



Case study on the strategy and application of enhancement solutions to improve remediation of soils contaminated with Cu, Pb and Zn by means of electro dialysis

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Abstract

Numerous studies have been conducted with electrochemical removal of heavy metals from spiked kaolinite. Meanwhile, when moving from kaolinite to real soils, new factors must be taken into account—factors influencing, e.g., the buffering capacity of the soil against acidification and the adsorption/desorption processes of the heavy metals. The present study gives some examples where it is necessary to use an enhancement solution to aid desorption of Cu, Zn and Pb during electro dialytic treatment. Dependent on the composition of the pollution, different choices can be made. In the case of a Cu-polluted calcareous soil, ammonia may be used as enhancement solution, due to the formation of charged complexes between ammonia and Cu. Thus, Cu is mobile at high pH when ammonia is added and Cu can be removed without dissolving the calcareous parts. Zn is also mobilized by ammonia, but to a lesser extent than Cu. In the case of Cu, Zn and Pb at the same time, alkaline ammonium citrate may be a solution. It was shown that this enhancement solution could mobilize these three pollutants, but optimization of concentration and pH of the ammonium citrate is still needed. When choosing a remediation scheme for electrochemical treatment of an actual industrially polluted soil, this scheme must be chosen on basis of characterization of soil and pollution combination.

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1. Introduction

1.1. Remediation strategy

Several different electrochemical soil remediation methods for removal of heavy metals have been/are

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developed. Meanwhile, the remediation goals of the methods vary. Some methods aim at stabilizing the heavy metals within the soil (e.g., Vengris et al., 2001), but for most methods extraction of the polluting heavy metals is the main emphasis. Some methods aim at removing the direct mobile part of the heavy metals leaving the adsorbed fractions of heavy metals or even further stabilize the remaining heavy metals, e.g., to use electrochemical processes to supply Fe(II) to reduce soluble species of Cr(IV) to the less toxic Cr(III) (Pamukcu et al., 1997). Most methods do meanwhile aim at removal of the heavy metals so the soil can meet target values for total concentrations (e.g., Reddy et al., 2003; Ottosen et al., 1997).

Experimental success with removal of various heavy metals from spiked kaolinites has been reported in numerous papers and these are summarized in Page and Page (2002). Meanwhile, when moving from kaolinite to soils, the many studies of different ways to enhance the process (as summarized in Page and Page, 2002), may indicate that the successful results obtained with spiked kaolinite cannot always be transferred directly to spiked soils or to soils sampled at polluted sites. The main difference being the variety of adsorption sites for heavy metals present in inhomogeneous soils (both related to organic and inorganic constituents) not being present in kaolinite. An example of this is found in Hécho et al. (1998), where it was shown that 99% Cr was removed from a spiked kaolinite in 18 days, whereas only 64% Cr was removed from a spiked soil during a similar experiment. Another example can be found in Reddy et al. (2003), where electrokinetic remediation experiments of Hg spiked kaolinite and glacial till was compared. The initial concentrations were about 500 mg/kg for both soils and the best remediation result obtained was 16 and 220 mg/kg, respectively.

To carry out a successful removal of heavy metals from soil by an electrochemical method, it is necessary to desorb the actual heavy metals during the process in order to be able to remove them by either electromigration or in an electroosmotic flow (Ribeiro and Mexia, 1997).

Enhancement techniques are mainly directed toward controlling pH and maintaining or bringing contaminants into solution by addition of enhancement solution to the soil (Page and Page, 2002). The

necessity for conditioning the electrolyte solution wherein the electrodes are placed was observed in the earliest works (e.g., Lageman et al., 1989). The present paper deals with the addition of enhancement solution to the polluted soil matrix to help desorption of different heavy metals for improved electrochemical removal.

1.2. Use of enhancement solution and their potential use for Pb, Cu and Zn removal

The one single parameter that has shown the most important in electrochemical soil remediation is soil pH and this is due to the pH dependency of adsorption/desorption processes. Often is an acidic front, which is developing in the soil from the anode end towards the cathode end during electrochemical soil remediation, used for mobilizing the heavy metals (e.g., Acar and Alshawabkeh, 1993 or Ottosen et al., 1997). The order of removal of different heavy metals in the acidic front have been reported: $Ni \approx Zn > Cu > Cr$ in a soil polluted from a chloralkali factory (Suer et al., 2003) and $Zn > Cu > Pb$ in different industrial polluted soils (Ottosen et al., 2001).

Enhancement solutions can be either used for changing the physicochemical conditions in the soil as pH and redox conditions, or the enhancement solutions can be used to form mobile complexes with the actual heavy metals. Addition of the enhancement solutions will be either before the remediation and/or during the action through the processing solutions at the electrodes. In the latter case, the electroosmotic flow can be used to supply the enhancement solution. Popov et al. (1999) found that the electroosmotic flow increased in the experimental soils after addition of different complexants as citric acid, ethylenediaminetetraethanoic acid (EDTA) or 1-hydroxyethane-1,1-diphosphonic acid (HEDPA) compared to distilled water. EDTA was found to enhance the removal of Pb and Zn from spiked soils (Yeung et al., 1996), (Wong et al., 1997). Even though EDTA is a good complexing agent, it may not be the best choice of enhancement solution due to the toxicity of EDTA itself.

Use of enhancement solutions is beneficial or even necessary for removal of heavy metals from, e.g., high buffering capacity soils or for some combinations of pollutants within a reasonable remediation time. Even

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