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Electrokinetic remediation of soils polluted by heavy metals (mercury in particular)

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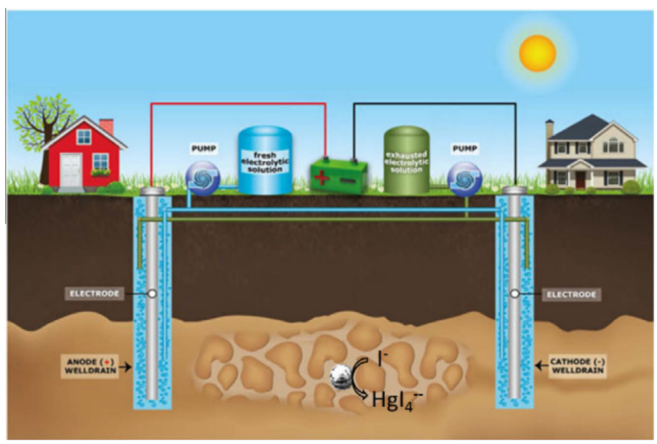
HIGHLIGHTS

- Due to an electric field, Hg^0 can be mobilized without using oxidizing chemicals.
- A proper management of hydraulic fluids allows to minimize pH adjustments.
- A significant abatement of Hg pollution can be obtained in short times.
- The outcomes from pilot-scale tests encourage further tests in field.

GRAPHICAL ABSTRACT



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ABSTRACT

The electrokinetic approach, for the extraction of contaminants from a soil matrix, requires the application of electric fields of suitable intensity, through saturated portions of the soil. When aimed at the removal of species present in metallic form (like mercury) or as poorly conductive minerals (like some sulfides), pollutants require to be preliminary dissolved, an action that can be facilitated by adding appropriate chemicals. In this paper, we show that the presence of an electric field is decisive, possibly because the pollutant-containing particles were able to act as polarizable species (and thus as improper electrodes). At first, tests were performed on small amounts of soil (about 200 g, in plastic bench cells); then, the process was scaled up, testing approximately 400 kg of soil. A 60% of total mercury was removed, in less than 3 months, by adopting specific expedients, in terms of hydraulic control as well as of plant design.

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1. Introduction

Due to the high impact of human activities on the environment, the remediation of contaminated matrices (soils and waters in particular) is attracting increasing interest, both in terms of R&D, as well as in terms of economic and administrative concerns. Concerning soils, the technologies currently used are extremely invasive, resulting in a low level of environmental and social sustainability [1].

Heavy metals, deriving from industrial activities or from mining sites, are quite common contaminants, especially in industrial

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sites. The resulting soil contamination is one of the most critical forms of environmental pollution. In fact, once heavy metals and their compounds have been dispersed in the soil, they may remain unaltered for long periods or migrate towards aquifers, thus spreading the pollution to other environmental matrices. Various methods are known for the reclamation of soils contaminated by heavy metals, and they can be typically carried out either *in situ* or *ex situ*. *In situ* processes are generally more convenient, from the point of view of overall decontamination costs, and limitation of matrix displacement; accordingly, they are preferred, when possible.

In Hg-polluted soils, the heavy metal can be present in elemental form (Hg^0), in the form of slightly soluble compounds of Hg^+ and/or Hg^{2+} (chlorides, oxides or sulfides, for example) or as organic complexes (for example, dimethyl-mercury, methyl- or phenyl-mercury salts). The poor solubility of mercury and its compounds in water makes their removal from the soil technically difficult, with obvious repercussions from an economical point of view.

The Electro-Kinetic Remediation Technology (EKRT) represents an interesting approach, as it is potentially able to allow results similar to *on-site* and/or *off-site* interventions, but with substantially higher levels of sustainability and acceptability. Electrokinetic processes are based on the application of electric fields through a given soil matrix (see Fig. 1A) which cause the migration of species having an electric charge [2–4].

Electrodes are generally immersed into suitably constructed wells containing an electrolytic solution. The wells are constructed so as to be permeable to liquids and ionic species, and are therefore in hydraulic communication with the soil. The migration of species through the soil substantially takes place via electromigration and electroosmosis (Fig. 1B). The former is the migration of ionic species through the soil solution, while the latter refers to the migration of the soil solution (which may contain dissolved pollutant species) through the pore system of the soil. The electrokinetic migration of ionic species generally occurs through both the mechanisms, whose relative importance depends on environmental conditions (porosity, soil texture, ionic strength of the electrolyte).

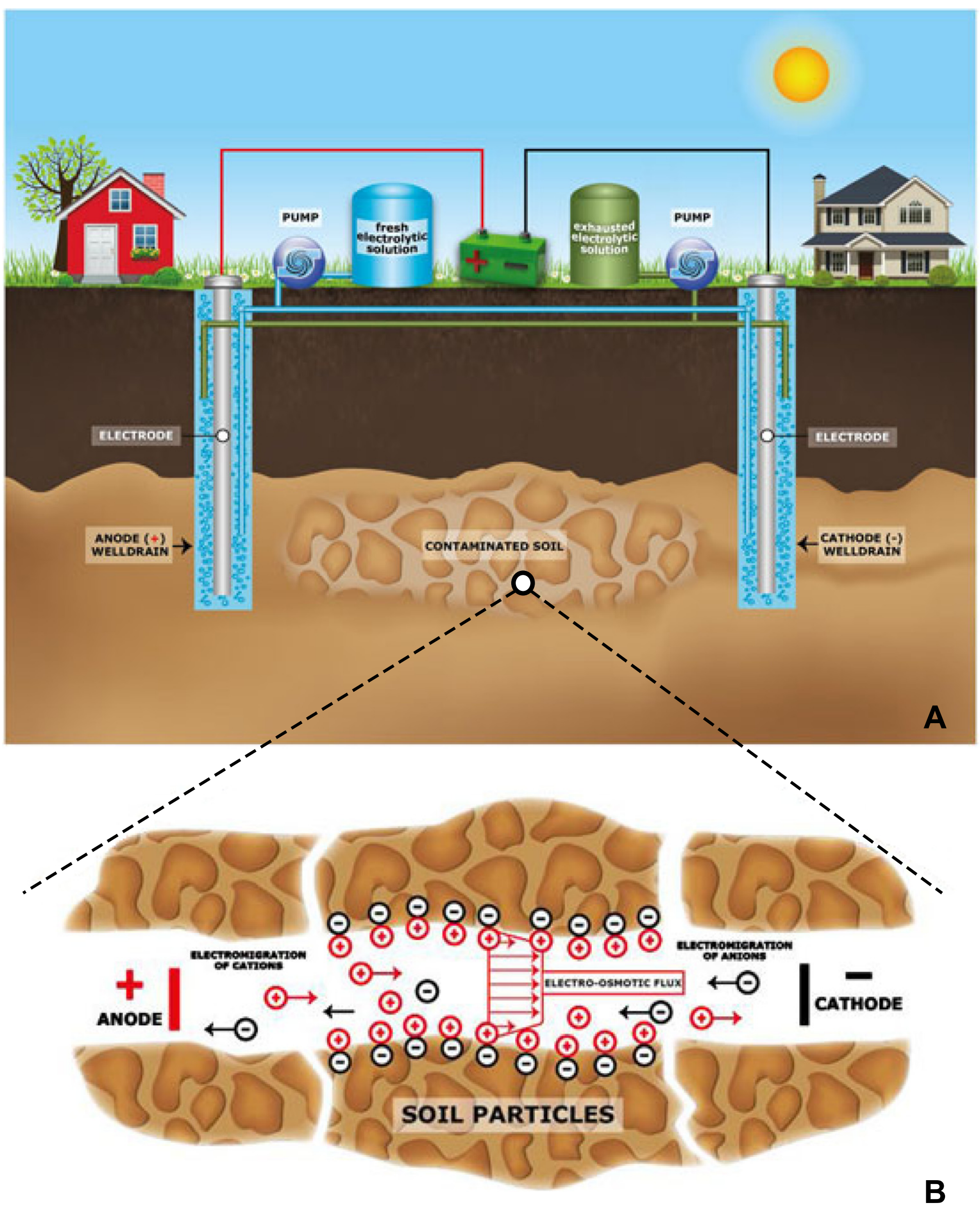

Fig. 1. (A) Schematic of a typical EKRT installation; (B) detail of the main mechanisms occurring during an EKRT remediation.

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