Phytotoxic properties of electrically-cleaned oil-contaminated soils (the use of Lepidium sativum L. biotest)

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Abstract. The changes in the properties of contaminated soil during electrochemical cleaning is very important. The results of research of phytotoxicity of soil contaminated with oil and mineralized formation water after electrochemical treatment are presented in this paper. A biotesting methodic with Lepidium sativum L. allowed to do complex assessment of the hazardous properties of contaminated soil. Lepidium sativum L is one of the most useful test object because of its high responsiveness to the presence of pollutants and ability to quickly germination. The most presentative parameters of this methodic are the percentage of seed germination and the total length of seedlings (sum of underground and aboveground parts length). A statistical analysis of the experimental data was carried out too.

1. Introduction

Electric methods of soil treatment can be used to solve various technical and environmental problems. This are pre-sowing soil treatment with small amperage, soil treatment in oil producing regions in order to increase reservoir productivity, irrigation and drainage technologies for desalination of agricultural lands and also the cleaning of contaminated soils of industrial and urban areas.

In the latter case, the electrochemical cleaning methods are indispensable for the removal of pollutants that have penetrated the soil to great depths and for the treatment of highly dispersed soils [1]. The technology of electrochemical cleaning allows to recultivate soil contaminated with heavy metals, phenols, radionuclides, salts and some organic substances [2]. So the use of electrical treatment is important for cleaning soils contaminated during the oil production when oil products and mineralized formation water pollute the soil contemporaneously. The effectiveness of the application and some technical features of the electrochemical treatment of oil-contaminated soils were considered by the authors in a number of publications [3-5].

A constant electric field applied to the soil causes electrochemical and electrokinetic processes. Electrochemical processes include electrolysis, electroflotation, electrocoagulation, electrodestruction, electrochemical disinfection, ion exchange, electrochemical oxidation [6] and leaching, electrodialysis. Electrokinetic processes are electroosmosis [7], electrophoresis and electromigration [8, 9]. Also there is electrostimulation of native microorganisms [10]. The method can be used to clean not only soils, but also groundwater [11].
It is very important to study potential negative effects of electric soil treatment, for example, pollution by physicochemical reactions by-products. It is necessary to monitoring changes in the physicochemical and toxicological soil characteristics.

So the phytotoxic properties of soil contaminated with oil and formation water after the electrochemical cleaning were studied with the use of Lepidium sativum L.

Biotesting is the procedure for establishing environmental toxicity using test objects that signal danger, regardless of which substances and in what combination cause changes in their vital functions [12].

Lepidium sativum is characterized by rapid and high seed germination, which decreases markedly in the presence of pollutants [13]. The advantage of this plant as a biological test object is that shoots and roots incur the influence of pollutants undergoing significant morphological transformation.

2. Practical part
The test medium was the model soil containing 1100 mg / kg of oil and 408900 mg / kg of mineralized formation water with a predominance of sodium, calcium, and magnesium chlorides [14]. This content of contaminants corresponds to the soil selected at the spill site that occurred at the oil field during production.

The electric soil treatment was carried out for 90 min at a current density of 340.4 A / m² (amperage is 0.8 A). The final oil content after cleaning was determined by IR-spectrometry [15] and amounted to 279.8 mg / kg. The total mineralization of the soil decreased by more than 2 times.

To analyze the effect of electrochemical treatment we used model contaminated soil (ordinary chernozem) and mixtures of contaminated soil with clean soil (“dilutions” of 2-, 4-, 8-, 16-, 32-fold ). The characteristics of used oil are presented at the tables 1, 2. The oil density is 0.880 g / cm³.

| The boiling point | Content (%) |
|-------------------|-------------|
| - up to 120 °C    | 8.0         |
| - up to 200 °C    | 4.5         |
| - up to 300 °C    | 13.5        |

| The impurity components | Content (% mass) |
|-------------------------|------------------|
| sulfur                  | 2.95             |
| paraffins               | 3.1              |
| tars                    | 14.6             |
| mechanical impurities   | 0.0076           |

Biological testing of contaminated soil after electrochemical cleaning using Lepidium sativum L. was carried out according to the standard method [16]. 100 g of the analyzed soil were put into plastic cups, 20 seeds were placed into a depth of 1-1.5 cm (figure 1). Uncontaminated soil was used for control. Each sample was poured with distilled water. Three samples are prepared for each type of soil mixture. The experiment time was seven days, after which the number of germinated seeds was counted and the length of the seedlings was measured. Next, statistical processing of data using standard methods and their analysis was carried out.
3. Research results and discussion

The dependence between the percentage of seed germination and dilution of the sample (and, accordingly, the concentration of pollutants) can be described by the equation:

\[ y = 64.29 + 0.779x \]  

(1)

The correlation coefficient is 0.69, which indicates a direct dependence.

The results of statistical analyze of seed germination data were presented in graphical form using the Statistica computer program (figure 2).

![Figure 1. Plastic cups with Lepidium sativum seedlings.](image1)

![Figure 2. The results of statistical analyze of Lepidium sativum seeds germination data.](image2)

The germination is approximately 48% in undiluted soil (native medium). The germination rate exceeds the control values starting from 4-fold dilution. A slight inhibitory effect is observed at the 2-fold dilution.
The average length of seedlings was determined for each type of soil mixture (i.e. each dilution). Statistical analyze of the obtained data allowed us to obtain the equation of the dependence of the seedlings length on the dilution value:

\[ y = 52.55 + 0.327x \]  

In this case, the correlation coefficient is 0.89. This is direct reliable dependence (figure 3).

**Figure 3.** The dependence of the seedlings length on soil dilution.

The seedlings length increase compared to control samples at 8-32-fold dilution. The small amounts of hydrocarbons serve are the source of organic matter for plants.

Analysis of Lepidium sativum seedlings length is presented in the diagram (figure 4).

**Figure 4.** The results of statistical analyze of the Lepidium sativum seedlings length.
4. Conclusion
The experiments showed that the toxicity of the soil sample after electrical treatment is reduced compared with untreated soil. According to the classification of the method, the toxicity of the sample is chronic. Previous studies of the phytotoxicity of contaminated soils before the electrochemical treatment showed its acute toxicity. This indicates an improvement of soil properties after cleaning.

The results of the analysis confirm that electrochemical cleaning of oil-contaminated soils using low amperage helps to reduce the toxic properties of soils without leading to secondary pollution. So this method can be used for efficient remediation of oil production territories with restoration of its macro- and micro-flora. Also electrochemical cleaning can be used before phytoremediation of soils [17].

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