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Editorial

Environmental Restoration of Metal-Contaminated Soils

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The growing industrialization of the last two centuries has improved life to a great extent in the countries where it occurred. However, several drawbacks were derived. Among them, many industrial activities gave and have given origin to dramatic environmental impacts on air, soil, and water.

Concerning soil, the most frequent contamination factor is represented by heavy metals. These pollutants derive from the metal industry, but also agriculture, mining, and waste disposal. Unlike other contaminants, they can persist in the environment for a long time, and this increases the probability to be distributed through the soil layers and transferred to groundwater, with the consistent risk to enter the food chain by water, crops, vegetables, meat, and fish.

Each metallic element has a level of toxicity responsible for health impacts over short, medium, and long times. When the metal concentration is known, the toxicological risk can be assessed by literature correlations, usually based on experimental data. When the risk is considered not acceptable for human health, the request for the reclamation of the polluted sites becomes extremely urgent. The management of a polluted site reclamation is considered one of the most challenging environmental issues to address, as it involves multiple inter-related factors. Several techniques have been developed to remove metals from soil. Traditional soil remediation methods, relying on physical and chemical techniques, have been recently supplemented by those based on biological processes, also called Nature-Based Solutions (NBS).

The multifaceted problems linked to soil heavy metal contamination require an integrated approach involving different expertise and proficiency. In this regard, the current Special Issue aims to focus and highlight the features of this multidisciplinary topic, thanks to the contribution of researchers with different backgrounds to combine knowledge from many disciplines.

A review [1] summarizes these features, showing the relevance of each. This manuscript also describes the main techniques that can be applied for the remediation of metal-contaminated soils. The study highlights the need for tighter cooperation between research and companies involved in remediation, to publish and disseminate the results from experience on a larger scale than the experimental/pilot one.

The first research manuscript presented in the Special Issue checks two methods to consider and assess the risk on human health due to soil ingestion, with a particular focus on bioaccessibility [2]. In this study, Zingaretti and Baciocchi studied the bioaccessible concentration of some metals achieved by two extraction methods, namely, the Unified BARGE Method (UBM) and the Simple Bioaccessibility Extraction Test (SBET). Notwithstanding the lower complexity of the second method, the results were similar, demonstrating that the SBET could be used for screening scopes, while the UBM can be adopted to obtain more accurate data. Then, they used these data to calculate the bioaccessible concentration and the cleanup goal and evidenced the need to include the bioaccessibility into the human health risk assessment (HHRA).

The manuscript by Cameselle et al. [3] presents the results achieved by the electrokinetic removal of heavy metals targeting the remediation of contaminated soils. The experimental runs compared the effect of pH on solubilization and transport of the metallic elements to enhance their removal. EDTA and citric acid were used to change pH. For four metals (Cd, Co, Cu, Zn), the long treatment time (65 days) and high citric acid concentration (0.5 M) resulted in their 70–80% removal, whereas for Cr and Pb, the right operative conditions must be found. As a whole, the results are encouraging for future studies.

Among the techniques tested and successfully applied to restore and clean up soils, sorption constitutes a good and cheap solution. In particular, the use of natural sorbents is emphasized, both for their low cost and the removal efficiency demonstrated in several studies. In the manuscript of Yurak et al. [4], peat, diatomite, vermiculite, and their mixtures were applied to remove one metalloid and five metals (As, Cd, Cr(III), Cr(VI), Cu, Pb). The best result for the removal efficiency was achieved with granular peat–diatomite, followed by large-fraction vermiculite, medium-fraction vermiculite, non-granular peat–diatomite, and diatomite. Unfortunately, one drawback was evidenced: the removal efficiency decreased with time.

Amirahmadi et al. [5] studied the metal adsorption by biochar in mining areas to remediate these heavily polluted soils. They investigated the Cd concentration and bioavailability in pots with loamy soil, monitoring the growth of oak seedlings in the presence of rice husk biochar. The results demonstrated that at the highest tested biochar addition (5% by weight), the bioavailability was always lower than in pots without biochar and also when the Cd concentration reached 50 mg kg^{-1}.

The uptake of one metalloid and some heavy metals (As, Cd, Ce, Co, Cr, Cu, Fe, La, Mn, Ni, Pb, V, Zn) by edible plants in urban soils is the main topic of the manuscript presented by Gaggero et al. [6]. They studied metal uptake in two common vegetables, namely, *Lactuca sativa* and *Brassica oleracea*, grown in contaminated soils, with and without soil amendment deriving from biodegradable wastes. Specifically, the authors analyzed the aerial parts and roots of these vegetables. Then, the results were compared with the ones observed in uncontaminated soil. It was shown that the plants grown in contaminated soils absorbed the toxic elements. When soil amendment was used, the toxic element accumulation was found mainly in the roots, with a limited amount of pollutants reaching the aerial parts (i.e., the edible parts).

As the last manuscript, but of no minor relevance, Han et al. [7] present the study carried out on the flow polluted with copper through a permeable membrane in the filters for contaminant removal, as occurs in Korean landfills. The experimental runs were performed in hydrophobic-coated capillary tubes to simulate the landfill in which similar flow conditions can be present. The results showed that in the center of the tube, the flow rate was always higher than near the surface, where the hydrophobic condition slowed down the hydrophilic contaminant. This also occurred when the pH was changed, namely when it increased from 4 to 10. The experimental data were modeled by computational fluid dynamics (CFD). From the applicative point of view, this means an effect by the pH condition, in terms of slowing down the flow rate by the hydrophobic surface, giving the opportunity of selective remediation.

Altogether, the Special Issue collected data and results coming from different features of the same environmental issue, namely the remediation of soils polluted with heavy metals.

All the studies evidenced the need to further investigate such features. Moreover, all the manuscripts highlighted the crucial point to transfer the current data to a larger scale, to obtain robust data and information for a real-scale application. In other terms, tighter cooperation between research and the industrial world is required.

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