Pb-removal as the treatment proceeded. The maximum removal rate for Pb obtained during phase 2 was 4mg/kg∙hour.

period with a low removal-rate, where the dissolved Pb was removed from the solution, and (4) a period with no further removal was substantially absent, (2) a period with a high removal rate involving dissolution of Pb in the soil-solution, (3) a period during EDR in suspension was initiated. The Pb-removal could be divided into four phases (1) a "lag-phase", where the influence of Pb-speciation and soil characteristics on remediation, while carbonate influences the remediation-time negatively. EDR remediation of fine grained, inorganic soils was documented to be feasible when the Pb is not associated with extremely stable compounds. The potential of treating other fine-grained materials in a suspended version of EDR had at this time been demonstrated by other researchers in the group. Therefore the possibility of treating the fine fraction of Pb-contaminated soils by suspended EDR was investigated. This technology was intended for combination with conventional soil washing, in which the lack of a treatment method for the remaining soil-fines has been the main limiting factor. First, the influence of current strength and liquid-to-solid-ratio (L/S) was examined. It was found that during the treatment, Pb was easily dissolved by the acidification resulting from water splitting at the anion-exchange membrane. When higher currents and/or higher L/S ratios were applied, water splitting also took place at the cation-exchange membrane, resulting in a slow-down of the acidification and in decreased remediation efficiency. The optimal current strength depended linearly on the L/S of the soil slurry. Complete remediation of the soil-fines from the initial 1170mg/kg Pb to reach the accepted level for sensitive land-uses set by the Danish government (40 mg/kg Pb) was shown to be possible, with the majority of the Pb being transported into the catholyte and precipitated at the cathode. Based on the results it is recommended that EDR should be implemented using a number of reactors in series, where the initial reactor works at the highest possible removal rate, and the final reactor works at the target Pb-concentration. Application of microbiolled siderophores, autotrophic leaching, heterotrophic leaching and biosurfactants were identified as potential methods for promotion of EDR of Pb contaminated soil. By these methods mobilization of Pb would occur due to complexation with much smaller substances than the previously examined and rejected exopolymers, why they were considered more efficient for mobilization of Pb in an electric current field. Siderophores, which are iron-chelating compounds produced by microorganisms under iron deficiency were investigated for their Pb-mobilizing ability. After having shown that a commercially available siderophore indeed was able to extract Pb from contaminated soil-fines, application of siderophores was however also rejected, primarily due to the insufficient concentrations produced by microorganisms in general and the unrealistic high costs of industrially produced siderophores in relation to the low value of the product to be treated. Furthermore no detection of siderophore production was possible during stationary suspended EDR of soil-fines, which after incubation with a siderophore producing organism in the presence of Pb and current, had been shown to produce high levels of siderophores. Although a study into the mechanisms behind this observation would have been of great academic interest, it was omitted because of the lack of relevance to treatment of Pb-contaminated soil. Autotrophic leaching, which is leaching by acidophilic, autotrophic microorganisms obtaining energy by oxidation of elemental sulfur, was shown to induce acidification of soil-fines in suspension, but removal of Pb from the treated soil-fines by suspended EDR was reduced considerably (from 94% without preceding heterotrophic leaching to less than 68% with preceding leaching) due to precipitation of Pb as lead-sulfate. The potential of heterotrophic leaching by autotrophic and acid producing microorganisms was tested by batch extraction of Pb from contaminated soil-fines with 11 organic acids at pH-values between 2 and 7, where acid-producing fungi grow. Five of the acids (citrlic acid, DL-malic acid, gluconic acid, tartaric acid and fumaric acid) showed ability to extract Pb from the soil fines at neutral and slightly acidic pH in excess of the effect caused by pure pH-changes. Addition of organic acids, however, severely impeded EDR, thus promotion of EDR of Pb from soil-fines by combination with heterotrophic leaching was also rejected. In contrast, enhancement of EDR with nitric acid showed promising results at current densities beyond what is optimal with distilled water as solvent. Consequently addition of nitric acid is recommended in cases where the removal rate is considered important, while suspension in pure water is recommended in situations where the energy expenditure and the chemical costs are limiting factors. Considering the results of the screening of siderophores, autotrophic leaching and heterotrophic leaching for promotion of EDR of soil-fines in suspension, it was decided to focus on the seemingly more promising unenhanced remediation. An investigation of the removal rates of Pb and common soil cations from soil-fines during EDR in suspension was initiated. The Pb-removal could be divided into four phases (1) a "lag-phase", where removal was substantially absent, (2) a period with a high removal rate involving dissolution of Pb in the soil-solution, (3) a period with a low removal-rate, where the dissolved Pb was removed from the solution, and (4) a period with no further Pb-removal as the treatment proceeded. The maximum removal rate for Pb obtained during phase 2 was 4mg/kg∙hour.
During phase 3, the high conductivity and low voltage suggested that removal might be accelerated by increasing the current density. During phase 1, dissolution of carbonates was the prevailing process. This dissolution resulted in a corresponding loss of soil-mass. The removal-order among the investigated soil cations was: Ca > Pb > Mn > Mg > K > (Al and Fe). Na was found to enter the soil from the electrolytes and a careful choice of electrolytes in order to meet any requirements by subsequent receivers of the soil-fines is recommended. It is also recommended to limit the dissolution of Fe- and Al-minerals by terminating remediation as soon as Pb-extraction ceases. The final work in this thesis provided evidence for feasible removal of a number of other toxic elements (As, Cd, Cu, Ni, Pb and Zn) by the method apart from demonstrating repeatability of experimental results. Also Cr was amenable to remediation, although removal from most of the investigated soils was slow compared to the other elements. In general therefore, conditioning of Cr-contaminated soil by addition of an oxidizing or a complexing agent is recommended. Hg was unsusceptible to EDR in suspension with 100% remaining in the soil after termination of the experiments. Some changes in the Hg-speciation towards mobilization were however established. Like for Cr-contaminated soil conditioning of Hg-contaminated soil with oxidizing or complexing agents is recommended. The maximum removals obtained after 10 days was 79% for As, 92% for Cd, 55% for Cr, 96% for Cu, 0% for Hg, 52% for Ni, 53% for Pb and 88% for Zn.

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