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Monitoring the Remediation of Oil-Contaminated Permafrost Soils on the Territory of the Tank Farm

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Introduction

According to the Ministry of Ecology, Nature Management and Forestry, over the past 12 years, the number of oil and OP spills has amounted to more than 316 cases, including the Arctic zone [1]. In most cases, spills are caused by road accidents. Spills also occur due to the technical condition of tanks, during transportation, discharge, pumping of OP, as well as due to weather and man-made disasters (floods, fires, explosions, etc.)

The problem of remediation of disturbed lands in permafrost conditions is difficult, since the soils are characterized by a low potential for self-recovery and are vulnerable even with insignificant man-made impacts.

Analysis and systematization of existing methods of cleaning oil-polluted soils, both according to literature data and the results of our own research, showed that in cryolithozone, the most environmental and effective is a biological method for treatment polluted soils with biological products based on aboriginal hydrocarbon-oxidizing microorganisms with sowing of perennial plant varieties [2-4].

The aim of the research was to evaluate the developed technology effectiveness of biological remediation of permafrost soils polluted with diesel fuel.

Object, Materials and Methods

In the central part of Yakutia (N 58.970185 E 126.233816), on the territory of the oil depot the experiment was carried out on the biological remediation of soils polluted with diesel fuel as a result of an accidental spill. For this, 5 experimental sites were laid.

The bioremediation technology consisted of the treatment the soils of the experimental sites with the biological product based on HCOM isolated from permafrost soils of Yakutia and capable of developing at low positive temperatures (from +4 °C) under conditions of insufficient aeration and moisture [5].

Sampling

Research scheme

Results

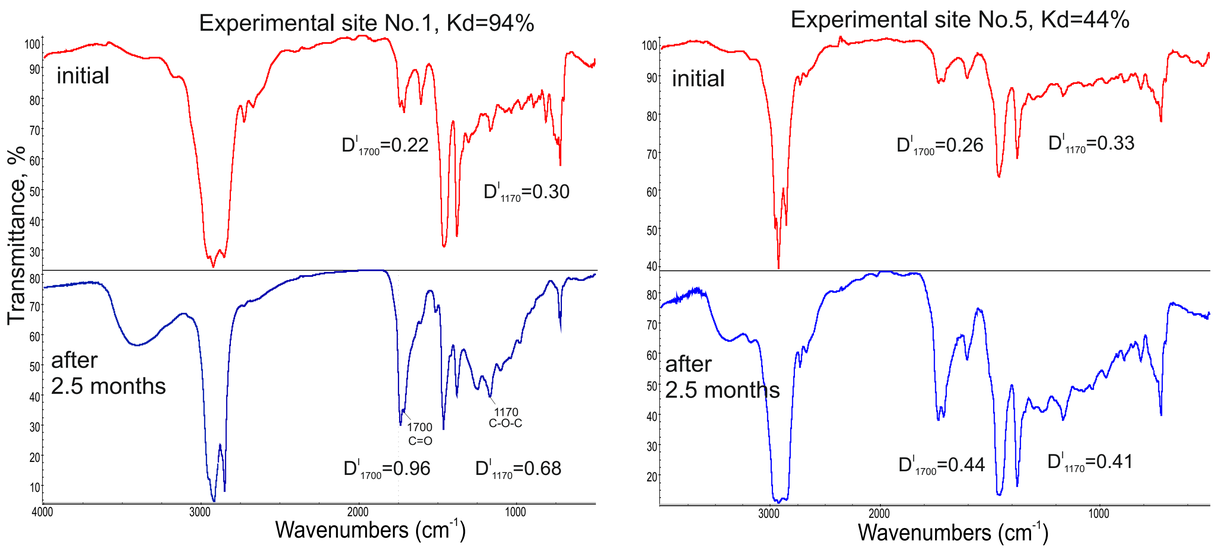
Geochemical characteristics of soil extracts before and 2.5 months after biological treatment

No. site	State oil pollution	Content OP*, mg/kg	Group component composition of soil extracts, %		
			HC**	Resins	Asphaltenes
1	initial	67528	89.5	7.4	3.1
	after 2.5 months	3804	6.8	58.9	34.3
2	initial	67043	88.8	8.4	2.8
	after 2.5 months	3812	8.3	52.7	39.0
3	initial	70495	92.5	5.6	1.9
	after 2.5 months	5979	69.4	21.1	9.5
4	initial	32148	79.3	11.8	8.9
	after 2.5 months	15485	72.5	18.6	8.9
5	initial	24533	87.0	9.8	3.2
	after 2.5 months	13677	70.6	20.3	9.3

*Signs: * OP – oil products, ** HC - hydrocarbons*

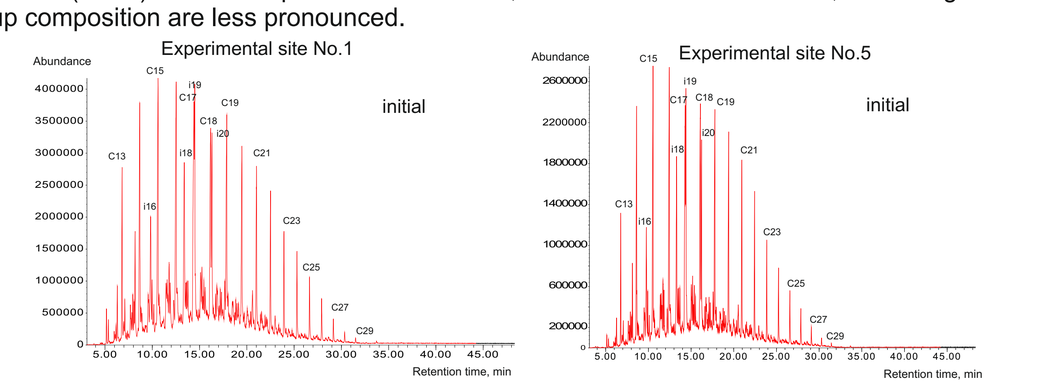
The initial content of OP in the soils of the experimental plots ranged from 24533 mg/kg to 67528 mg/kg. The level of pollution of samples is characterized as high and very high. 2.5 months after the biological treatment, the residual content of OP in the soils at the experimental sites decreased in several times at the sites No.1 – No.3.

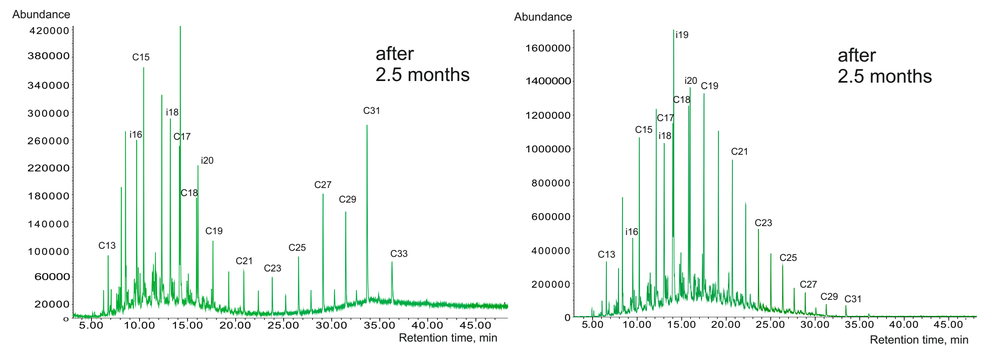
According the data of FT-IR spectroscopy decrease in the concentration of OP was accompanied by a change in the structure-group composition of soil extracts. The degree of destruction (Kd) of oil pollution ranged from 44 to 94%.



FTIR spectra of soil extracts samples from experimental sites No. 1 and No. 5 before and 2.5 months after biological treatment

After 2.5 months biological treatment, in the group composition of the samples of sites No.1 and No.2, the content of HC significantly decreased and the content of resins and asphaltenes increased (Table). In the samples from other sites, the same trend is observed, but changes in the group composition are less pronounced.





Mass chromatograms m/z of 57 saturated HC in soil extracts of the samples from experimental sites No.1 and No.5 before and 2.5 months after biological treatment

C_{13}... C_{31} - n-alkanes; i_{16}... i_{20} - isoprenoids

In the soil extracts of initial samples, relatively low molecular homologues with maxim of n-alkanes on n-C15,16,17 dominated in the n-alkanes composition. The values of the ratio (i-C19 +i-C20)/(n-C17+n-C18) and the CPI coefficient are close to unity.

2.5 months after biological treatment at the site No.1, the appearance of second maximum of n-alkanes in the high-molecular region on n-C31 was noted, which is characteristic for the natural background. In the composition of saturated HCs, the quantity of relatively low molecular homologues of n-alkanes decreased, which was reflected in a decrease in the coefficient ∑b.b.t.-n-C20/∑n-C21-e.b.t. At the same time the content of isoprenoids increased, as the values of the ratio of isoprenoids/n-alkanes and CPI coefficient.

The (i-C19+i-C20)/(n-C17+n-C18) ratio increased, which is concerned as indicator reflecting the degree of biodegradation of oil pollution. The changes in the individual composition of saturated HC in comparison to the initial pollution indicate processes of biodegradation of oil HC have taken place.

Dynamics of changes in the individual composition of saturated hydrocarbons

Parameters	No. experiment sites			
	No. 1		No. 5	
State oil pollution	initial	after 2.5 months	initial	after 2.5 months
$\Sigma_{b.b.t}$ -n-C_{20}/Σ n-$C_{21-e.b.t}$*	3.53	1.00	3.74	2.37
Maximum n-alkanes	n-$C_{15,16,17}$	n-C_{15} и n-C_{31}	n-$C_{15,16}$	n-$C_{17,18}$
CPI**	0.98	1.90	0.96	1.00
Isoprenoids/n-alkanes	0.33	0.51	0.36	0.52
i-C_{19}+i-C_{20}/n-C_{17}+n-C_{18}	1.02	1.50	0.95	1.33

** – b.b.t. temperature of beginning boiling; e.b.t. temperature of end boiling*

*** – the relation of the sum of even alkanes to odd*

Conclusions

The complex of physico-chemical methods of analysis used in the work showed their high information content in the study of changes in the composition of the initial oil pollution on the territory of the oil depot.

It was found that changes in the content of OP and the chemical composition of oil pollution in permafrost soils during diesel fuel spills occur as a result of the processes of evaporation of light HC, chemical oxidation and biological destruction of HC, caused by the activity of indigenous hydrocarbon-oxidizing microorganisms introduced during the biological treatment of soils.

The detected directional changes in the composition of saturated HCs, redistribution of HCs both within homologous series and between different rows of homologues, as well as changes in chemical structure of the soil extracts simultaneously with the decrease in the residual content of OP indicate the processes of biodegradation of oil pollution had took place. The results of the experiment showed the effectiveness of the treatment performed on the bioremediation of polluted permafrost soils using the developed biological product based on aboriginal hydrocarbon-oxidizing microorganisms.

Own research and analysis of literature data have shown that biological methods of purification based on using of microbial preparations are more environmentally friendly, eliminate negative consequences for the natural environment; they are more economical and therefore more promising.

In connection with a development of oil and gas complex at the North-East of Russia, the results obtained can be used in the development of technologies for remediation of disturbed lands.

Literature

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