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Removal of heavy metal and organic matter by electrokinetic ultrasonic remediation technology

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Abstract

In this study, the coupled effect of electrokinetic and ultrasonic remediation technology was investigated for removing of heavy metal and organic matter at the same time. The laboratory tests were conducted using specially designed and fabricated electrokinetic and ultrasonic devices. The electrokinetic technique was applied to remove mainly the heavy metal and the ultrasonic technique was applied to remove mainly organic substance in contaminated soil. Diesel fuel and Cd were used as a surrogate contaminant for this test. A series of laboratory experiments involving electrokinetic and electrokinetic+ultrasonic flushing test were carried out. An increase in permeability and contaminant removal rate was observed in electrokinetic+ultrasonic flushing test.

Key word : electro, ultrasonic, permeability, removal, oil, contamination, soil, ground

1. Introduction

The effect of stress waves on fluid flow through porous media was proposed by numerous researchers. Lakshimi(1993) suggested the mechanisms responsible for the observed increase in transport rates and unit-operation processes due to ultrasonic energy. Kim(2000) conducted falling-head permeability tests on sand samples using a sonication probe and found that hydraulic conductivity of the samples increased abruptly and oil in contaminated soil removed.

Electrokinetic soil processing is a new, innovative, and cost-effective remediation technology that employs conduction phenomena under electric currents for transport, extraction, and separation(Chung, 1999). The driving mechanisms by electrokinetics for species transport are ion migration by electrical gradients, pore fluid advection by prevailing electroosmotic flow, pore fluid flow due to any externally applied or internally generated hydraulic potential difference, and diffusion due to generated chemical gradients. As a result, cations are accumulated at the cathode and anions at the anode.

2 Experimental methodology

The electrokinetic(ek) and electrokinetic(ek) ultrasonic soil flushing tests were conducted by using the setup shown in Figure 1. The test chamber is made of a plexiglas cylinder having an insider diameter of 10cm with a height of 30cm. The cylinder was filled with contaminated sand. In the side part of the cylinder are installed inlet and outlet tubes. The inlet tube is connected to a reservoir of de-aired water, which is connect to the water tap; and the outlet tube is used to maintain constant heads by allowing overflow of excess water. Outlet tube is connected to a burette for measuring the outflow quantity.

The test setup used in this study was made to combine the electrokinetic flushing processor and the ultrasonic flushing processor. Photography for test setup is shown in Figure 1, and more detailed schematic view of the test setup is shown in Figure 2. The elecrokinetic flushing processor consists of three parts: anode electrode, cathode electrode, and electric power supplier. The ultrasonic flushing processor consists of three parts: a generator, a converter, and an acoustic horn. The transmitting acoustic horn, which is mounted on top of the soil sample, is used for generation ultrasound. The test specimen was then subjected to ultrasonic waves at 28kHz frequency from ultrasonic test setup and to electric power at 1.0V/cm from electrokinetic test setup. Tests were continued to maximum 100 minute.

Figure 1: Photography for test setup

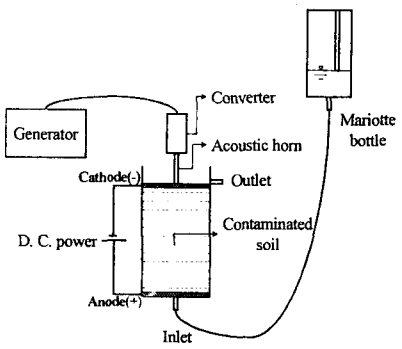

Figure 2: Test setup for soil flushing experiment

The test soil was sand, a fine aggregate, and a natural soil obtained Jumunjin, East beach of Korea. Diesel fuel and Cd were used as a surrogate contaminant to demonstrate the soil contaminated by organic substance and heavy metal. Some physical properties of test soils are shown in Table 1. The flushing tests were conducted for two conditions: electrokinetic(ek) flushing, electrokinetic(ek)+ ultrasonic flushing. Hydraulic gradient for the flushing process was constant to 1.0. In the tests, the soil specimens were thoroughly mixed with diesel fuel of 770ml and Cd of 500ppm(385mg in test soil).

Table 1. Physical properties of test materials

Sand			Diesel fuel		
Specific gravity	Maximum dry density	Minimum dry density	Specific gravity	Solubility in water	Centistoke (mm^2/sec)
2.62	1.60	1.40	0.80	0.075~31.3	0.564

3 Results and Analysis

The pore water was allowed to flow upward through the specimen and contaminant was allowed to migrate upward from the specimen under the actions of hydraulic gradient, ultrasonic waves, electroosmosis and electromigration generated in this testing mechanism. The effluent was collected in a 500ml polypropylene cylinder. The effluent in the cylinder was allowed to stand overnight for gravitational segregation of oil from water. The volumes of the separated water and oil were then measured. Also, Cd concentration of effluent was measured by laboratory chemical analysis facilities.

The test results for the accumulated flow volume with time are presented in Figure 3. The figure shows the accumulative water flow is varied and increased with time. The accumulated flow volume with time is higher in the case of ek+ultrasonic flushing tests than in the case of electrokinetic flushing tests. It means that the ultrasonic process has a role to increase the liquid outflow due to sonication effects, but electrokinetic process has not due to short test duration and sandy soil. Normally, electroosmosis by electric power is not or few developed in a short time and in sandy soil.

The test data shown in Figure 3 were used to compute the discharge velocity. The computed discharge velocity was used to compute the coefficient of permeability of the test soils. The Figure 4 shows the variation of permeability with time. According to Figure 4, the permeability of specimen is considerably increased by applying the ultrasonic process. This can be attributed to the combined effects of hydraulic gradient and sonication. The permeability is high in the tests used the ultrasonic process compare with in the tests not used the ultrasonic process.

The mean permeability throughout the total test time is calculated from the results in Figure 4. The calculated mean permeability is shown in Figure 5. In this graph, we can see that the mean permeabilities of test soils are 2.68E-04cm/sec for electrokinetic flushing and 5.14E-04cm/sec for electrokinetic+ultrasonic flushing, respectively.

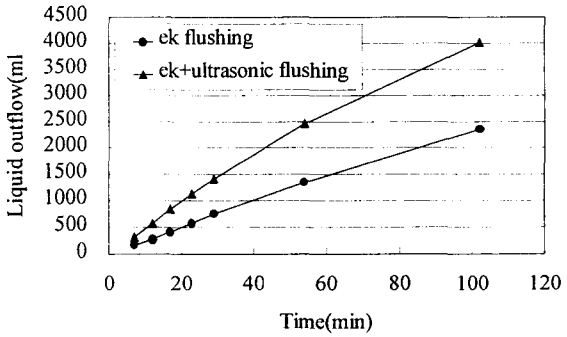

Figure 3: Accumulated flow volume with time

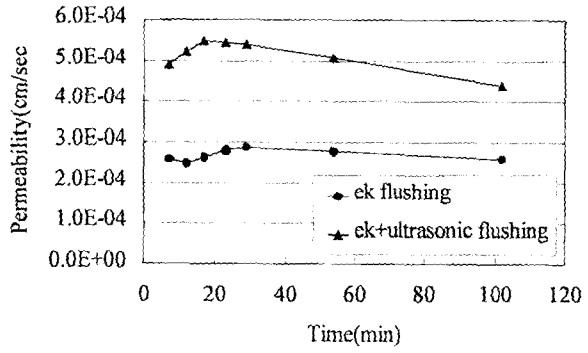

Figure 4: Permeability with time for test sample

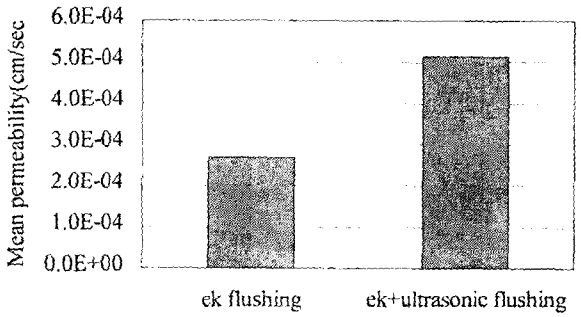

Figure 5: Mean permeability of test soils

The quantity of oil removal is measured from the liquid outflow, and oil removal rate is calculated. The results of calculated oil removal rate is shown in Figure 6. The Cd concentration is measured from the liquid outflow and shown in Figure 7. In the Figure 6, it is suggested that the oil contaminant is removed with time elapsed, and the percent of oil removal is increased with time and reached a constant after about 24 minute. According to this figure, it is shown that the maximum percentages of oil removal rate for all tests are approximately 65%. The removal velocity of oil is high in the case of ultrasonic process for a very short time.

In the Figure 7, it is demonstrated that Cd concentration of outflow is increased with time. The Cd contaminant in soil specimen is steadily removed with time elapsed. The heavy metal contaminant such as Cd is migrated and removed by electromigration phenomena induced from electrokinetic process and acoustic force induced from ultrasonic process.

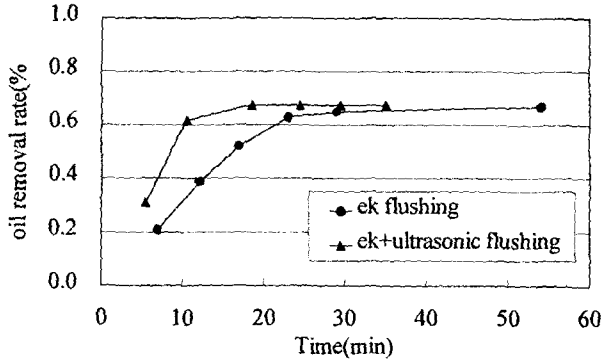

Figure 6: Oil removal rate with time

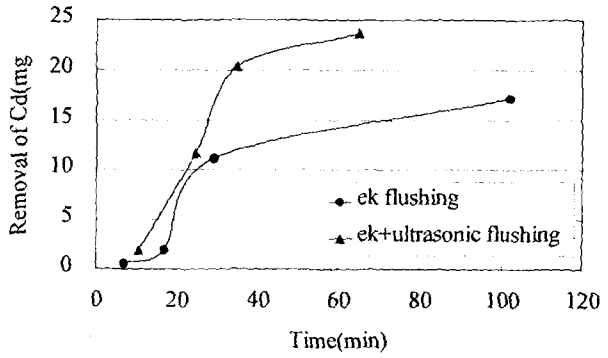

Figure 7: Removal of Cd with time

4. Conclusions

In this study, the coupled effect of electrokinetic and ultrasonic technique is demonstrated by laboratory tests. A series of tests were conducted for electrokinetic flushing and electrokinetic+ultrasonic flushing. The test results showed that the ultrasonic technique can enhance mainly the removal of organic matter from contaminated soil, the electrokinetic technique can enhance mainly the removal of heavy metal from contaminated soil. And the combined new technique can be effectively applied in removal of organic substance and heavy metal from contaminated soils at the same time.

References

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