Change in capillary moisture capacity of oil-contaminated soil after washing with Tween-80

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Abstract. The change in capillary moisture capacity of gray forest soil was analyzed at various levels of oil and diesel fuel contamination (50, 150 and 300 ml/kg), as well as as a result of reagent treatment of contaminated soil samples using the nonionic surfactant Tween-80. The concentration of Tween-80 in the wash solutions was 1, 5 and 10 g/L. The ratio of the system components was: 100 g of soil: 400 ml of water: 100 ml of washing solution. Treatment of oil-contaminated soil with washing solutions was carried out for 1 hour with continuous stirring (60 rpm) and a temperature of 20 °C. Contamination of gray forest soils with oil and diesel fuel has led to a decrease in capillary moisture capacity. Thus, the moisture capacity indicator moved from the category "best" (40-50% according to the classification of Kaczynski, 1965) to "satisfactory" (25-30%) or "unsatisfactory" (less than 25%). After washing oil-contaminated soils with surfactant solutions, the values of capillary moisture capacity were restored from the level of "unsatisfactory" to "good" or "best", although they remained somewhat lower than the level of the parameter of the original (uncontaminated) soil. The results obtained demonstrated an improvement in the studied and so important (in terms of yield) agrophysical parameter of oil-contaminated soil after its treatment with Tween-80. This confirms the prospects of using reagent treatment of oil-contaminated soils using this nonionic surfactant. At the indicated ratio soil : aqueous phase : washing solution, and the contamination level is up to 150 ml/kg (oil) and 300 ml/kg (diesel fuel), the optimal concentration for washing contaminated soil is 5 g/l Tween-80. When reclaiming soils contaminated with oil at a concentration of 300 ml/kg, it is recommended to increase the concentration of surfactants in washing solutions to 10 g/l.

1 Introduction

Extraction, refining and transportation of oil and petroleum products are often accompanied by oil pollution of soils. The reasons for this may be oil spills due to damage and accidents of pipelines, tank failures, problems with rail and sea transportation [1-3]. Considering that

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the demand for oil and petroleum products increases every year, the anthropogenic impact of the oil industry on the environment continues to increase.

Soil pollution with oil and oil products leads to disruption of natural biocenoses, deterioration of the agrophysical and agrochemical properties of soils, reduction in agricultural yields, and deterioration of the environmental situation in oil production areas [4-10].

The technologies used for the physical and chemical purification of soils from oil pollution are usually multi-stage, labor-intensive and associated with high material costs [11]. Therefore, recently there have been works on the use of surfactants (surfactants) for the remediation of soils contaminated with hydrophobic substances, in particular oil hydrocarbons [12-17]. In addition, in many cases, surfactants are already found in the original petroleum products [18]. In connection with the above, it is of interest to assess the influence of surfactants on some agrophysical properties of oil-contaminated soils. Their agricultural value is closely linked to these soil characteristics.

The purpose of this work is to study changes in the capillary moisture capacity of gray forest soil contaminated with oil or diesel fuel after washing soil samples with solutions with different concentrations of the nonionic surfactant Tween-80.

2 Materials and methods

The object of study - gray forest soil - was selected on the territory of the Botanical Garden of Irkutsk State University (Irkutsk, Russia). It was characterized by the presence of a gray-humus accumulative horizon, the quantitative characteristics of which were close to the lower limits of the dark-humus horizon. It is 20–25 cm thick and has a lumpy or lumpy-powdery structure. The soil reaction was slightly acidic (pH=6.3) in the upper part of the profile and neutral in the lower part (pH=7.0). The humus content in horizon A was 5% [19]. Oil (density 0.85 g/cm^3) from the Markov oil and gas condensate field (Verkhnemarkovo village, Irkutsk region, Russia) and diesel fuel (summer grade, GOST 305-2013) were used as model pollutants in the experiments.

Oil or diesel fuel was added to experimental samples of gray forest soil in concentrations of 50, 150 and 300 ml/kg and mixed thoroughly. Samples of contaminated soil weighed 100 g were distributed into 250 ml plastic containers, where they were kept for 24 hours until the oil products were completely absorbed into the soil. After this, the soil was poured into 500 ml flasks and 400 ml of water and 100 ml of surfactant washing solution were added. The latter were aqueous (distilled water) solutions of Tween-80 in concentrations of 1, 5 and 10 g/l. The flasks were kept for an hour on a BIOSAN OS-20 laboratory shaker (Biosan, Latvia) at a stirring speed of 60 rpm and a temperature of 20 °C.

After this treatment, soil samples were separated from the washing solution by filtering through paper filters (Blue Ribbon) and dried at room temperature for 24 hours.

Then, the capillary moisture capacity (%) of the tested soil samples was determined by the thermostat-weight method [20] (GOST 28268-89). The capillary moisture capacity indicator was assessed using N.A. Kachinsky's gradation. According to him, a capillary moisture capacity of 40-50% is considered the best, 30-40% is considered good, 25-30% is satisfactory, and less than 25% is unsatisfactory [21].

The following were used as a control: 1) uncontaminated soil samples washed with Tween-80 in accordance with the manipulations described above; 2) uncontaminated soil samples, washed with distilled water in accordance with the manipulations described above.

All experiments were carried out in at least 3 independent experiments with 3 parallel measurements. For statistical processing of the obtained data, the Microsoft Excel software package was used. The significance of the differences in results was determined using the

Student's test. The conclusions were made with the probability of an error-free prediction P≥0.95.

3 Results of research

The capillary moisture capacity of unpolluted gray forest soil without treatment with surfactant solutions was 62.1±0.9%. This corresponds to the best capillary moisture capacity (Kaczynski, 1965). Washing uncontaminated soil samples with washing solutions slightly reduced the tested parameter at Tween-80 contents of 5 and 10 g/l (to 54.9±0.1 and 51.9±0.1%, respectively). However, according to the gradation of N.A. Kachinsky (1965), the observed decrease in capillary moisture capacity did not lead to a deterioration in soil quality, since it is considered the best in the range of 40% and above. Unsatisfactory capillary moisture capacity of soils was caused by oil pollution at all concentrations studied (50, 150 and 300 ml/kg). Thus, in the presence of 50 ml/kg of oil, the indicator decreased to 22.6±1.0%, at 150 ml/kg - to 19.1±1.5%, at 300 ml/kg to 12.5±2.3 % (Table 1).

Table 1. Change in capillary moisture capacity (%) of gray forest soil under the influence of oil and leaching with Tween-80.

Oil concentration in soil, ml/kg	Capillary moisture capacity, %			
	Before surfactant treatment	After treatment with a surfactant in concentration		
		1 g/l	5 g/l	10 g/l
50	22.6±1.0	37.5±0.2	50.2±0.1	48.0±0.1
150	19.1±1.5	25.9±0.1	41.9±0.6	40.1±0.1
300	12.5±2.3	22.6±1.7	25.8±0.2	33.7±0.2
0 (control)	62.1±0.9	60.0±0.1	54.9±0.1	51.9±0.1

As a result of washing oil-contaminated soil with Tween-80, the capillary moisture capacity increased. Thus, after using a washing solution containing 1 g/l Tween-80, the capillary moisture capacity of the soil sample was 37.5±0.2%, at 5 g/l – 50.2±0.1%, and at 10 g/l l – 48.0±0.1% (Table 1). The indicated values remained lower than those of samples in which the soil was not exposed to oil contamination. That is, washing with Tween-80 did not lead to the restoration of the studied agrophysical indicator of the soil to the original parameters. However, the values of capillary moisture capacity when using surfactants increased from the level of “unsatisfactory” to “good” or “best”. This indicates the fundamental possibility and prospects of the applied reagent treatment of oil-contaminated soil with detergents. The best effect was obtained when using 5 g/l Tween-80. Increasing its concentration to 10 g/l did not add efficiency to the process, but increased the consumption of the reagent by 2 times, which is irrational from an economic point of view.

A similar trend was noted at an oil contamination level of 150 ml/kg (Table 1). Washing soil samples containing 150 ml/kg of oil led to an increase in their capillary moisture capacity from unsatisfactory (19.1±1.5%) to satisfactory (25.9±0.1%) at 1 g/l Tween-80, and to good – at 5 and 10 g/l Tween-80 (up to 41.9±0.6 and 40.1±0.1%, respectively).

At the highest tested level of oil contamination (300 ml/kg), it was possible to restore the studied agrophysical parameter to the “good” level only when using 10 g/l Tween-80. In this case, the value of the capillary moisture capacity of the soil after washing with a surfactant solution increased from 12.5±2.3% to 33.7±0.2%. This value corresponds to the lower limit of the “good moisture capacity” level in the Kaczynski gradation). After using leaching solutions containing 1 g/l Tween-80, the capillary moisture capacity of the soil was 22.6±1.7% (i.e. remained unsatisfactory), and with 5 g/l – 25.8±0.2% (lower limit of the level of “satisfactory moisture capacity” in the Kaczynski gradation) (Table 1).

Thus, at a level of oil contamination of up to 150 ml/kg, reagent soil treatment with washing solutions containing 5 g/l Tween-80 may be promising (treatment time - 1 hour, ratio of system components is 100 g soil : 400 ml water : 100 ml of washing solution). When reclaiming soils contaminated with oil at a concentration of 300 ml/kg, it is recommended to increase the concentration of surfactants in washing solutions to 10 g/l.

Similar experiments were carried out when soil was contaminated with diesel fuel.

Contamination of gray forest soil with diesel fuel at a concentration of 50 ml/kg led to a decrease in its capillary moisture capacity from 62.1±0.9% (uncontaminated soil) to 42.6±0.1%, at 150 ml/kg of oil product - to 30 .9±0.2%, and at 300 ml/kg – up to 25.7±0.2% (Table 2). These values, according to the gradation of Kaczynski (1965), correspond to the best, good and satisfactory capillary moisture capacity, respectively. It should be noted that diesel fuel had a less negative effect on the tested agrophysical parameter of the soil than oil.

Table 2. Change in capillary moisture capacity (%) of gray forest soil under the influence of diesel fuel and rinsing with Tween-80.

Oil concentration in soil, ml/kg	**Capillary moisture capacity, %**			
	Before surfactant treatment	**After treatment with a surfactant in concentration**		
		1 g/l	**5 g/l**	**10 g/l**
50	42.6±0.1	43.6±0.3	53.7±0.3	50.0±0.1
150	30.9±0.2	35.6±0.3	43.9±0.1	42.0±0.1
300	25.7±0.2	27.1±0.2	35.9±0.1	33.9±0.1
0 (control)	62.1±0.9	59.9±0.1	54.9±0.1	52.0±0.1

As a result of washing soil samples contaminated with diesel fuel at a concentration of 50 ml/kg with solutions containing 5 and 10 g/l Tween-80, their capillary moisture capacity increased from 42.6±0.1% to 53.7±0.3 % and 50.0±0.1%, respectively. In soil samples treated with 1 g/l surfactant, the values of capillary moisture capacity before (42.6±0.1%) and after washing (43.6±0.3%) were comparable.

At a diesel fuel contamination level of 150 ml/kg, the capillary moisture capacity of soil samples (30.9±0.2%) as a result of treatment with Tween-80 at a concentration of 1 g/l increased to 35.6±0.3%, at 5 g/l l – 43.9±0.1%, at 10 g/l – 42.0±0.1%. The same trend was observed when the degree of soil contamination with diesel fuel increased to 300 ml/kg. In this case, the capillary moisture capacity of the samples after washing with Tween-80 solutions increased from 25.7±0.2% to 27.1±0.2% (at 1 g/l Tween-80), to 35.9±0.1 % (at 5 g/l Tween-80) and up to 33.9±0.1% (at 10 g/L Tween-80).

The experiments carried out demonstrated the effectiveness of using reagent treatment of oil-contaminated soils using the nonionic surfactant Tween-80. Washing soil samples with washing solutions containing 1, 5, and 10 g/L Tween-80 led to an improvement in capillary water capacity compared to contaminated soil samples. A comparison of the effectiveness of soil treatment with Tween-80 solutions at the indicated concentrations allowed us to draw the following conclusion. When the level of soil contamination with oil is up to 150 ml/kg and diesel fuel is up to 300 ml/kg, it is advisable to carry out reagent soil treatment with washing solutions containing 5 g/l Tween-80 (treatment time - 1 hour, the ratio of system components is 100 g of soil: 400 ml water : 100 ml rinsing solution). When reclaiming soils contaminated with oil at a concentration of 300 ml/kg, it is recommended to increase the concentration of surfactants in washing solutions to 10 g/l.

With an increase in the amount of oil and petroleum products in the soil, its hydrophobicity increases. This reduces the soil's ability to absorb moisture and conduct it through soil capillaries [22-23]. Surfactants make soil wettable [24] because the hydrophobic tail of the wetting agent chemically binds to the hydrophobic surface of soil

particles, while the hydrophilic head attracts water molecules, thereby allowing them to penetrate the soil and thus increasing infiltration [25].

4 Conclusion

Thus, after adding oil to oil-contaminated soil, the capillary moisture capacity decreased more than after treatment with diesel fuel. Treatment (for 1 hour) of oil-contaminated soil with washing solutions containing Tween-80 in concentrations of 1, 5 and 10 g/l, with the following ratio of system components: 100 g of soil: 400 ml of water: 100 ml of washing solution, led to an improvement (increase) capillary moisture capacity compared to contaminated soil samples. The results obtained demonstrate the promise of using reagent treatment of oil-contaminated soils using the nonionic surfactant Tween-80. At the indicated ratio soil : aqueous phase : washing solution, and the contamination level is up to 150 ml/kg (oil) and 300 ml/kg (diesel fuel), the optimal concentration for washing contaminated soil is 5 g/l Tween-80. When reclaiming soils contaminated with oil at a concentration of 300 ml/kg, it is recommended to increase the concentration of surfactants in washing solutions to 10 g/l.

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