

ELECTROCHEMICAL REMEDIATION TECHNOLOGIES FOR SOIL, SEDIMENT AND GROUND WATER

Falk Doering², Niels Doering², Joe L. Iovenitti¹, Donald G. Hill¹, and William A. McIlvride¹

¹Weiss Associates, 5801 Christie Avenue, Suite 600, Emeryville, CA 94608, Fax: 510-547-5043, jli@weiss.com,

²P2-Soil Remediation, Inc.

ABSTRACT

ElectroChemical Remediation Technologies (ECRTs) are phenomena related to colloid electrochemistry and belong to the class of Direct Current Technologies (DCTs) where DC electricity is passed between two electrodes. The primary distinctions between ECRTs and traditional electrokinetics are the (1) operative mechanisms, (2) energy input, (3) nature of the direct current, and (4) resulting outcome. Employing low-energy, proprietary AC/DC current, ECRTs are patented in the United States and Europe. They generate reduction-oxidation reactions at the pore scale and, through the Induced Complexation (IC) process, mobilize and remove metals in soil, sediments and ground water, and through the ElectroChemical GeoOxidation (ECGO) process, destroy organics in soil and sediments. ECRTs are successful both *in-situ* and *ex-situ*. Among the contaminants remediated to below regulatory standards are VOCs, CVOCs, SVOCs, PAHs, PCBs, phenols, fuels, other hydrocarbons, explosives, mercury, cadmium and lead. In many of the more than 50 successful projects, multiple contaminants have been removed with a single system, including combinations of metals and organics. ECRT projects are documented, ISO 9001-certified and insurable. ECRTs work rapidly, on the order of months, at costs well below excavation and disposal. Site data are presented below.

Technical Basis and Benefits of ECRTs

ECRTs use a proprietary AC/DC current passed through soil between electrode pairs to create an induced polarization field. In this field, soil particles behave as capacitors and discharge electricity many times per second, creating redox reactions that mineralize organic molecules to carbon dioxide and water. Neither pumping nor chemical additives are used in either the ECGO or IC processes. The reaction rates are inversely proportional to grain size, such that ECRTs remediate faster in clays and silts than in sands and gravels.

Metals remediation occurs when the redox reactions create ionic complexes that are much more mobile in soil and ground water than simple metal ions or free metals. These complex ions move to the electrodes under the electric field and are electrochemically plated on. When remediation goals are achieved, the electrodes are removed for metals recycling/disposal.

ECRTs achieve rapid cleanup, on the order of months, require less energy than electrokinetic methods, and cost less than conventional remediation such as excavation. A wide range of contaminants of concern, including metals and organics, may be treated with a single system. ECRTs work *in-situ* or *ex-situ*, in all soil types, generally produce no regulated waste streams, are safe, quiet, and do not interfere with surface activities. The projects are well documented, ISO 9001-certified, and insurable. Two case histories taken from the many successful projects are presented below.

IC Case History (Metals Remediation)

IC removed mercury from sediments in the Union Canal in Scotland. The canal contains brackish water (total dissolved solids = 3,500 mg/l) and is 10 m wide x 1.1 m deep, with a silt bottom containing both elemental and organic mercury from an upstream detonator factory. The area remediated was 220 m³. Two electrode pairs were placed within the silt at the canal banks; six locations were sampled within the remediation cell and one outside the cell.

The initial mercury concentration within the cell ranged from 33 to 1570 mg/kg, and averaged 243 mg/kg. After 12 days of remediation, the concentration ranged from 9 to 417 mg/kg and averaged 119 mg/kg; after 26 days, the concentration ranged from 0.7 to 11 mg/kg and averaged 6 mg/kg. A total of 76 kg (168 lbs) of mercury was plated on the electrodes during the 26 days of remediation. The cleanup objective was 20 mg/kg. A mass balance calculation showed good agreement between the plated-on mercury and the concentration reduction in the sediments.

ECCO-PAH Case History (Organics Remediation)

In Enns, Austria, 500 tons of silt and fine sand from a former manufactured gas plant site contaminated with poly-aromatic hydrocarbons (PAHs) and their derivatives were piled for *ex-situ* remediation. The pile measured 12 m x 14 m x 3 m high.

Table 1. "Official" Regulator Approved
Chemical Analysis Results

Days	1	36	70
Naphthalene	80.7	81.3	17.29
Acenaphthylene	35.2	44.1	0.98
Acenaphthene	9.8	22.2	0.6
Fluorene	38.6	503.1	1.13
Phenanthrene	326.8	83.7	7.35
Anthracene	47.8	11.9	1.45
Fluoranthene	107.5	23.4	2.98
Pyrene	230.2	81	8.38
Benzo(a)anthracene	71.3	17.6	1.48
Chrysen	81.8	17.9	2.04
Benzo(b)fluoranthene	50.7	9.6	2.09
Benzo(k)fluoranthene	47.3	4.2	1.21
Benzo(a)pyrene	110.3	17.9	3.75
Indeno(123-cd)pyrene	47.8	26.2	1.09
Dibenz(ah)anthracene	9.5	25.6	2.98
Benzo(ghi)perylene	59.5	37.9	0.54
Total PAHs (1-16)	1354.8	1007.6	55.33

Note: All concentrations are in milligrams per kilogram (mg/kg)

Soil sampling by the local regulators showed a maximum concentration of US-EPA 1-16 PAHs (Method 8270) at approximately 11,000 mg/kg. The average PAH concentration from a separate, composite soil sample was 1,354 mg/kg.

Two electrode arrays at an average distance of 6.2 m were installed in the pile. Each consisted of three steel pipes, 8 m x 192 mm (OD), laid above each other at 0.5 m, 1 m, and 1.7 m above ground. An irrigation system humidified the pile. Soil samples for chemical analysis were composited from three cores taken from varying depths at eight different locations. The regulator and the technology developer each received a 30-gram aliquot. The regulator used an independent chemical laboratory for analysis in compliance with the German Standard Method DIN 38407, T.8. The results are shown in Table 1. The remediation was completed in 70 days when the "official" chemical analysis indicated that the average total PAHs (1-16) concentration in the pile was 55 mg/kg. The cleanup objective was 100 mg/kg.

The technology developer analyzed the split samples with qualitative gas chromatography-mass spectroscopy (GC-MS), using an internal standard of 1,3-dibromopropane. The results are shown in Figure 1. At 36 days of remediation (Figure 1b), the high-molecular-weight compounds have disappeared and lower weight compounds are forming.

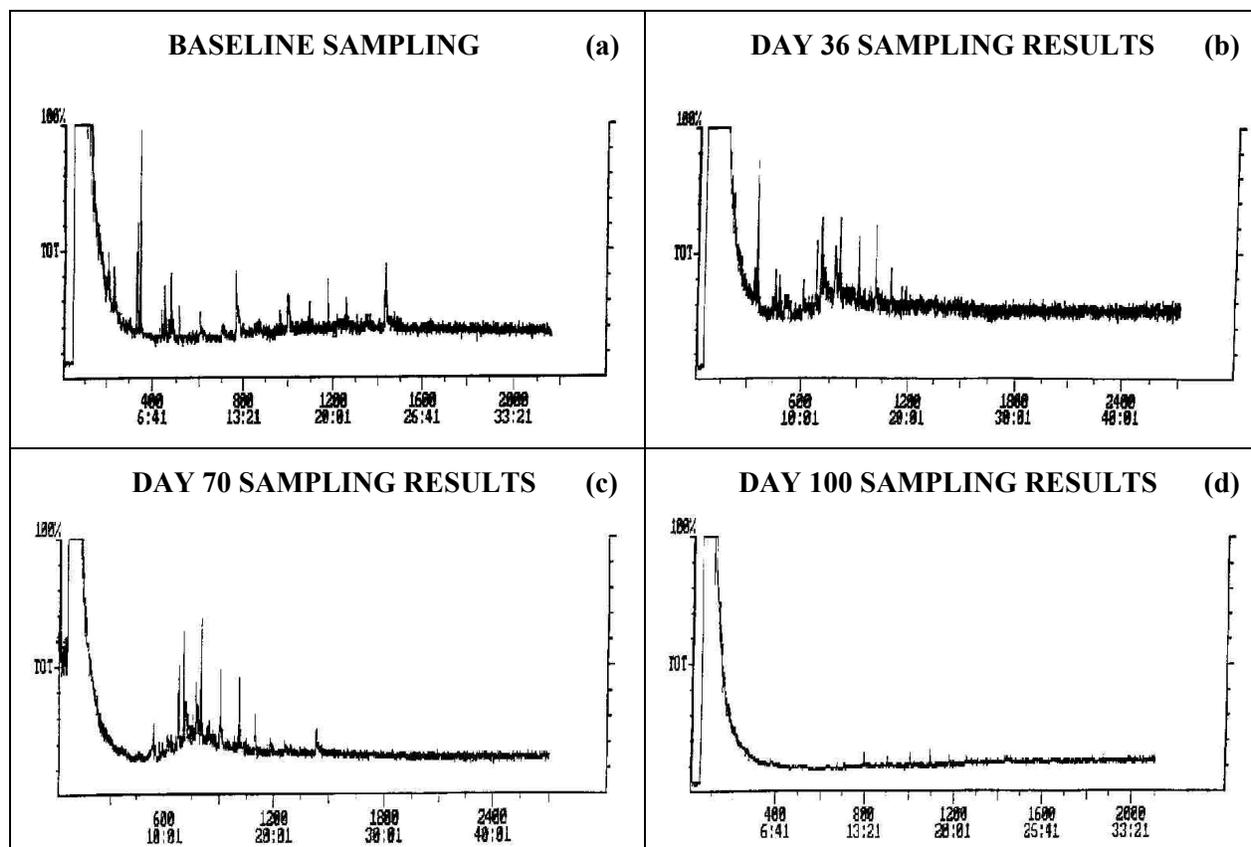


Figure 1. GC-MS Chromatograms for Official Regulator Chemical Analysis Indicate a Total Average PAH (1-16) Concentration of (a) 1354 mg/kg, (b) 1000 mg/kg, (c) 55 mg/kg, and (d) Not Quantified. See Table 1 for “Official” Analysis.

By remediation day 70, the objective of reducing the total average PAH (1-16) concentration to 100 mg/kg was achieved (Table 1). However, the technology developer obtained permission to continue for another 30 days to validate the postulation that ECGO would mineralize the organic contaminants to carbon dioxide and water. Figure 1d presents the GC-MS chromatogram for soil samples collected by the regulator at 100 days of remediation, showing that all compounds were reduced to near detection limits. The PAHs were at or near not-quantifiable concentrations and only organic acids, ketones, and esters were detected.

Conclusion

ECRT redox reactions, induced by electrochemical means, have been shown to be effective for metals remediation with the IC process, and organics remediation with the ECGO process, meeting site cleanup objectives in a matter of months.