on "Soil Pollution Assessment and Sustainable Remediation Strategies" attempted to cover all these topics, the main classes of soil pollutants, concentrations and soil–plant–water interactions, bioavailability assessment, risks to human health, negative effects on the environment (e.g., freshwater and groundwater, soil organisms, soil functions, ecosystem services), soil quality evaluation and sustainable soil remediation strategies. Studies in real soil pollution scenarios and remediation in long-term field studies were encouraged.

This issue includes nine articles, one communication, and two reviews. Regarding soil pollutants and their source, van Schothorst et al. [1] have evaluated two sources of light density microplastics in vegetable production systems, in Southeast Spain and in The Netherlands: the application of organic fertilizers, like compost; and the use of plastic mulch, both suspected of being major sources of microplastics to the environment. Pollutants in

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agricultural soils were also the target of the study reported by Cruz et al. [2], concerned about the growing development and use of engineered nanoparticles in agriculture. To assess the environmental risks connected to the mobility and toxicity of Ag-nanoparticles in agricultural soils (used as an alternative to conventional fungicides), these authors have evaluated their dissolution in three contrasting soils, using chemical extraction procedures, and the potential effects on soils exoenzymes activities [2]. Agricultural practices have also concerned Andiloro et al. [3], in a communication of their first results on the evaluation of the risk of soil contamination as a consequence of using orange peel residues as a fertilizer. In fact, in a circular economy perspective, organic matter-cycling to soils is of extreme importance, but the risks of that practice need to be assessed.

Potentially toxic elements (PTEs) are of great concern, and several authors have addressed them, assessing both their sources and remediation options. Mourinha et al. [4] published a review on the PTEs contamination of soils in the Portuguese sector of the Iberian Pyrite Belt, affected by the intensive exploitation of polymetallic sulfide ore, presenting different solutions for the remediation of these soils, already assessed in similar environments (e.g., PTEs immobilization by soils amendments, phytotechnologies). Mining environments were also the concern of Boente et al. [5], that have evaluated the impact of the old Pb production in soils from the Linares Mining District (Southern Spain), looking also to the metallurgical sector as a potential source of soil pollution, that may affect agricultural soils and residential areas. Petruzzelly and Pedron [6] presented a review on the dynamics of tungsten in soil, considering the growing importance of its use in the production of green energy and other hi-tech applications, and the lack of knowledge on tungsten retention, mobility, and bioavailability in soils.

Several authors have evaluated the use of soils amendments to cope with the contamination by PTEs. Moreira et al. [7] assessed a non-conventional organic amendment, cork powder, versus a traditional organic amendment, horse manure, to control the availability of cadmium in an artificially contaminated soil, using lettuce as an indicator plant. On the other hand, Palmeggiani et al. [8] used biochar, produced from hardwood, and iron sulphate to ameliorate a former mine Technosol, mainly contaminated by arsenic (As), and their impact on metal(loid)s mobility and on *Alnus* sp. growth. The authors have verified the ability of *Alnus* sp. to grow in the contaminated and treated soils, due to its tolerance towards As, allowing its use in the phytoremediation of this type of mine-contaminated soil [8]. Quagliata et al. [9] evaluated the growth of an energy crop, hemp (*Cannabis sativa* L.), in a copper (Cu)-contaminated soil, which offers a very interesting possibility for the phytomanagement of this type of soils. The authors have also assessed the effectiveness of an environment-friendly sulphate in improving the plant ability to cope with the Cu-induced oxidative stress [9]. Cepoi et al. [10] evaluated the bioremediation capacity of the edaphic cyanobacteria *Nostoc linckia*, which they have considered "an important candidate for the bioremediation of soils contaminated with chromium, in association with other metals", but without discussing how the metal-accumulating microbial biomass could be separated from the soil, essential to consider this strategy as a "soil decontamination" option.

Soil contamination with PAHs has been addressed by Deary et al. [11], who have evaluated the effects of metal co-contamination in the structural selectivity of PAHs removal in soils, hindered by the adverse effect of co-contaminants on microbial activity, while Satouh et al. [12] assessed the adsorption of PAHs by natural, synthetic, and modified clays. These low-cost and highly effective adsorbents could be interesting to immobilize this group of contaminants in soils [12], preventing their further spread.

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