



## Study of Impact Factor on Electrokinetic Remediation of Copper Contaminated Soils†

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The efficiencies of electrokinetic remediation of copper contaminated soils were studied by means of experiments in this paper. The influence of electrolyte, pH value of cathode solution, voltage gradient, remediation time and initial concentration of copper on electrokinetic processes was inspected and migration and variation characteristics of copper were analyzed as well. The results indicated that electrokinetic transport process can promote desorption and migration of copper in soils effectively; and the migratory performance of Cu was related closely to the electrolyte, the effect order was  $\text{KCl} > \text{KNO}_3 > \text{Na}_2\text{SO}_4 > \text{KH}_2\text{PO}_4$ ; voltage gradient and experiment time had correlativity with the removal efficiency of copper. The removal efficiency was 83.60 % when voltage gradient was  $2 \text{ V cm}^{-1}$ , cathode solution of citric acid-sodium citrate buffer  $\text{pH} = 5$ , electrolyte of KCl and remediation time was 5d.

**Keywords:** Electrokinetic remediation, Copper, Soil, Migration.

### INTRODUCTION

Technology of electrokinetic remediation was applied in the end of the 1980s. The rise of a remediation of contaminated soil and groundwater technologies used to remove heavy metals, organic compounds, petroleum hydrocarbons and other pollutants. Because of its simple, fast, low consumption, *etc.*, it was applied by domestic and foreign scholars' attention<sup>1-4</sup>. The method of test is the electrode into the soil-liquid system, through direct current, through the electro-migration, electrophoresis, electro-osmosis and other reactions of heavy metals and other pollutants in the soil in which migration occurs. The technology is developed rapidly in recent years, in the Netherlands, the United States and other countries. In China, the researchers have entered the field test phase<sup>5-7</sup>. But electrokinetic remediation as an emerging green technology, there are still many repair mechanism not clear, pending for further study.

### EXPERIMENTAL

**Experimental soil:** Actual industrial complex composition of contaminated soil, often containing more than one heavy metal pollutants in order to reduce the interference of other factors, soil testing was used for configurations. Original soil was collected from a domestic university campus, soil

samples were taken back after dried mashed, roots and other impurities removed after grinding through a 20 mesh sieve. The soil with a concentration of copper ( $\text{CuSO}_4$ ) was mixed configured to a copper concentration of 1100 mg/kg of the contaminated soil, air-dried soil after mixing ground through a 20-mesh sieve and stored for use.

**Experimental device:** Electrokinetic remediation apparatus was shown in Fig. 1. Device consists of soil chamber (12 cm × 10 cm × 5 cm), the anode chamber (4 cm × 10 cm × 5 cm), the cathode chamber (4 cm × 10 cm × 5 cm) and DC power supply, anode chamber to accommodate electrolyte. The anode chamber and the cathode chamber purity graphite composite electrode comprises a plate electrode (9 cm × 1 cm × 5 cm) and permeable anode reaction layer, near the soil side of the punch (cell density of 50 %) the glass and attached to the top layer of filter paper and the soil will be separated from the composite electrode, an electrode material for easy removal and updates.

**Experimental method:** Weigh accurately 0.3 Kg soil (70 °C drying to remove the moisture). The initial soil pH of 6.5-7.0, layered soil compaction would be filled into the electrolytic cell, the electrolyte to the anode and cathode pool into 0.1 mol/L electrolyte to the water overflows from the over flow port, when the liquid level decreased 2-3 cm anode

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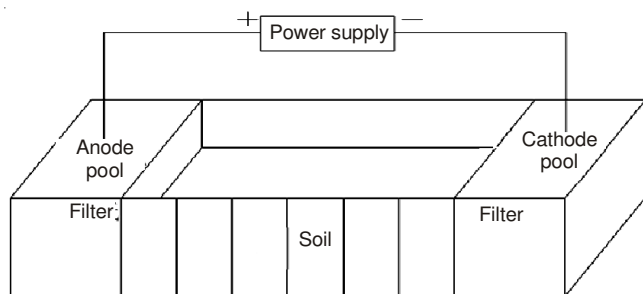


Fig. 1. Schematic diagram of electrokinetic remediation apparatus

chamber to continue to inject the electrolyte, after 24 h, level no longer drops, the whole soil chamber soil is saturated with water. Experiment investigated the electrolyte, the cathode cleaning liquid, the voltage gradient, the initial concentration and an electrolysis time of five factors, experimental design shown in Table-1.

**Sample analysis:** Total copper of soil was determined to aqua regia digestion method for determination of copper in soil<sup>8</sup>. Completion of the experimental soil from the anode to the cathode were divided into six segments, the sixth soil placed in an oven (70-75 °C) drying, milling through 100 mesh sieve, 105 °C drying 2 h, weighed 0.3 g soil 10 mL of aqua regia (HCl: HNO<sub>3</sub> = 3:1) 100 °C water bath for 2 h, cooled, allowed to stand 12 h, with an atomic absorption spectrophotometer (WFX-130A, Beijing rayleigh Analytical Instruments) Cu concentration was measured.

Take 5 g sieved (100 mesh) of the soil, add 25 mL of de-ionized water, with a pH meter (DELTA320, Leici Instruments, Inc.) was measured soil pH. Each experiment was done two parallel experiments, the results take the average of two experiments.

## RESULTS AND DISCUSSION

**Effect of electrolyte on migration:** In the applied voltage gradient 2V/cm, cathode cleaning solution using distilled

water, Cu initial concentration of 1100 mg/kg, electrolysis time of 5d, we analyze migration effects of different electrolytes to soil pH and soil copper, shown in Fig. 2. The reason for the water in case of power electrolysis occurs in bipolar electrolytic cell reaction occurs as follows:

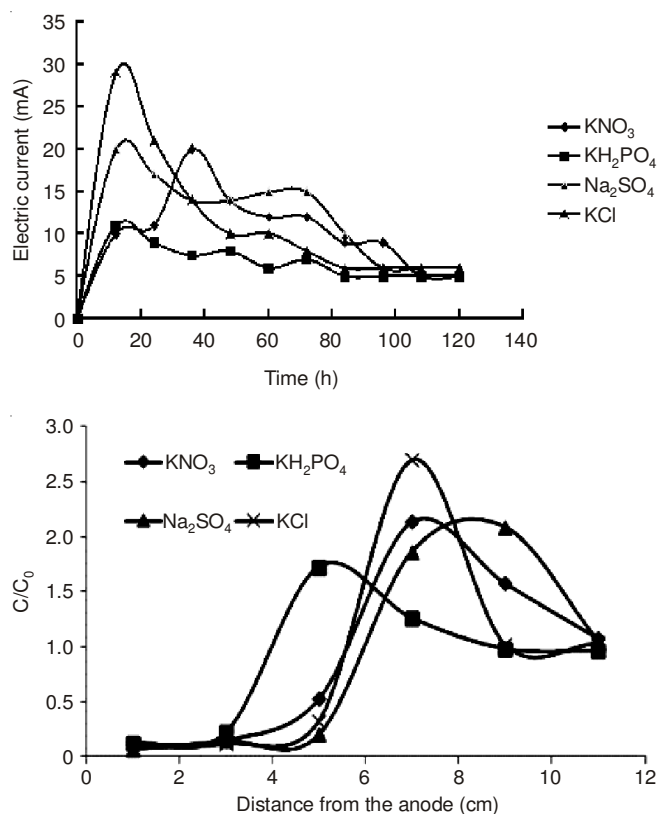


Fig. 2. Change of electrical currents and distribution of copper in soil with electrolyte

TABLE-1

EXPERIMENTAL DESIGN OF ELECTROKINETIC TREATMENT OF COOPER CONTAMINATED SOIL

Experiment	Electrolyte		pH of fluid of cathode cleaning		Voltage gradient (V/cm)	Electrolysis time (d)	Initial conc. of copper (mg/kg)
	Electrolytes	Conc. (mol/L)	Fluid of cathode cleaning	pH			
1	KNO <sub>3</sub> , KH <sub>2</sub> PO <sub>4</sub> , Na <sub>2</sub> SO <sub>4</sub> , KCl	0.1	Distilled water		2	5	1100
2	KCl	0.1	0.1 mol/L citric acid-sodium citrate	3	2	5	1100
				4			
				5			
3	KCl	0.1	0.1 mol/L citric acid-sodium citrate	5	0.5	5	1100
					1		
					2		
					3		
4	KCl	0.1	0.1 mol/L citric acid-sodium citrate	5	2	3	1100
						4	
						5	
						6	
						7	
5	KCl	0.1	0.1 mol/L citric acid-sodium citrate	5	2	5	500
						800	
						1000	
						1200	
						1500	

H<sup>+</sup> in the cathode chamber is consumed, pH increases, the anode chamber OH<sup>-</sup> is consumed, pH decreased<sup>8,9</sup>. The electric field under the action of OH<sup>-</sup> ions generated by the cathode to the anode along the direction of cell proliferation and with positive charge of H<sup>+</sup> in the electric field migrate to the cathode, the anode to the cathode to form a soil pH gradually increasing trend<sup>10</sup>. OH<sup>-</sup> diffusion cathode electrolysis-generated into the soil, forming an ion precipitation pH focusing effect occurs not only led to the soluble ion concentration, current decreased<sup>11</sup>, will block the soil voids, reducing the transport properties of Cu ions<sup>12</sup>. Therefore Cu in soil certain (distance anode 6-8 cm) continue to accumulate, using KCl as electrolyte, the distance cathode 7 cm at the initial concentration of Cu concentration was 2.7 times.

**Effect of cathode cleaning fluid on migration:** The applied voltage gradient 2V/cm, electrolyte KCl, Cu initial concentration of 1100 mg/kg and an electrolysis time of 5d when power restored to analyze different pH of 0.1 mol/L citric acid -sodium citrate buffer solution (cathode cleaning liquid) of current, soil pH and the transition effect of Cu in soil, the results shown in Fig. 3<sup>13-16</sup>.

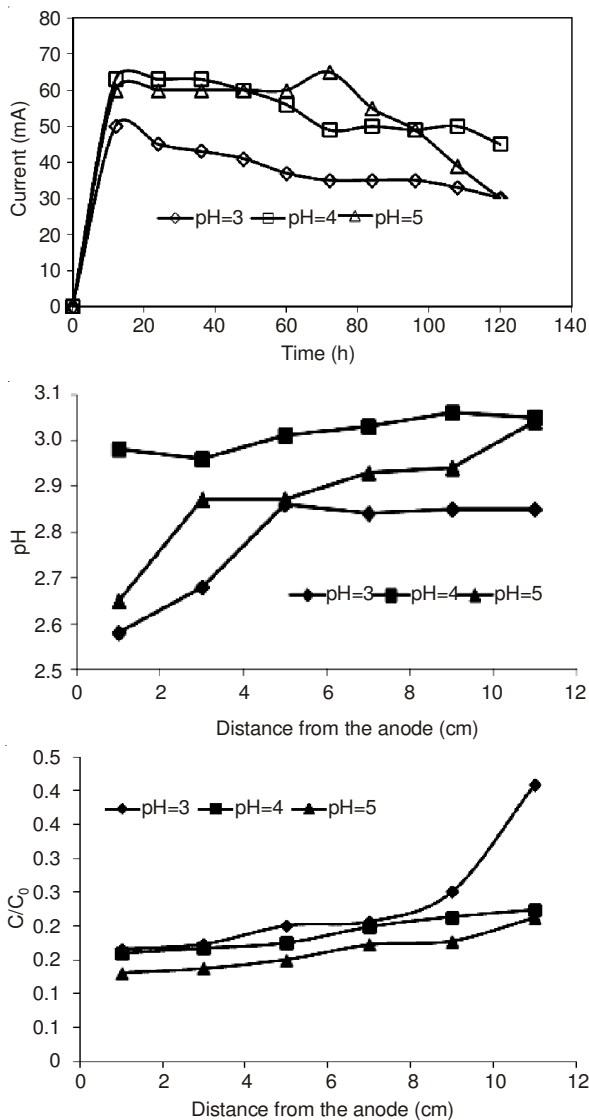


Fig. 3. Change of electrical currents, distribution of pH and copper in soil with cathode cleaning solution

**Effect of voltage gradient on migration:** In the electrolyte KCl, 0.1 mol/L citric acid-sodium citrate buffer (cathode cleaning liquid) has a pH of 5, Cu initial concentration of 1100 mg/g and an electrolysis time of 5d, the analysis on the current voltage gradient and soil Cu migration effect (Fig. 4).

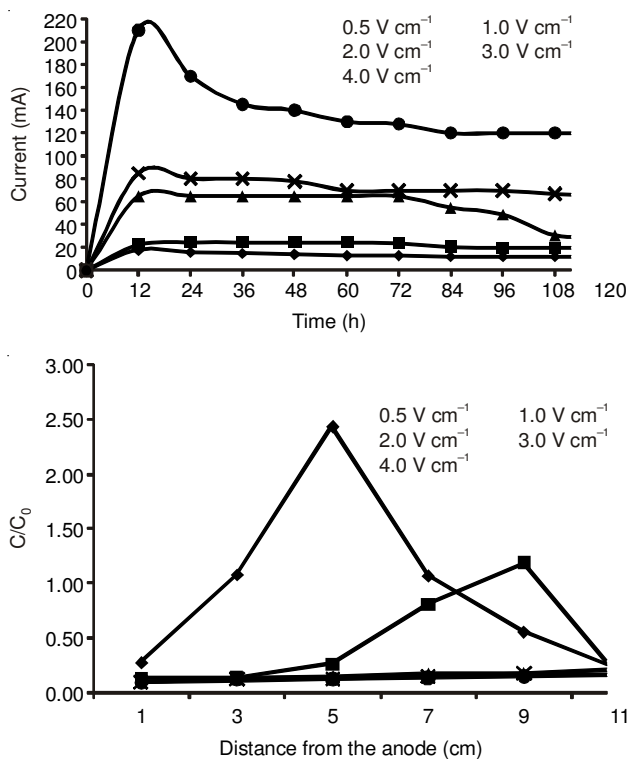


Fig. 4. Change of electrical currents and distribution of copper in soil with different voltage gradient

**Effect of repair time on migration:** The voltage gradient of 2 V/cm, electrolyte KCl, 0.1 mol/L citric acid - sodium citrate buffer (cathode cleaning liquid) has a pH of 5, Cu initial concentration of 1100 mg/kg, the analysis of soil electrolysis time effect of Cu in the migration (Fig. 5).

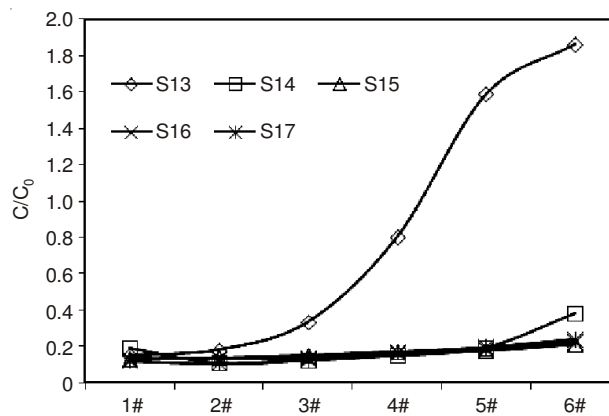


Fig. 5. Distribution of copper in soil (S13-S17)

**Effect of initial concentration of Cu on migration:** Voltage gradient is 2 V/cm, electrolyte KCl, 0.1 mol/L citric acid-sodium citrate buffer (cathode cleaning liquid) has a pH of 5 and the time of electrolysis is 5d, effects of different initial concentrations in soil migration effect of Cu (Fig. 6).

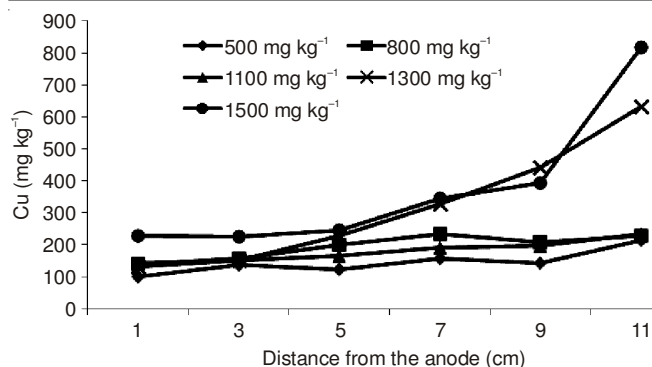


Fig. 6. Distribution of copper in soil

## Conclusion

Different electrolytes on the transport properties of Cu was  $\text{KCl} > \text{KNO}_3 > \text{Na}_2\text{SO}_4 > \text{KH}_2\text{PO}_4$ . The power generated was significantly improved during repair enrichment of Cu and low pH redox reactions may reduce the mobility of Cu by cathodic cleaning solutions. Removal efficiency of Cu is increased with the voltage gradient and the electrolysis time in-creased with the increase in the voltage gradient of 2 V/cm, the electrolysis time was 4 d most appropriate. Changes of initial concentration of Cu only influent concentration of Cu the soil near the cathode.

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