Phytoextraction of potentially toxic elements

Subjects: Agriculture, Dairy & Animal Science
Contributor: Luigi Giuseppe Duri, Diana Agrelli

Phytoextraction of potentially toxic elements (PTEs) is eco-friendly and cost-effective for remediating agricultural contaminated soils, but plants can only take up bioavailable forms of PTEs, thus meaning that bioavailability is the key for the feasibility of this technique. The soil-plant interactions can change the bioavailable forms of PTE in soil, which are in dynamic equilibrium, leading to a continuous re-equilibration process between these forms.

Keywords: bioavailability ; phytoextraction efficiency ; soil equilibrium

1. Introduction

The phytoremediation approach represents an economically more realistic and cost-effective option than excavation, soil washing and in situ or off site soil disposal or even soil sealing, especially for agricultural areas producing food for the increasing world population.

Soil contamination by potentially toxic elements (PTEs) is of great concern due to their harmfulness for the biota at certain concentrations and to their persistence in the environment [1]. When contaminant concentrations in a site overcome the screening values stated by the national legislations, the site has to be subjected to a site-specific risk analysis for calculating risk thresholds. When contaminant concentrations overcome also risk thresholds, the site must be subjected to remediation projects [2]. In the case of agricultural soils, it is crucial to also analyze the risks that a contaminant can enter the food chain, for this purpose chemical [3] and biological essays [4] have been proposed.

Various soil remediation techniques exist, but many of them are complex and expensive. In recent years, much research has been done on soil phytoremediation because it is an in situ eco-friendly and cost-effective method with respect to the others [5]. The main phytoremediation mechanisms are the phytostabilization, which reduces contaminant mobility toward other environmental compartments, and the phytoextraction, which exploits the ability of some plants to take up potentially toxic elements from the contaminated soil [6]. The best suitable plants for phytoextraction are the hyperaccumulators, i.e., plants capable of growing in soils with very high concentrations of PTEs they accumulate in extremely high levels in their tissues [7]. As an alternative, fast-growing high biomass crops that accumulate moderate levels of PTEs in their shoots can allow a greater phytoextraction efficacy since the high biomass yield can more than compensate for the lower PTE concentration in plant tissues [8]. In any case, the contaminant to be absorbed by the plants must be in a bioavailable form in the soil [1]. PTEs in the soil from anthropogenic sources tend to be more mobile and bioavailable than the geogenic ones [5]. This may promote their transfer to other environmental compartments and to the food chain. Therefore, a realistic remediation objective through phytoextraction can be the progressive reduction of the contaminant to safety levels of its bioavailable portion rather than its total removal [9]. However, the bioavailability of a PTE is closely linked to the nature of the element, to the chemical forms in which it occurs in soil, and to the chemical and physical characteristics of the soil itself. This determines the repartition of the element between the various soil geochemical fractions and the soil solution (in which the element is in a readily bioavailable form) [3][10]. This repartition is controlled by dynamic equilibria between different forms elements and soil fractions, that must be considered in planning strategies of phytoremediation. After short-term phytoextraction (or only few cycles of phytoextraction), the readily bioavailable fraction of the respective element may be replenished through repartition between soil fractions and soil solution, and the kinetics of replenishment can change over time [9].

2. Considerations of our research experience

Consecutive croppings of hyperaccumulator plants on polluted soils, achieved a significant reduction of the bioavailable metal concentrations in soil along with changes of the soil pH and equilibrium between PTEs pools. The different bioavailability of PTEs could be reflected in their uptake and translocation by the hyperaccumulator plants, which extract PTEs from the soil and can move them from roots to shoots and leaves. Across the time the PTEs extraction changes, because there are modifications of soil properties due to the previous plant growth.

This observation highlights that bioavailability in soil-plant systems is a dynamic concept changing with soil, plant, and time. So, the legislations in future remediation projects should start to consider to reduce the concentration of metal bioavailable fraction rather than the total.

In this perspective, the monitoring of specific soil-plant interaction can be an important step in soil remediation programs, providing valuable indications of the phytoextraction techniques efficiency.

References

1. Antonio Cristaldi; Gea Oliveri Conti; Eun Hea Jho; Pietro Zuccarello; Alfina Grasso; Chiara Copat; Margherita Ferrante; Phytoremediation of contaminated soils by heavy metals and PAHs. A brief review. *Environmental Technology & Innovation* **2017**, *8*, 309-326, 10.1016/j.eti.2017.08.002.
2. Massimo Fagnano; Definition of a site as contaminated: Problems related to agricultural soils. *Italian Journal of Agronomy* **2018**, *13*, 1-5, 10.4081/ija.2018.1348.
3. Rocco Claudia; Agrelli Diana; Tafuro Maria; Caporale Antonio Giandonato; Adamo Paola; Assessing the bioavailability of potentially toxic elements in soil: A proposed approach. *Italian Journal of Agronomy* **2018**, *13*, 16-22, 10.4081/ija.2018.1348.
4. Luigi Giuseppe Duri; Nunzio Fiorentino; Eugenio Cozzolino; Lucia Ottaiano; Massimo Fagnano; Bioassays for evaluation of sanitary risks from food crops cultivated in potentially contaminated sites. *Italian Journal of Agronomy* **2018**, *13*, 45-52, 10.4081/ija.2018.1348.
5. MIR ZAHOOR AHMAD; BHAROSE RAM; LONE ASHIQ HUSSIAN; MALIK ZAHID AHMAD; Review on phytoremediation: An ecofriendly and green technology for removal of heavy metals. *Crop Research* **2017**, *52*, 74-82, .
6. Fiorentino Nunzio; Mori Mauro; Cenvinzo Vincenzo; Duri Luigi Giuseppe; Gioia Laura; Visconti Donato; Fagnano Massimo; Assisted phytoremediation for restoring soil fertility in contaminated and degraded land. *Italian Journal of Agronomy* **2018**, *13*, 34-44, 10.4081/ija.2018.1348.
7. Fernando Guerra; Felipe Gainza; Ramón Pérez; Francisco Zamudio. Phytoremediation of heavy metals using poplars (Populus spp): a glimpse of the plant responses to copper, cadmium and zinc stress; Ivan A. Golubev, Eds.; Nova Science Publishers, Inc. : New York, 2011; pp. 387-413.
8. Nunzio Fiorentino; Massimo Fagnano; Adriana Impagliazzo; Mauro Mori; Valeria Ventorino; Astolfo Zoina; Paola Adamo; Olimpia Pepe; Assisted phytoextraction of heavy metals: compost and Trichoderma effects on giant reed (Arundo donax L.) uptake and soil N-cycle microflora. *Italian Journal of Agronomy* **2013**, *8*, 244-254, 10.4081/ija.2013.e29.
9. C. Keller; Daniel Hammer; Metal availability and soil toxicity after repeated croppings of Thlaspi caerulescens in metal contaminated soils. *Environmental Pollution* **2004**, *131*, 243-254, 10.1016/j.envpol.2004.02.030.
10. Diana Agrelli; Paola Adamo; Teresa Cirillo; Luigi Giuseppe Duri; Ida Duro; Evelina Fasano; Lucia Ottaiano; Luigi Ruggiero; Gelsomina Scognamiglio; Massimo Fagnano; et al. Soil versus plant as indicators of agroecosystem pollution by potentially toxic elements. *Journal of Plant Nutrition and Soil Science* **2017**, *180*, 705-719, 10.1002/jpln.201700050.
