POLLUTION

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THE POSSIBILITY OF USING DRILING WASTEWATER IN THE REMEDIATION OF DISTURBED LAND

Research article

Abstract

The paper examines the possibility of using drilling wastewater in the remediation of disturbed land. The samples were examined using concentration meter, spectrophometer, and pH meter. Studies on the metal content were carried out by atomic emission spectrometry with inductively coupled plasma. It was found that the liquid drilling waste contains a complex of biophilic elements: N, Ca, Na, K, P, S, Cl, Fe, Cu, Co, Mn, Zn. Three soil plots for sowing grasses on liquid drilling waste were studied. The soil was furrowed and the grass mixture was sown using working solutions. The possibility of using drilling wastewater as a meliorate in the conditions of forest-tundra and tundra zones of the Krasnoyarsk Territory has been established. The results of experimental data indicate that the use of components of liquid drilling waste in the formulation of agrochemical preparations does not have a negative effect on seed germination and plant growth.

Keywords: drilling waste water, disturbed land, meliorate.

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ВОЗМОЖНОСТЬ ИСПОЛЬЗОВАНИЯ БУРОВЫХ СТОЧНЫХ ВОД ПРИ РЕКУЛЬТИВАЦИИ НАРУШЕННЫХ ЗЕМЕЛЬ

Научная статья

Аннотация

В работе исследована возможность использования буровых сточных вод при рекультивации нарушенных земель. Исследование проб проводилось с помощью концентратомера, спектрофотометра и pH-метра. Исследования на содержание металлов проводились методом атомно-эмиссионной спектрометрии с индуктивно-связанной плазмой. Установлено, что в жидких отходах бурения содержится комплекс биофильных элементов: N, Ca, Na, K, P, S, Cl, Fe, Cu, Co, Mn, Zn. Исследованы три участка почвы для проведения посева трав на жидких буровых отходах. Для проведения опытных испытаний на участках проведено бороздование почвы и посев травосмеси с применением рабочих растворов. Установлена возможность применения сточных буровых вод в качестве мелиоранта в условиях лесотундровой и тундровой зонах Красноярского края. Результаты экспериментальных данных свидетельствуют, что использование в рецептуре агрохимических препаратов компонентов жидких буровых отходов не оказывает негативного влияния на всхожесть семян и рост растений.

Ключевые слова: буровые сточные воды, нарушенные земли, рекультивация, мелиорант.

1. Introduction

The Land Code of the Russian Federation requires persons whose activities have led to a deterioration in the quality of land to ensure their restoration. One of the ways to prevent the degradation of land resources and the restoration of soil fertility is to carry out reclamation. The land is brought into a condition suitable for its further use in accordance with its intended purpose, including the elimination of the soil pollution consequences. The creation of protective forest stands is carried out through reclamation activities [1], [2].

The technical component of such measures envisages the layout, the formation of slopes, removal of contaminated disturbed soil, applying topsoil, construction of hydrotechnical and meliorative structures. These actions create the necessary conditions for the prevention of land degradation and the implementation of measures for the next biological stage.

Different from technical activities, biological measures are a longer stage of restoration work, since they include a complex of agrotechnical and phytomeliorative measures to improve the agrophysical, agrochemical, and biochemical properties of the soil. The biological stage of reclamation includes the application of fertilizers and peat-sand mixture, soil milling and planting herbs [3].

The land used by oil and gas production enterprises should be paid to special attention, because the technological processes of extracting oil and gas from the subsurface have an extreme load on the components of the environment. Drilling waste is a multi-tonnage and often toxic to the environment. In this connection, the question of their rational use or finding the best ways to dispose of them is increasingly raised.

During the construction of oil production wells, from 320 to 550 cubic meters of drilling waste is generated for every 1 thousand meters of drilling [4]. At that, liquid drilling waste makes up from 220 to 350 cubic meters in the absence of re-use systems.

The background content of chemicals and the amount of biophilic elements in the forest-tundra soils in the licensed areas of oil and gas fields in the Krasnoyarsk Territory generally do not exceed the standard values. At the same time, it is noted that the soils of the forest-tundra zone are quite poor in the content of biogenic elements and their compounds. Thus, the following elements are almost completely absent: Ca, P, K, Mg [5], [6], which affects the conditions for the implementation of reclamation works.

2. Methods

A land plot was selected for the pilot tests on the territory of the Turukhansky district of the Krasnoyarsk Territory at a distance of 140 km north-west of the city Igarka. The thickness of the frozen rocks in this area is from 400 to 480 meters. The average annual temperature fluctuations on the bottom of the frozen rocks layer from 1,5 to 2,5 degrees below zero are characteristic for the zone of continuous distribution of permafrost.

The climate of the region is sharply continental with long winters and short summers, large annual and daily temperature differences. The duration of the winter period is 8 months from October to May. The average annual air temperature is 8,4 degrees below zero.

The selected land plot is characterized by loamy clay tundra soils, a relatively flat landscape and the lack of vegetation on it. The experimental plot does not belong to land plots with a limited type of use, that is, it does not fall into the protection zone of drinking water sources, or specially protected natural territories. The main limiting factors here for plants are severe climatic conditions: low air temperatures during growth, late spring and early autumn frosts, and a short growing season [7].

The experimental land plot was divided into 3 sub-plots of 2 square meters each (Fig. 1), figure example below:

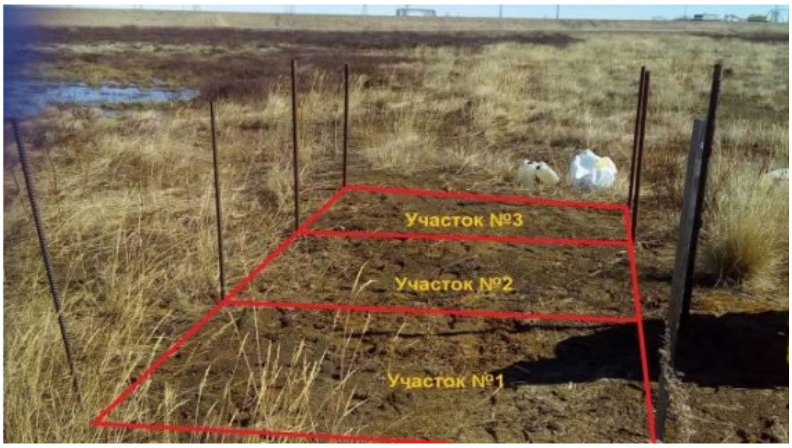

Figure 1 – Experimental land plot:
the plot number 1 (control). The sowing of herbs was carried out on an aqueous solution with the addition of fertilizers;
the plot number 2 (experimental). Grass sowing was carried out in accordance with the recommendations [8];
the plot number 3 (experimental). Grass sowing was carried out on drilling wastewater.

The background content of biogenic elements in the study area is presented in Table 1.

Table 1 – The background content of biogenic elements in the studied soils

Chemical element	Background concentration, mg/kg	Maximum permissible concentration, mg/kg
Cu	12,4	3,0
Zn	34,2	23,0
Mo	1,8	-
Sn	2,4	-
Na	11,0	-
SO_4^{2-}	42,9	160,0
Cl	29,2	360,0

Two samples of drilling waste water from each of the two different sludge barns were taken [9] for definition the quantitative chemical composition of liquid waste. A stainless steel bucket was used for sampling; thereafter the samples were combined into a single sample in a five-liter plastic bottle. The samples were examined using the concentration meter KN-2, the spectrophotometer DR 2800, and the pH-meter pH-410.

Studies on the metal content were carried out by atomic emission spectrometry with inductively coupled plasma. The presence of hydrocarbonates was performed in accordance with GOST 31957 - 2012 [10].

The results of laboratory tests are presented in Table 2.

Table 2 – Composition of drilling waste water

Parameter	Average value, mg/l	Exceeding the maximum permissible concentration
Cl^-	827,0 ± 245,0	in 2,3 times
HCO_3^-	2433,0 ± 1227,0	absent
Ca	451,0 ± 351,0	absent
K	794,0 ± 218,5	absent
Suspended solids	475,0 ± 65,0	absent
NO_3^-	32,0 ± 21,5	absent
NH_4^+	4,4 ± 3,5	absent
SO_4^{2-}	410 ± 154	in 2,6 times
PO_4^{3-}	1,8 ± 1,0	absent
Cr	0,2 ± 0,001	absent
Mn	1,3 ± 0,002	absent
Fe	48,4 ± 5,6	absent
Co	< 0,1	absent
Ni	< 0,1	absent
Cu	0,1 ± 0,001	absent
Pb	< 0,1	absent
Cd	0,1 ± 0,001	absent
As	< 0,01	absent
Al	1,7 ± 0,02	absent
Si	5,7 ± 0,9	absent
Petroleum products	21100	absent
pH	10,2	-

The calculation of the environmental hazard coefficients of drilling waste water components using the program "Calculation of the waste hazard class" (Version 4.0) (developer INTEGRAL) allowed us to classify the waste to the fifth hazard class. Biological testing of the sample confirmed the calculated data.

The formulation of working solutions for the treatment of soil plots is selected empirically and presented in Table 3.

Table 3 – Formulation of working solutions

Component	The plot number 1 (control)	The plot number 2 (experimental)	The plot number 3 (experimental)
Water, l	10	-	-
Drilling waste water, l	-	10	10
Potassium humate, ml	30	30	-
Sodium-carboxymethylcellulose, g	10	10	-
Microbiological fertilizer Baikal EM1", ml	10	10	-
Superphosphate double, g	50	50	-
A mixture "Northern Garden", g	40	40	40

Bentonite was not used in the preparation of working solutions, since local loamy soil was used. Also, potassium-based fertilizers (complex fertilizers, potassium chloride, etc.) were not added to the working solution, because the drilling waste water contains potassium in its composition.

3. Results and Discussion

According to the results of observations of the first vegetative season, it was established:

1. The lawn grass sprouted on the land plots number 1, number 2 and number 3, as well as the local flora partially overgrown (mushrooms, northern sedge, narrow-leaved cypress (Ivan-tea), and others). The height of germination of the grass mixture was up to 5 cm.

2. There is a greater germination of seeds and their survival rate in plots number 1 and number 2, than in plot number 3. This is expressed in the fact that the density of overgrowth of lawn grass was about 36 sprouts per 10 cm^2 on the land plot number 1; about 29 sprouts per 10 cm^2 on the land plot number 2 and about 13 sprouts per 10 cm^2 on the land plot number 3.

3. The germination of grass mixture seeds and their further growth is observed mainly in furrows on all three sites. This observation indicates the protective properties of furrows for seeds from wind and water erosion. Figure 2 shows the observations of the first growing season.

Figure 2 – Results of observations during the first growing season

The previously mentioned observations evidence using of waste drilling water in the agrochemical formulation is no negative effect on the germination and growth of seeds.

According to the results of observations of the second vegetative season, it was established:

1. The destruction (freezing) of the planted lawn grass mixture occurred on all areas.
2. Local flora germinated on all land plots: northern sedge, narrow-leaved cypress (Ivan-tea). The most intensive vegetation growth is observed on the land plots number 1 and number 2.
3. New vegetation sprouts are visible in the places of extinct grass on all land plots.
4. In this instance we observed an increase in the density of overgrowth of local flora on the land plots number 1 and number 2 in comparison with the first vegetative season. Figure 3 shows the observations of the second growing season.

Figure 3 – Results of observations during the second growing season

The above observations indicate using of waste drilling water in the agrochemical formulation is not negatively affected and there is a positive effect on the growth of local flora.

Soil samples of the experimental site number 2 were taken from two points of 15 cm a depth at the end of the 1st growing season to determine the level of soil contamination. Further, the samples were combined into a single sample and transferred to the experimental laboratory the content of petroleum products, chlorides, sulfates and surface-active substances in the soil. The initial high concentrations in the drilling waste water of petroleum products, chlorides, and sulfates were the reason for soil samples research, as well as the lack of data on the surface-active substances content. The results of the tests showed the content of petroleum products was 11 mg/kg, the surface-active substances 0,8 mg/kg, chlorides 0,129 millimole/100 g (for potassium chloride 96,105 mg/kg), sulfates 0,34 millimole/100 g (for sulfur 108,8 mg/kg). According to the conducted studies, the excess of the maximum permissible concentration in the soils by the test substances was not detected.

According to the conducted research, bentonite can be replaced with clay or loam.

The economic analysis made it possible to identify the feasibility of using drilling waste water for reclamation of disturbed land, taking into account the formulation [8]. The cost of the work can be reduced by eliminating the purchase and delivery of bentonite when working on clay or loam. In addition, the cost savings will be achieved due to the absence of the need to use potash fertilizers.

4. Conclusions

According to the quantitative chemical composition of drilling waste water, they contain a complex of biophilic (biogenic) substances related to both micro and macronutrients: K, Cl, Ca, Na, N, S, SO_4^{2-}, Mn, Co, Cu, Zn, Fe, P. The results of the calculation of the hazard class showed, that drilling waste water belongs to the fifth class of environmental hazard, that is, practically non-hazardous. In accord with the estimates, about 770 cubic meters of drilling waste water can be used during the reclamation of the land plot allocated for exploration and evaluation drilling. The using of agrochemical solution with drilling waste water on loamy soils showed favorable results.

Thus, it is possible to use drilling waste water in the reclamation of disturbed land as a meliorate in the forest-tundra and tundra zones.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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