LIFE PROJECT - SEKRET
LIFE12 ENV/IT/000442

"Sediment ElectroKinetic REmediation Technology for heavy metal pollution removal"

DELIVERABLE ACTION B1

"Design and specification of demonstration plant"

Report n.1 – General design report

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1. INTRODUCTION

Electro-reclamation (ER) is a soil remediation technology that uses electrokinetic effects to remove inorganic contamination. It belongs to the group of so-called physicochemical remediation technologies. Under the influence of an electric field, a number of electrokinetic phenomena occur:

- Electromigration or the movement of ionic species in pore water or groundwater.
- Electroosmosis or movement of water from anode to cathode.
- Electrophoresis or movement of charged particles.

It is difficult to recover ionic contamination from ground and ground because soil is a powerful ion exchange medium. Ions of, for example heavy metals, cyanide, arsenic or other polar species, are adsorbed on contact by soil particles. Flushing alone will not recover this contamination: to desorb and to mobilize it, pH must be changed. However, flushing with strong acids usually destroys the basic soil structure. A solution is electrokinetic acidification using the technology of electro-reclamation.

The electrokinetic phenomena result in displacement of ions and water soluble pollutants, thereby disturbing the existing electrochemical equilibrium between the solid phase (metal salts, clay and other organic soil particles) and the liquid phase (ground- and pore water). This results in desorption, for example, of heavy metals (cations) or cyanides (anions) by ion exchange from the solid (immobile) phase to the liquid (mobile) phase. A second effect is the generating of H+ ions at the anode and OH- ions at the cathode as a result of the dissociation of water. H+ ions move twice as fast as OH- ions and 5 to 6 times faster than heavy metals. As a result, the soil acidifies from the anode into the direction of the cathode, leading to an increase in solubility of the pollutants and thus to accelerated desorption. However, a similar but slower drift of hydroxyl ions moves from the cathode displacing anions adsorbed on the soil particles. This results in increased alkalinity into the direction of the anode. If no measures are taken, the soil around the anode will, after a certain period, acidify (pH reduction) to such an extent that practically all energy is used for the transport of the H+ ions. Likewise pH around the cathode will increase to such an extent that precipitation of metal hydroxides will take place in the soil. These negative effects are avoided by actively managing pH around the anodes and cathodes. This is accomplished by integrating anodes and cathodes in a special electrolyte management system (EMS). This system is also used to remove the contaminants that have collected around the electrodes.

2. PRACTICAL REALIZATION SEKRET PILOT PLANT

The key elements of the electrokinetic installation are as follows:

- Ion-permeable electrolyte wells are placed in the basin filled with contaminated dredging. The electrolyte wells are connected to a centralized electrolyte management system (EMS). Each well has an electrode inside. The result is alternating rows of anodes and cathodes. Electrolytes are circulated in a closed loop between the electrode wells and the EMS. Via these electrolytes, pH is maintained at a predetermined value. The electrodes are then energized. The water in the electrolytes is electrolyzed, forming H+ ions and O2↑ at the anodes, and OH- ions and H2↑ at the cathodes. These ions are then made to migrate through the well casing into the dredging to generate a temporary and localized pH shift, which desorbs the contaminating ions.
- Once desorbed, the contaminating ions migrate to their respective electrodes, under the influence of the potential applied (electromigration). The anions migrate to the anodes, the cations to the cathodes. Here they pass through the electrode well screen and are taken up by the circulating electrolytes.
- Critical for the control of system performance is the careful management of the pH and other electrolyte conditions within the electrode casings.
- During a first step contaminants are recovered from the circulating electrolytes by ion-exchange resins. During a second step the electrolytes are further treated by Reverse Osmosis. The remaining fluid (H O) can be used again as electrolyte. In case a 3rd step is needed, will be made of a precipitation and filtration device.

3. DESIGN AND DIMENSSIONS OF DEMONSTRATION PLANT

3.1 The treatment basin

The basin is constructed with removable panels of prefabricated reinforced concrete. The basin is lined by a HDPE / LDPE membrane and protected by a geotextile. The basin is completely covered with a roof and is removable. The electrodes will be installed along 9 anode rows and 9 cathode rows, with 6 electrodes per row. Distance between the electrodes of equal charge and opposite charge will be 1 m. A total of 54 anodes and 54 cathodes will be inserted in vertically arranged slotted PVC pipes. The sediment to be treated is placed inside the basin with a thickness of 1.25 meters. The armor of the prefabricated elements is electrically connected to the cathode to ensure cathodic protection. Length of the electrode connection cables is approximately 930 m, while the length of the pipes (Ø 50mm, for circulating anode and cathode electrolytes) is approximately 370 m.

3.2 The electrical power system

This system is realized by connecting it to the mains (3-phase 400V AC) with a maximum power of 50 kW. The control of voltage and current is achieved by means of parallel connected inverters with an automatic control device capable of varying the applied voltage in order to maintain a constant voltage, current or power. The device controls the voltage to maintain the design value (being defined by means of preliminary laboratory scale tests), however without exceeding the voltage of 48V for safety reasons. Subsequently, the current is rectified by a diode bridge and applied to the electrodes.

3.3 The electrolyte management system

This system consists of two independent hydraulic circuits for monitoring and conditioning of the anolyte and catholyte. Each of the two circuits is equipped with a recirculation pump, a system for pH measurement, an automatic device for dosing base (anolyte) and acid (catholyte) to keep the pH to the preset operating values. Two buffer/homogenization tanks are used, one for the anolyte circuit and one for the catholyte circuit.
The operating pH values are defined by means of laboratory experiments. For both circuits a pH of approximately pH = 3 is expected.
The anolyte circuit is equipped with a chlorine meter. The anolyte tank is confined and connected to the abatement system for the treatment of chlorine gas, while the tank of the catholyte is equipped with a vent to atmosphere.

3.4 The electrolyte treatment system

3.4.1 The precipitation section

This section is used to remove chemical species which are able to precipitate under controlled pH conditions. A base is used to increase the pH to a desired level to reach the conditions for precipitates formation. The removal of solid precipitates is carried out by means of filter bag device.

3.4.2 The resin treatmenet section

This device enables the removal of metals still present in solution after the precipitation treatment. This treatment allows further refinement of the process electrolytes. It is operated intermittently and can be bypassed.

3.4.3 The reverse osmosis section

RO is used to control the salinity of electrolytes to optimal values. The system will be equipped with high-pressure pump and filter cartridge. The treatment will be operated intermittently.
The concentrate extracted from the membranes is collected in a separate wastewater tank and transported to an authorized liquid waste treatment facility. Before treatment, the fluids will be conditioned by means of dosing of acid or base in a dedicated tank in order to achieve the optimum pH for treatment.

3.4.4 The section for the collection and treatment of gas

This section is dedicated to the control of the gas in the anolyte circuit for emergency blocking any chlorine gas emission to the atmosphere. A system of gas pipes is installed in the basin for the collection of gas from the anode wells. The gas is then sent to the anolyte tank and through a vent pipe will be conveyed to a scrubber. The safety is ensured by creating a slightly depressed atmosphere in the anolyte tank. The scrubber is a wet-type unit with a recirculating solution of sodium hydroxide.
The concentration of chlorine in the liquid phase is constantly monitored. Furthermore, a sensor of gaseous chlorine is placed at the gas outflow of the scrubber. In case of detection of chlorine gas the system controller (PLC) will promptly stop all processes automatically.
The gas produced at the cathodes is also collected and it is immediately released to the atmosphere to prevent any possibility of a fire hazard.

3.5 Control and monitoring system

The plant will be equipped with a control system for the management and automation of electromechanical devices. Specific probes are installed for a continuous monitoring of process parameters. In the event of a system malfunction or emergency, the control system will send SMS text messages via GSM operators for alarm alert.

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