First trials in electrokinetic remediation of heavy metals from a contaminated marine dredged sediment from a European port

N. García-Blas; E. Jiménez-Relinque; RA Nevshupa; M. Castellote

Institute of Construction Science Eduardo Torroja- IETcc-CSIC, Spain

nieves.garcia@ietcc.csic.es; eva.jimenez@csic.es; r.nevshupa@csic.es; martaca@ietcc.csic.es

Abstract

Dredged marine sediments are often contaminated with a wide variety of pollutants, such as heavy metals and organic compounds. This complicates their reuse and contributes to a loss of biodiversity and degradation of the ecosystems, implying also a risk for humans due to the transfer of contaminants to the benthic food chain. Despite decades of research, there is not an established method to decontaminate sediments yet. The electrokinetic technology is a promising method to remediate sediments, owing to its advantage of extracting both heavy metals and organic compounds. It relies on **the application of a low-intensity electric field directly to the material**. The electric field mobilizes ionic species from the material towards the electrodes due to electromigration. Non ionic species can be transported due to electrokinetic phenomena, as electroosmosis and electrophoresis. In this work, different trials were carried out to check the effectiveness of different electrolytic solutions in the removal of heavy metals and the interactions between the pollutants and the material, in order to develop the most suitable treatment for this heavily contaminated sediment, obtained from a European port. Different enhancing solutions were equilibrated with the sediment in order to find the most effective solution to test with the sediment for its remediation in future research.

The sediment

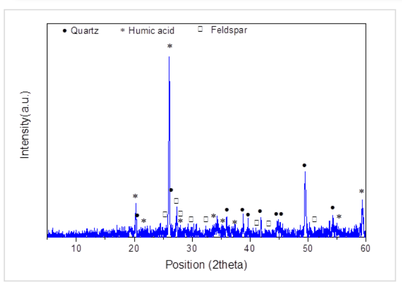


Figure 1: X-Ray Diffractogram pattern of the sediment

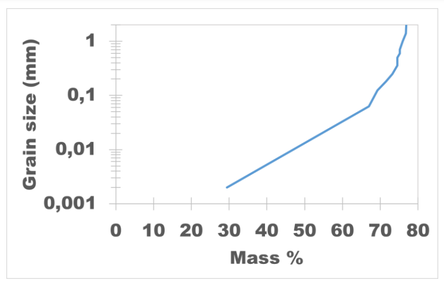


Figure 2: Granulometric distribution

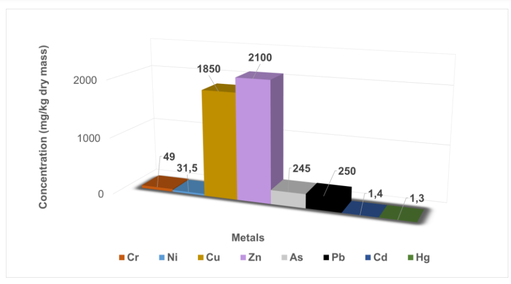
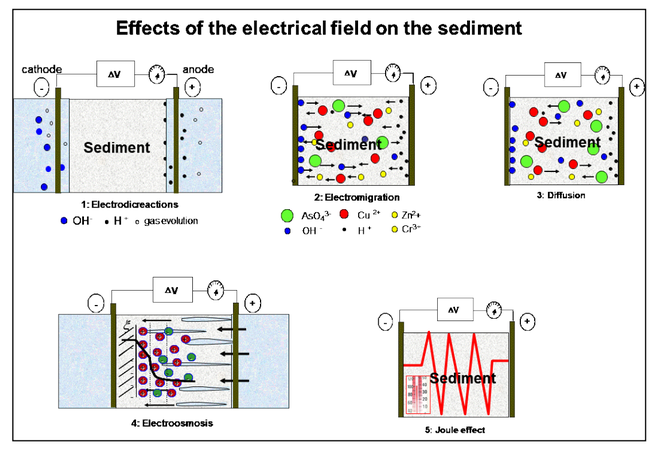


Figure 3: Initial concentration of metals

$CaCO_3$ (g/kg)	Total organic carbon (TOC) (g/kg)	Solids concentration (mass %)	Agglomerated mass (g)	Dry matter (mass %)	Microtox solid phase test
10,2	21	33	0	34,85	>16 g/L of sediment

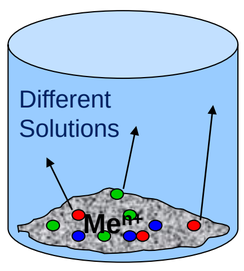
Organic compounds	mg/kg
Total Organostannic compounds	<0,09
Total Polycyclic Aromatic Hydrocarbons (PAH)	<0,48
Total Petroleum Hydrocarbons (TPH): C10-C40	70
Total Polychlorinated Biphenyl (PCB): 28, 52, 101, 118, 138 153, 180	<0,007

The mechanisms of electrokinetic remediation



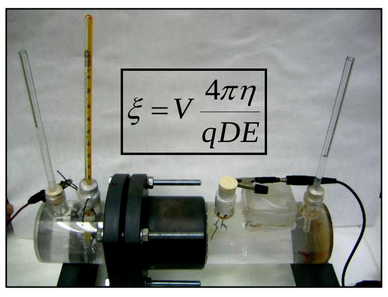
Methodology

Equilibrium tests with enhancing solutions



- **Desionized water**
- **Nitric acid 1M**
- **Sodium hydroxide 1M**
- **Citric acid 0,2M**
- **Acetic acid 0,5M**
- **Oxalic acid 0,2M**
- **EDTA 0,2M**
- **Potassium ioide 0,2M**

Electrokinetic tests



Test	Anolyte	Catholyte	Direct Electrical field (V)
1	Water	Water	No
2	Water*	Water	12, 20, 30
3	Water	Acetic acid	12

- Samples: pH, conductivity, voltage, intensity, electroosmotic flux, metals and Infrared spectroscopy
- *During the last week, samples taken were replaced by H2O2
- Tests 1 and 2: 3 weeks, Test 3:1 week

Some results

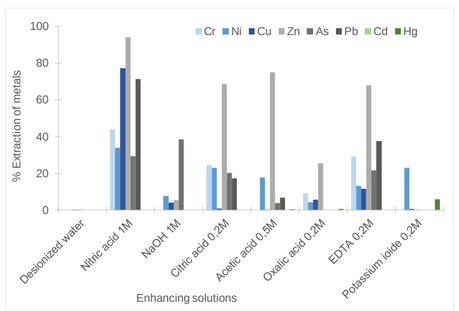


Figure 4: % extraction of metals according to the tested Enhancing solutions

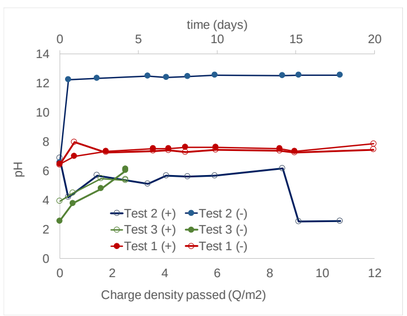


Figure 5: pH in function of the charge density passed in tests 2 and 3, (test 1 in function of the time)

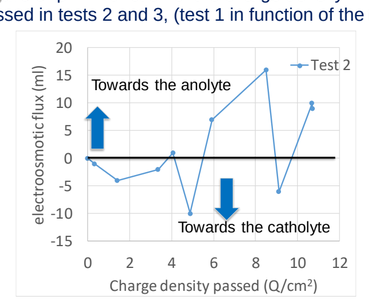


Figure 6: EOF in function of the charge density passed in test 2

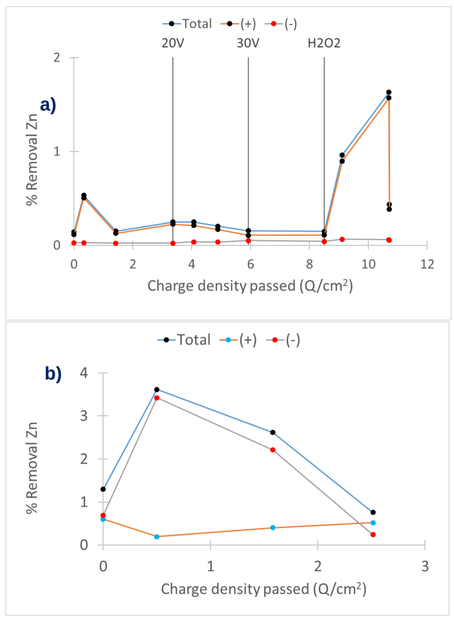


Figure 7: ***a)*** Example of % removal of Zinc from test 2. ***b)*** Example of % removal of Zinc from test 3

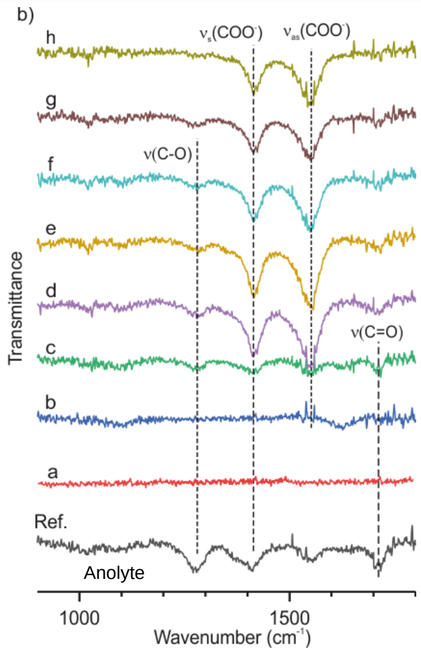


Figure 8: IR results from the anolyte from Test 3

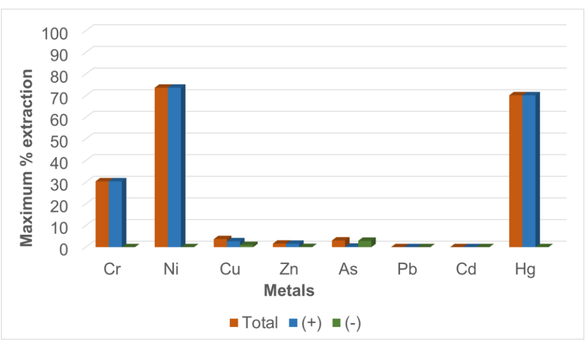


Figure 9: Maximum % extraction of metals in test 2

Conclusions and Future Research: It is posible to tune electrokinetic experiments to remove specific contaminants. There is not one enhancing solution able to extract all the metals from the sediment. From the equilibrium experiments, concentrated HNO_3 seems to be the most effective in extracting Cu, Zn and Pb. NaOH and EDTA seem to be the optimum to extract arsenic and chromium, respectively. No application of electrical field led to no removal of metals at all. Addition of acetic acid in the catholyte at a low potential (12V) resulted globally in more decontamination than water at high potential (30V). Addition of H_2O_2 seems to strongly increase the extraction of several metals (Ni and Cu). Changing conditions during the tests might result in the precipitation of metals in the solutions and/or re-ingress into the sediment due to reversal of the electroosmotic flow. No organic contaminants were extracted with the enhancing solutions tested. Design of the remediation process should incorporate the particularities of the different contaminants in their interaction with the extracting solutions and the characteristics of the sediment. More experiments are needed to optimise enhancing solutions, including those specific for organic contaminants (surfactants).

References: SedNet WP books, Vol 1-4, Elsevier; eBook ISBN: 9780080466675.; Alshawabkeh, A.N., Bricka, R.M., 2000. Basics and applications of electrokinetic remediation. Environmental Science and Pollution Control Series. Marcel Dekker, Inc., pp. 95e112; Castellote, M., Llorente, I., Andrade, C., 2006. Influence of the composition of the binder and the carbonation on the zeta potential values of hardened cementitious materials. Cem. Concr. Res. 36, 1915e1921; Rozas, F., Castellote, M., 2012. Electrokinetic remediation of dredged sediments polluted with heavy metals with different enhancing electrolytes. Electrochim. Acta 86, 102e109.

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