



Comparison of 2-compartment, 3-compartment and stack designs for electrodialytic removal of heavy metals from harbour sediments

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ABSTRACT

Comparisons of cell and stack designs for the electrodialytic removal of heavy metals from two harbour sediments, were made. Multivariate modelling showed that sediment properties and experimental set-ups had the highest influence on the heavy metal removal indicating that they should be modelled and analysed separately. Clean-up levels of Cu, Pb and Zn were significantly higher for the cell designs, implying that longer time and relatively more electric charge and energy would be necessary to achieve similar clean-up levels in the stack design experiments.

In the studied experimental domain, the optimal current density for the 2- and 3-compartment cells was 0.12 mA/cm² (center value) removing the highest quantity of Cu, Pb and Zn per Wh. The highest percentages removed were 82% Cu, 81% Pb and 92% Zn were however achieved at higher current density. For the stack experiments conducted at same electric charge per unit sediment, energy consumption was a magnitude higher and the highest clean-up levels were 21% Cu, 42% Pb and 73% Zn.

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1. Introduction

Electrodialytic remediation (EDR) is based on applying an electric field of low current to the contaminated material and is among the electrokinetic remediation methods used for removing heavy metals from contaminated materials. The electric field initiates electrolysis reactions at the electrode, producing protons at the anode and hydroxyl ions at the cathode. Since the effective ionic mobility of protons is higher than that of hydroxyl ions, an acidic front prevails in the contaminated material [1] and heavy metals are subsequently desorbed, mobilised and transported by electromigration towards the cathode. The rate of acidification of the contaminated material depends on its physical and chemical properties; a high buffering capacity in soil will, for instance, retard the acidification as may high levels of organic species and salts [2–4].

EDR controls the formation and progress of the acidic and alkaline fronts by making use of ion exchange membranes, which physically separate the contaminated material from the electrodes

and circulating electrolytes. In addition, they control the transport of ions between the contaminated material and electrolytes, preventing the introduction of protons and hydroxyl ions from the electrolysis reactions into the contaminated material. Acidification of the contaminated material is however still achieved, mainly due to water splitting at the anion exchange membrane [5] and the hydroxyl ions produced are transported across the membrane to the anolyte while the protons advance towards the cathode (Fig. 1).

EDR has been successfully used for the removal of heavy metals from different contaminated solid materials such as soil, harbour sediments, wood, fly ash and sewage sludge [6–10]. During the last decade, the majority of EDR studies have been conducted on lab scale using a 3-compartment design (Fig. 1), consisting of a centre compartment with the polluted material and two adjoining compartments in which electrolytes are continuously circulated. Experimental variables shown to have significant effect on the heavy metal removal in this design include current density, remediation time and liquid-solid (L/S) ratio of the contaminated material [10–12]. In addition, several studies have shown that applying a stirred rather than a stationary set-up significantly improves the removal of heavy metals from soil [13], harbour sediment [14] and fly ash [15].

Recently, a new design for EDR lab-scale experiments, consisting of a 2-compartment cell, has been developed and

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patented at The Technical University of Denmark. The polluted material compartment is adjoined by one compartment in which electrolyte is circulated. A cation exchange membrane separates the two compartments and ensures that desorbed elements from the contaminated material are transported to the electrolyte while preventing hydroxyl ions produced in the electrolysis reactions from entering the contaminated material compartment. The anode is placed directly in the polluted material, leading to acidification

due to the direct supply of protons. Few studies have been conducted in the 2-compartment cell and the influence of experimental variables on EDR in this design has not been as well documented as for the 3-compartment cells. A recent study, however, established that the acidification time was significantly reduced, the final pH was lower and lower voltages were observed in the 2-compartment compared to the 3-compartment cell. In addition the higher conductivity in the 2-compartment cell was

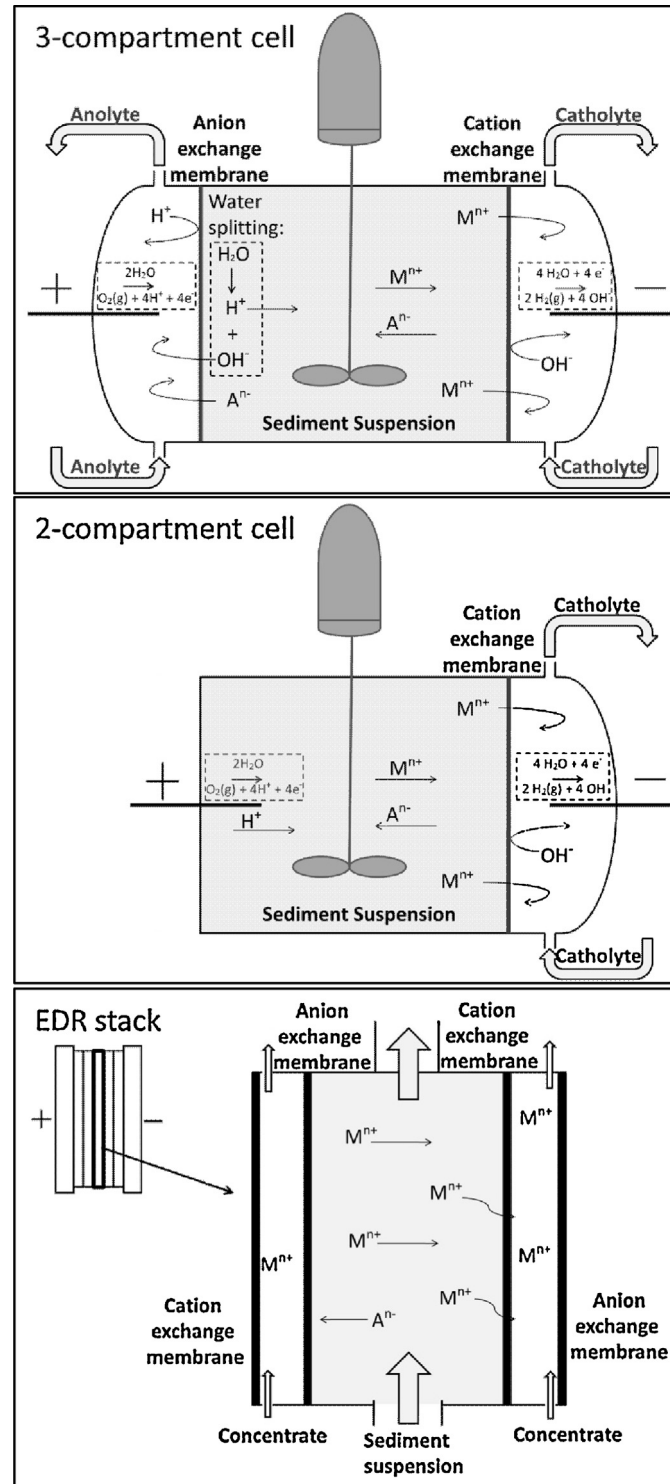


Fig.1. The EDR cell and stack designs: 3-compartment cell, 2-compartment cell and stack.

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