Soil Washing: A Promising Technique for Heavy Metals Removal from Contaminated Soils

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Heavy metal (HM) contamination of soils is extremely diffused worldwide as consequence of natural events and anthropogenic activities. According to the history of the contamination, to the physical and chemical characteristics of the soil, and to the oxidation state of the contaminant, the metal can be more or less mobile and soluble, so representing a serious threat for the living species, being well ascertained the acute and chronicle toxicity of most of heavy metals.

The lecture presents one of the most promising and applied techniques able to accomplish the remediation of heavy metal contaminated soils, known as soil-washing. More in details the lecture deals with chemical-washing which is applied to the finest and most contaminated fraction of soils, giving just a few details on physical-washing treatments.

The first part of the lecture is dedicated to the characterisation of the contamination through the sequential extraction procedure. Such a characterisation is fundamental to verify the applicability of the washing process, and to optimize it, previewing the maximum removal efficiency which can be potentially attained.

Heavy metals, in fact, are distributed throughout soil components and are associated with them in many different ways. The knowledge of metal speciation is fundamental to understand if they can be removed from the soil using a washing agent, and is helpful for the correct choice of the agent. Generally a sequential extraction procedure allows to identify the following fractions of the metal in the soil: i) water soluble; ii) exchangeable; iii) carbonate bound; iv) iron and manganese oxides bound; v) organically bound; vi) residual (bound to clay minerals). Different extraction procedures have been proposed in the nineties, and recently a great efforts of harmonisation has been carried out, obtaining a standardized procedure, used worldwide, known as BCR three-step sequential extraction procedure, which has either an original formulation and a modified one. Both are discussed and compared in the lecture.

The second part of the lecture is dedicated, instead to the process analysis, starting from the choice of the washing agent. Strong and weak acids, bases, chelants, oxidizing and reducing agents and low-cost materials are taken into account, illustrating they applicability to specific cases. Different parameters affecting the removal efficiency are illustrated and discussed, including slurry concentration, reaction time, pH conditions, solution concentration.

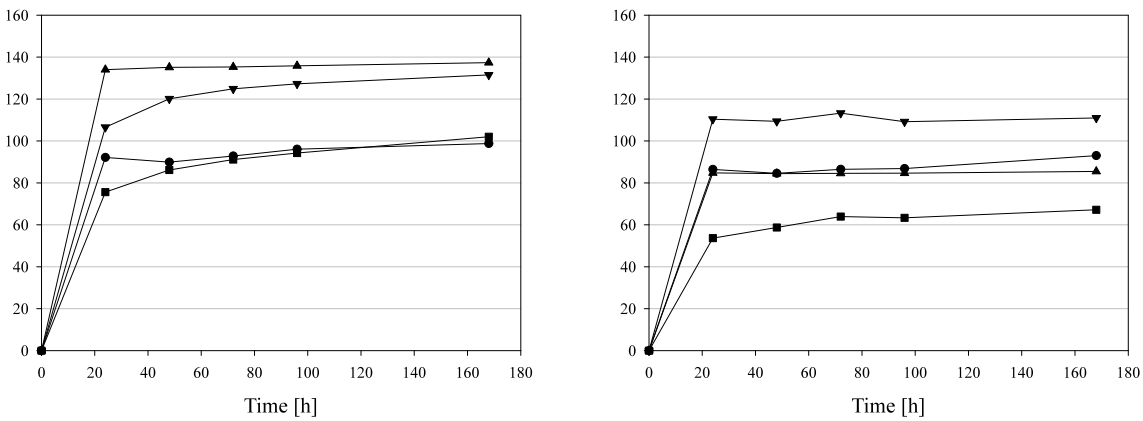
Process kinetics are analyzed in details referring to the most commonly used washing agents.

Some results obtained on naturally contaminated soils are presented to better understand the real applicability of the process. As an example in Figure 1 are reported the efficiency obtained in a soil washing experiment using HCl, varying the slurry concentration.

In order to define a complete soil-washing treatment cycle two more issues are discussed in the last part of the lecture: i) the possibility of returning the soil to its original use or, at least, of giving it a new safe use after the washing treatment; ii) the possibility of recovering the exhausted washing solution.

It is therefore analysed the possibility that the residual fraction of the contaminant is mobilized in the environment as consequence of natural events presenting the results obtained on aged soils: moreover the results of ecotoxicity tests performed on decontaminated soils are illustrated and discussed.

Finally washing solution regeneration, reuse and disposal are considered comparatively, in view of an economical optimisation of the process, especially in case of expensive reactants utilisation. Possible regeneration processes are illustrated, giving some information about the removal efficiency which can be obtained with regenerated agents, and the biodegradabilty of certain washing chelants is presented, supported by experimental and field results.



(a) solid content of the slurry = 25 g l^{-1} (b) solid content of the slurry = 50 g l^{-1}

Figure 1. Removal efficiencies in soil-washing experiments using HCl (0.5 M): ● Cd ;▲ Zn; ▼ Cu; ■ Cr.

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