Experiment Results of Conduction, Spectral Induced Polarization and Dielectric Characteristics for Chrome-Contaminated Soil

Yuqiang Liu, Changxin Nai, Lu Dong, Qi Wang
Research Institute of Solid Waste Management
Chinese Research Academy of Environmental Sciences
Beijing, China
E-mail: liuyq@craes.org.cn

Abstract—**In soil sample with different water content, chromate pollutants with different concentrations are added to experimentally observe the changing relationship of sample resistivity, complex resistivity and complex dielectric constant with contamination concentration and water content. It is demonstrated from the observations of the soil sample that the amplitude of both the sample resistivity and complex resistivity decrease with the increase in contamination concentration and water content, while the phase of complex resistivity takes on a tendency of decreasing first and then increasing with the increase in contamination concentration and water content; the real part and imaginary part of the complex dielectric constant increase with the increase in contamination concentration and water content. Simultaneously, it is worthwhile to point out that multiple detection methods are necessary to evaluate the situation of site pollution because various contamination concentration and water content have significant influence on the test results.**

Keywords-spectral induced polarization; conduction; dielectric characteristics; contamination content; water content

I. INTRODUCTION

Currently, the problem of soil chrome pollution has become more and more serious in China[1]. Herein, because of numerous chrome contaminated sites with large contaminated areas, which have severely contaminated the surrounding soil, rivers and underground water resources, it is imperative to carry out evaluation of chrome residue contaminated sites and to repair the contaminated soil and underground water[2].

Electrical method is an important geophysics method to investigate and monitor the abnormality of geologic body such as soil[3]. Whereas, the frequently used methods include the resistivity method based upon the difference of conductivity, the complex resistivity method based upon the differences of spectral induced polarization property as well as electromagnetic detection based upon dielectric dispersion characteristics.

There is no report about physical properties of the chrome contaminated soil. This study will search for the relationship of conductivity, spectral induced polarization property and dielectric characteristics with the concentration of chrome pollutant and water content.

II. MATERIALS AND METHODS

A. Materials

The soil samples are collected from the yard of China Environmental Science Research Institute. Prepare Na_2CrO_4 solution with 17 different concentrations, starting from 0mg/kg to 4000mg/kg at certain interval. And each concentration has 10%, 20% and 30% volumetric water content, respectively. the physical properties of in blank soil sample are shown in Table 1, and the analysis on metallic element is shown in Table 2:

TABLE 1 PHYSICAL PROPERTIES OF THE SOIL SAMPLE

PH	Sand/%	Slit/%	Clay/%	Density	Ecp(ds/m)	Temp./℃
7.61	30.7	53.2	16.1	1.18	0.028	27

TABLE 2 METAL CONTENT OF THE SOIL SAMPLE (UNIT: MG/G)

Na	Mg	K	Ca	Fe
12.9	26	16.9	20.5	0.2

B. Methods

Four-phase electrode method is used to determine resistivity and complex resistivity, while coaxial terminal open circuit reflection method is used to determine complex dielectric constant.

III. EXPERIMENTAL RESULTS

A. Resistivity

Figure 3 has demonstrated soil sample resistivity vs chrome concentration in three different water contents. It can be seen from this figure that, when chrome concentration is relatively low, namely, within the low range of 0~750mg/kg (chrome mass content), the resistivity ρ of contaminated soil sample is rapidly decreasing as compared to the resistivity ρ_0 of uncontaminated soil sample and the change is relatively fast. With the increase of chrome concentration, this change tends to be mild and smooth. In overall, however, their decreasing levels are somewhat different. Hereinto, in case that the water content changes from low to high, i.e., from 0.1 to 0.3, the changing curves become increasingly

steeper; when chrome concentration is up to 4000×10^{-6}, the values of resistivity are approaching the same number no matter what the water content is. This kind of changing rule is very favorable to various electrical methods based upon the differences of resistivity, because abnormal reaction will occur obviously at low range of chrome concentration[4-5].
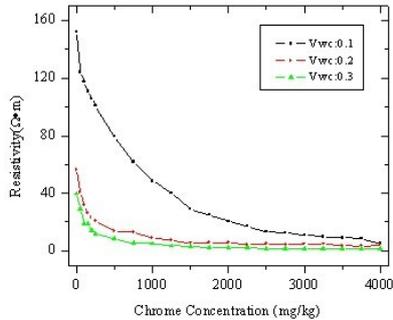

Figure 1. Soil sample resistivity vs chrome concentration in different moisture content

B. Complex Resistivity

Soil dispersion character of complex resistivity. Figure 2 shows the test result of soil complex resistivity dispersion character with different water content. Because the soil has induced polarization effect, which makes it possesses both resistance and capacitance[6]. At the lower range of frequency, the soil has plenty of time for the process of re-charging and discharging, so its phase shift is relatively larger.
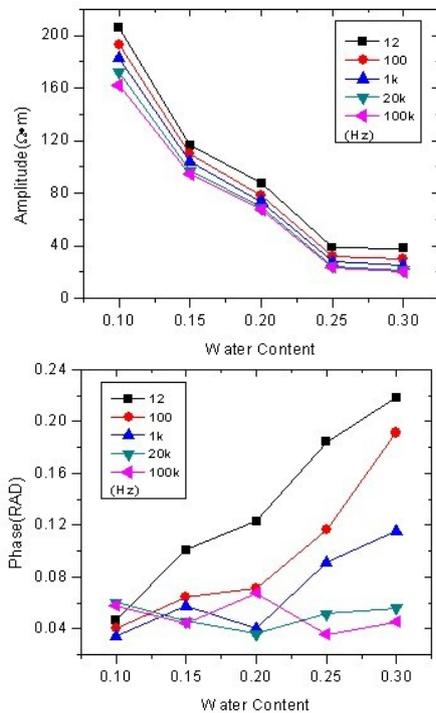

Figure 2. soil complex resistivity dispersion character with different moisture content

With the increase in frequency, the time for re-charging and discharging process becomes shorter, therefore, its induced polarization effect becomes weaker, which shows that the amplitude and phase shift of complex resistivity tends to decrease; for the soil contaminated with low concentration, at up to certain frequency, the phase shift reaches minimal and then rises, mainly because of the electromagnetic induction effect that makes the soil possess the capacitive characteristics; for the soil contaminated with high concentration, the increase of ion concentration makes the induced polarization effect stronger at lower frequency and makes the medium polarize at high frequency and electromagnetic induction effect weaken, which shows the phase decreases blankly. In case of lower frequency $(10^{-n} \sim 10^{n} Hz)$, much clearer induced polarization effect will be observed[7].
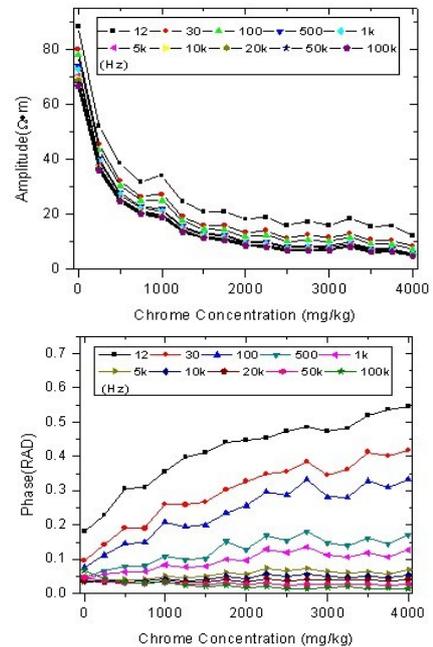

Figure 3. soil complex resistivity dispersion character with different moisture content

Complex resistivity under different contamination concentrations. Figure 3 shows the changing curve of amplitude and phase of complex resistivity, in-phase resistivity and out-phase resistivity with the contamination concentration at 10 kinds of frequency including 12Hz, 30Hz, …, and 100kHz. It turns out that the amplitude of complex resistivity decreases with the increase in the contamination concentration because of the increase in conductive ions; the changing curves have similar features under various frequencies, namely, frequencies have influence on its value but without dispersion character. However, the phase changing curve of complex resistivity shows different features under different frequencies: the curve under higher frequency can be regressed the straight line parallel to the X-axis, namely, the contamination concentration has insignificant effect on the imaginary part; whereas under lower frequency especially lower than 12Hz,

the imaginary part shows significant difference under various concentrations, with smaller capacitance under lower concentrations (weak induced polarization effect) and larger capacitance under higher concentrations (strong induced polarization effect).

C. Complex Dielectric Constant

The experiment shows that both the real part and imaginary part of soil complex dielectric constant are dependent upon volumetric water content of soil; in addition, chrome pollutant in soil has significant influence on the real part and imaginary part of soil complex dielectric constant. In case that volumetric water content（V_{wc}）of contaminated soil is 0.2, when the pollution salt is added, the real part of complex dielectric constant increases to some extent. For the unsaturated soil, water and air coexist in the micropores of soil. The interface between the fluid in soil micropores and air or soil particles would generate space charge polarization effect due to migration of ions[8-9]. Space charge polarization effect leads to the increase in complex dielectric constant, which can compensate for the decreased part of complex dielectric constant due to orientation polarization effect[10]. Therefore, it is generally acknowledged that the generation of space charge polarization effect makes the complex dielectric constant of soil slightly increase.
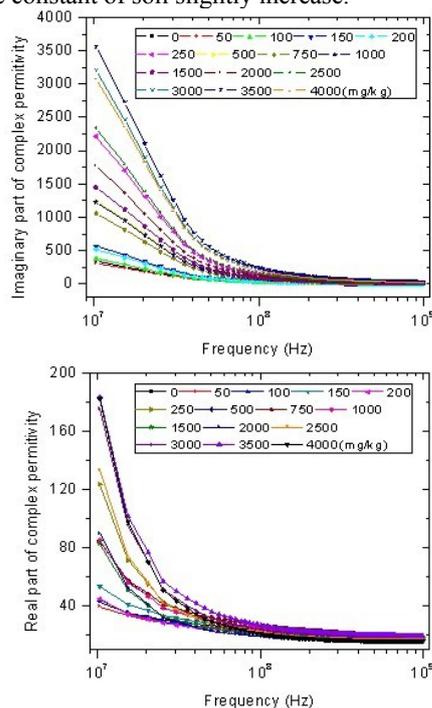

Figure 4. dielectric dispersion character of soil with different pollution concentration

IV. CONCLUSIONS

Both water content and contamination concentration have influence on resistivity, so the single resistivity method is not effective to evaluate the contaminated sites.

Dispersion character of soil complex resistivity is significant at low frequency, but slightly weak at high frequency. Similar to resistivity method, the influence of water content on the test results must be removed when contamination concentration is finally determined.

For the range of low frequency, in case that water content and contamination concentration increases, because the space charge polarization effect becomes stronger, the real and imaginary part of complex dielectric constant of contaminated soil would increase to some extent. For the range of high frequency, the changing curve of the real part and imaginary part of complex dielectric constant with concentration has no clear features

Both water content and contamination concentration have similar influence on the test results. The single test method is unable to make correct evaluation on contamination concentration, therefore, multiple detection methods must be united to differentiate the influence of water content and contamination concentration.

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