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Main factors affecting soil electrodynamic remediation

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Abstract

Electrokinetic remediation is a new chemical method for the treatment of contaminated soil, which has entered the stage of field application. Electrodynamic remediation is a process of centralized treatment or separation by driving pollutants to be enriched to the electrode area by the combined action of electrochemistry and electrodynamics (electroosmosis, electromigration and electrophoresis, etc.). This paper summarized the main factors affecting soil electrokinetic remediation, in order to provide theoretical guidance for the improvement and development of electrodynamic technology.

Keywords

Soil remediation; electrochemical technology; influencing factors.

1. Introduction

Electrodynamic remediation is a process in which pollutants are enriched to the electrode area by the combined action of electrochemistry and electrodynamics, and then concentrated treatment or separation, that is, electrodes are inserted on both sides of the contaminated soil, plus a low-voltage DC electric field. Under the action of low intensity DC, the pollutants in the soil move to the electrode through electromigration, electroosmosis and electrophoresis. Pollutants near the electrode can be removed by electroplating, ion exchange, collection or recovery. There are many factors affecting soil electrokinetic remediation. This paper summarizes the factors such as soil pH value, soil particle surface potential, soil chemical properties, soil moisture content, soil temperature and electrode materials, in order to provide a theoretical basis for the development of electrokinetic technology.

2. The main factors affecting soil electrokinetic remediation

2.1. Soil pH value

When a high DC electric field (> 5V) is applied to the electrode in the soil, it will lead to the electrolysis of water and the production of hydrogen ion (H^+) in the anode and hydroxyl ion (OH^-) in the cathode, so that the pH in the anode region is reduced to 2 and the pH in the cathode region is increased to 12.

Anode:： $2H_2O-4e^-$"O_2#+$4H^+$

Cathode: $2H_2O+2e^-$"H2#+2OH^-

Because the concentration of H^+ in the solution is much higher than that of OH^-, and the direction of electroosmosis is toward the cathode, the speed of the acid toward the cathode is much faster than that of the alkali surface. After a period of time, the whole soil system showed

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acidity except the cathode. The change of pH in soil solution affects the solubility, morphology and adsorption characteristics of pollutants. For some weakly alkaline metals, different pH conditions have different forms. Some amphoteric metals according to different pH conditions will exist in positive or negative ions, for example, metal Zn exists as cationic form (Zn^{2+}) under acidic conditions, but as metallate ions (ZnO_2^{2-}) under alkaline conditions. The solubility of metal ions is the lowest at the pH step, and they precipitate in the form of $Zn(OH)_2$. Under the condition of high pH, the anions move to the anode, and the increase of pH in the cathode region will lead to the formation of precipitation. Deposition reduces the ion concentration in the pore flow, that is, the electrical conductivity in this area, resulting in an increase in the electric field gradient and the treatment cost. At the same time, the change of pH affects the soil surface electrokinetic potential (Zeta potential). For Kaolin, when the Zeta potential increases to 10 mV near the anode, the electroosmotic flow decreases or even in the opposite direction. In order to carry out the repair process, the voltage must be increased to maintain a certain electroosmotic flow, resulting in an increase in energy consumption and an increase in repair cost. In the cathode region, the zeta potential decreased to-54 mV, and the electroosmotic flow increased, which led to the formation of non-uniform streamline in the soil. Even the interruption of flow has a negative impact on the effect of soil remediation.

2.2. Zeta potential

The rate of soil electroosmosis directly affects the rate of electrokinetic remediation process. The zeta potential on the surface of soil particles is the internal factor that determines the soil electroosmosis rate. Zeta potential refers to the potential difference from the interface (sliding interface) of the relative motion between the colloid and the medium to the interior of the solution. It is obvious that the Zeta potential determines the motion of the colloid in the electric field. When the electric field strength and the dielectric condition are fixed, the magnitude (absolute value) of the Zeta potential value determines the electrophoresis speed of the colloidal particles. The higher the Zeta potential value, the greater the u.

Obviously, the higher the zeta potential, the faster the rate of electrical repair, which we found in practical application. With the increase of pH value of the cleaning solution, the concentration of acid ion in the solution increased, and the absolute value of Zeta potential increased, which enhanced its adsorption on the surface of clay particles. However, when selecting the pH value of the cleaning solution in the electric repair experiment, it should be considered to have sufficient buffer capacity to prevent metal ions from precipitating under alkaline conditions. In addition, at low concentration, with the increase of ionic strength, the amount of anion adsorption and the absolute value of zeta potential increase. Further increasing the ionic strength of the solution will lead to the compression of the electric double layer on the surface of clay particles. The absolute value of zeta potential decreases. Therefore, the effects of pH value and ionic strength of cleaning solution on zeta potential should be comprehensively considered, and the most suitable cleaning solution should be selected to improve the rate of electro remediation.

2.3. Soil chemical properties

The characteristics of soil affect the removal efficiency of pollutants, including adsorption, ion exchange, buffer capacity and so on. On the surface of fine-grained soil, the interaction between soil and pollutants is very intense. The experiment to determine the adsorption isotherm and ion exchange capacity showed that metal ions are adsorbed by soil by coordination, and the amount of adsorption is related to soil type and soil pH. The adsorption capacity of sodium montmorillonite is the largest, followed the kaolinite, and the moraine is the last. Ionic pollutants must be analyzed or ion-exchanged before they can be removed. For example, sodium montmorillonite has strong adsorption and buffering capacity, which makes the analysis of metal cations very difficult and increases the difficulty of electrical repair.

2.4. Soil moisture content

In order to play a role in the process of electric remediation, the soil water content must be higher than a certain minimum. Preliminary experiments showed that the minimum value is lower than the soil water saturation value, which may be between 10%~20%. If the soil moisture content is less than 10%, the treatment effect will be greatly reduced. For example, the experimental study of Livermore National Laboratory in the United States showed that the treatment effect of insoluble liquid dense organic matter (DNAPLS) often leads to system blockage. With the electrolysis of water, the moisture content of soil near the anode decreases. In order to maintain a certain current intensity, water can be added to the anode soil, but the problem of adding water should be considered in the actual operation, too much water will make the pollutants infiltrate into the deeper soil layer.

2.5. Soil temperature

In the process of electrodynamic remediation, excessive current produces a certain amount of heat, which increases the temperature of soil, affects the process of electromigration and electroosmosis, and then reduces the restoration efficiency. Therefore, in the electrodynamic remediation experiment, the best current density is selected to reduce the thermal effect caused by current, which can improve the removal rate of heavy metal pollutants. The results showed that the soil temperature near the anode and cathode increases to 26.9 ℃ and 38.6 ℃ respectively, showing a trend of increasing from anode to cathode, because the resistance of the soil near the cathode increases and produces more Joule heat, which reduces the remediation efficiency. According to the previous studies, the current density is generally less than 0.5 mA/cm^2. Within this limit, properly increasing the current and temperature will help the metal to be resolved from the soil system, increase the ion strength in the whole system, and increase the current density, so as to improve the remediation effect.

2.6. Electrode material

The effect of electrodynamic repair is related to the electrode material used. In the process of electrodynamic repair, different electrode materials, electrode shape and electrode arrangement will have a certain impact on the electric field direction and discharge rate. Cylindrical high-purity graphite electrodes arranged in a circular way are more conducive to the generation of non-uniform electric field than plate-shaped high-purity graphite electrodes arranged in a rectangular way, thus promoting the migration of pollutants in the soil and conducive to the removal of pollutants in the soil.

3. Prospect

In fact, soil is a complex system, and there are many factors affecting soil electrokinetic remediation, so the related basic research needs to be further carried out and improved. For example, the interaction between pollutants and soil under electric field, the migration of microorganisms and the change of activity and so on.

Electrokinetic remediation is a newly developed in-situ soil remediation technology, which is a process of separating and extracting heavy metal pollutants from contaminated soil. Electrokinetic technology is mainly used for the remediation of low permeability soils and is suitable for the removal of most heavy metal pollutants. Compared with other heavy metal contaminated soil remediation technologies, metal ions in electrokinetic technology are completely removed and will not cause secondary pollution, and the soil structure will not be destroyed in the remediation process. and it is not affected by the low permeability and low hydraulic conductivity of soil, so it is one of the more promising technologies in the remediation of heavy metal contaminated soil.

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