

RECTANGULAR AND CIRCULAR CELLS FOR FIELD-MODEL SCALE EXPERIMENTS IN EK PROCESSES WITH CR(VI)

G.M.S. Losito¹, V. Pazzi¹, R. Mazzearelli¹, A. Trova¹, V. Lapenna², E. Rizzo²

1 DICEA, Florence University, Italy

2 IMAA-CNR Hydrogeosite laboratori, Potenza, Italy

Actually, the heavy metal contamination is a problem of international dimensions both for environment and human health. Consequently, the remediation of polluted soils by heavy metals con-

cerns wide areas of the planet. The electrokinetic (EK) remediation is an alternative method (Hamed et al., 1991; Reddy et al., 2001; Kim et al., 2009) to the traditional ones (soil washing, solidification/stabilization): it can be applied “in situ” and is one of the promising separation technologies and the most effective technique for fine-grained and/or clayey soil (Acar and Alshawabkeh, 1993). In the current technologies the EK remediation request high power levels (some MW), with consequent security and cost problems (US Army Environmental Center, 2000). Starting from 1998 at the Applied Geophysics Laboratory of the University of Florence many experiments have been carried out to find an experimental procedure for the EK remediation that requests lower voltage levels (Losito et al., 1998; Cherubini et al., 2002). In this work we present the results of the last experiments carried out to study the electrical mobilization of a selected heavy metal [Cr(VI)] at different local content. The Cr(VI) has been selected because it is widely used and is one of the most toxic elements.

The EK metal mobilization has been applied to a field-scale model starting from the previous experiences (Cherubini et al., 2002; Losito et al., 2009).

The heavy metal can be found in natural soils in two main ways (concentrate or diffused), so we selected two different experimental cells (rectangular and circular, respectively) to study these conditions of initial pollutant distribution. The experiments have been carried out using Cr(VI) as a solution of $\text{Na}_2\text{CrO}_4 \cdot 4\text{H}_2\text{O}$: the initial concentrations of Cr(VI) was $360 \text{ mg}_{\text{Cr(VI)}}/\text{kg}_{\text{dry soil}}$. The current electrodes in the rectangular cell were @Sigaform HLM carbon bars by SGL Carbon Group (40 mm x 20 mm x 25 mm), instead to obtain a circular electrode for the circular cell we used a nylon-carbon robe by Pozzi – Electa s.r.l. (low voltage electrode) but a steel bar as point high voltage electrode. We used a non-polarizable rectangular plastic tank (50 cm x 75 cm x 35 cm; polluted volume: 6 l) to study the rectangular geometry (Fig. 1a-b) and a non-polarizable cylindrical plastic tank (r = 55 cm, h = 80 cm; polluted volume: 30 l) to study the circular geometry (Fig. 2a-b). The experiments have been carried out in two laboratories: the rectangular cell at the Applied Geophysics Laboratory of the University of Florence and the circular one at the IMAA-CNR Hydrogeosite laboratory (Potenza – Italy). The selected sand of the two experiments was quite different to simulate natural conditions of work: for the rectangular tank we used a natural sand from Figline Valdarno (Florence – Italy) without silt and clay component ($\text{Ø}_{\text{mean}} = 2 - 0.25 \text{ mm}$); for the circular tank we used a very fine silica sand from Melfi (Potenza – Italy) with a small content of silt ($\text{Ø}_{\text{mean}} = 0.125 - 0.063 \text{ mm}$).

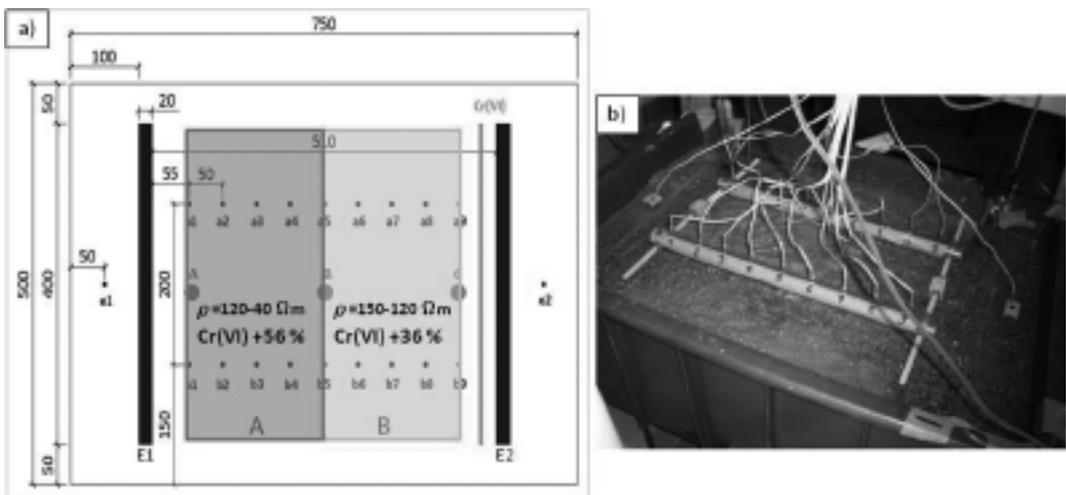


Fig. 1 – Layout (a) and photo (b) of the rectangular cell (dimensions in mm) (Applied Laboratory of Geophysics of Florence University, Italy).

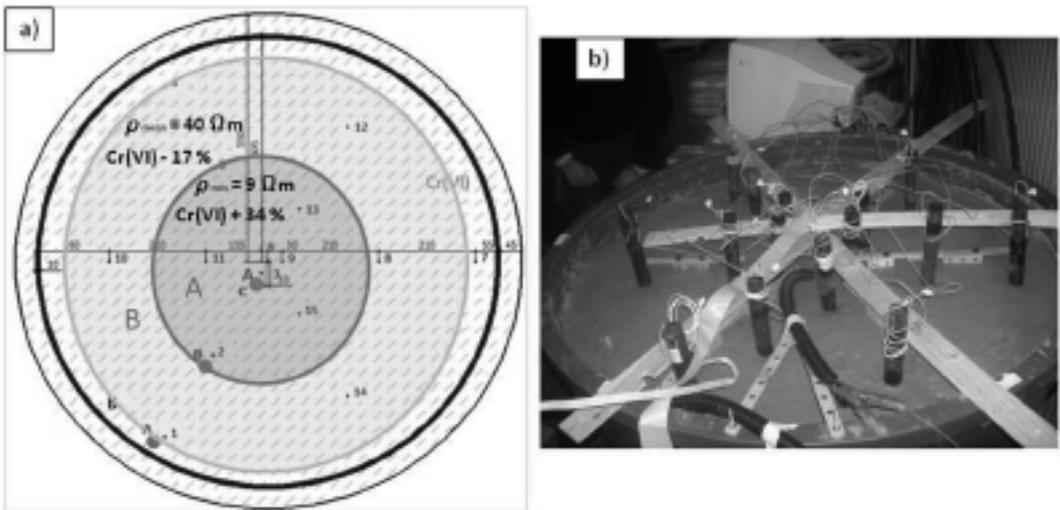


Fig. 2 – Layout (a) and photo (b) of the circular cell (dimensions in mm)(at the IMAA-CNR Hydrogeosite laboratory, Potenza – Italy).

The initial Cr(VI) distributions are shown in Figs. 1a-2a using the dark grey colour (line in Fig. 1a and filling in Fig. 2a); the small dots of the Figs. 1a-2a show the monitoring steel electrodes point; the large dots of the Fig. 1a-2a show the chemical sampling points (A-B-C); black lines in Fig. 1a show the current electrodes (E1-E2); in Fig. 2a black circle shows the low voltage electrode, while the black dot shows the high voltage one; in Fig. 2b black cylinders are the classical non-polarizable electrodes (PMS 9000: Pb-PbCl₂ NaCl, Ø = 32 mm) used to compare the electrical response (Fig. 3) of classical and “point” electrodes.

To obtain the Cr(VI) mobilization process, we applied selected signals as follow: a) the rectangular cell experiment (Fig. 1a): DC voltage (t = 72 h, V = 50 V, E1: high voltage electrode); positive SIN voltage (t = 48 h, V_{MAX} = 53 V, E1: high voltage electrode) and positive SIN voltage with inverted polarity (t = 48 h, V_{MAX} = 53 V, E2: high voltage electrode); b) the circular cell experiment (Fig. 2a): positive SIN voltage (t = 24 h, V_{MAX} = 53 V, black circle: low voltage electrode) using as central point electrode (high voltage electrode) a stainless steel bar because two previous experiments, made using the nylon-carbon robe, failed for the mechanical cracking of graphite.

The experiments carried out to optimize the electrokinetic mobilization process show that: i) the

soil-heavy metal system has a charge/discharge time period of 24 h (Fig. 4) as founded in the previous experiences (Cherubini et al., 2002), even though the clay

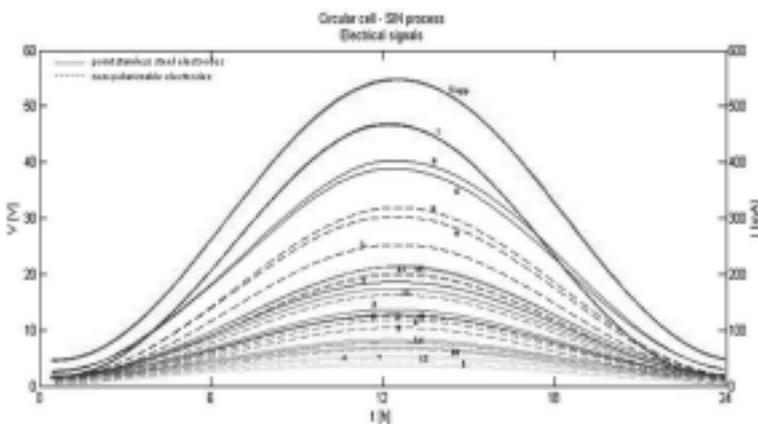
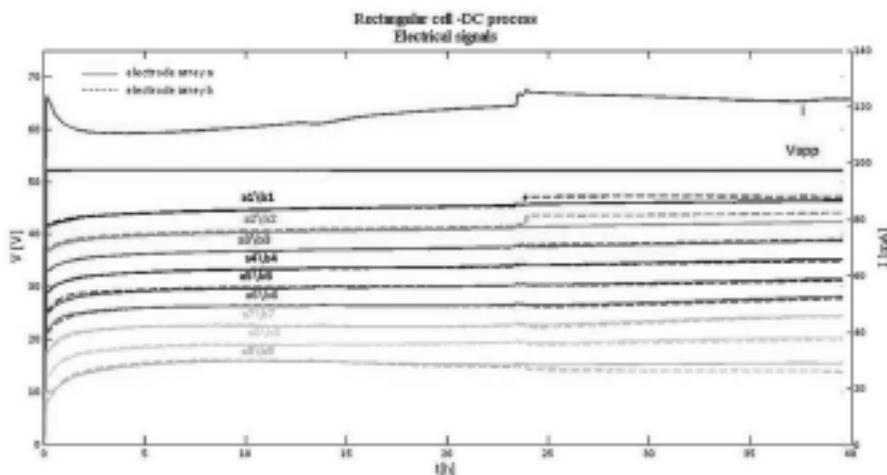


Fig. 3 – Electrical signals monitored in the circular cell during the SIN process. The trace number is the electrode code: see Figure 2a for the locations of each electrode.

Fig. 4 – Electrical signals monitored in the rectangular cell for the DC process: trace numbers are the electrode code. See Fig. 1a for the locations of each electrode.



content of the sand is very low; ii) the comparison between electrical signals monitored using stainless steel point electrodes and non-polarizable ones (Fig. 3) shows that the signals are constantly shifted. Consequently to calculate the local resistivity we can use each electrode type in a correct way; iii) the local resistivities calculate following the Telford equation (Telford et al., 1990) indicate high level of metal mobilization. In particular in the rectangular cell the minimum resistivity value occurred near E1 electrode (Fig. 1a) shows that the EK mobilization moved the Cr(VI) from the starting location (near E2 electrode) to the opposite electrode. In the circular cell the same phenomenon occurred: the metal flow to the centre is indicate by the lower resistivity value in the central area ($\rho=9 \Omega\text{m}$) that is about 25% of the mean resistivity value of the external area. These results are in agreement with sample results: we measured, in fact, the resistivity of five sample ($\varnothing=4 \text{ cm}$; $L=5 \text{ cm}$; three have been sampled from the circular tank near the points A, B, C (Fig. 2a) at the end of the energization process, the other two was made by no-polluted sand and $360 \text{ mg}_{\text{Cr(VI)}}/\text{kg}_{\text{dry sand}}$ polluted sand) with the 2-electrodes technique. This measures have been carried out at the IMAA-CNR Hydrogeosite laboratory; they show that the no-polluted sand sample has the high resistivity value ($100 \Omega\text{m}$), the three samples from the cell have a resistivity that decrease from the boundary of the tank to the centre (A: $48.8 \Omega\text{m}$; B: $23.5 \Omega\text{m}$; C: $16.7 \Omega\text{m}$) and the $360 \text{ mg}_{\text{Cr(VI)}}/\text{kg}_{\text{dry sand}}$ polluted sand has a resistivity of $17.9 \Omega\text{m}$.

The chemical analysis results, carried out at the Chemical Department of Florence University, show that: a) in the rectangular the EK process moved in the B-zone (Fig. 1a) the 36% of the injected Cr(VI) and in the A-zone the 56%, confirming so the observed local resistivity values; b) in the circular the EK process removed from the external area the 17% of the starting Cr(VI) content, shifting the metal in the central area (+ 34% Cr(VI) content).

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