

# Utilization of drilling cuttings with extraction of ground for recultivation of disturbed soils

E V Gaevaya<sup>1</sup>, Y E Bogaychuk<sup>2</sup>, S S Tarasova<sup>2</sup>, L N Skipin<sup>1</sup>, E V Zakharova<sup>1</sup>

<sup>1</sup> FSBEI of Higher Education «Tumen industrial university», Lunacharskogo St., 2, Tumen, 625001, Russia

<sup>2</sup> «R&D Institute «Neftegazsproekt», Melnikaite str. 70, Tumen, 625027, Russia

E-mail: ele-gaevaya@ya.ru

**Abstract.** Drilling of wells is connected with formation of the bore mud represented by the drill cutting with waste drilling mud. Bore mud has negative physical-chemical, physical and chemical properties: high content of salts, increased alkalinity, ash structure, soil overcrust, low airing, weak filterability and so on. In case of phosphogypsum adding to the bore mud, pH level decreases from the alkaline (10.5 U) to weakly alkaline 7.6 U, decrease of pH is connected with the influence of phosphogypsum acidity and neutralization of the more mud. Concentration of chloride ions and sulphate ions in reclaimed bore mud was  $70 \pm 7$  and  $456 \pm 46$  correspondingly. Presence of oil products in received soil was 198.0-219.0 mg/kg. When adding phosphogypsum, sand, sorbent and humic formulation «Rostok» to the bore mud, it has shown good germinating ability of cultures- phytomeliorants (93,3%). 100% germinating ability was observed in meadow grass with a height of overground sprouts 10.7 cm, germinating ability of red fescue was 80% with height of overground sprouts 9.6 cm.

## 1. Introduction

In the process of well drilling, transformation of original raw material into drilling cuttings takes place. As a result, liquid phase of drilling cuttings appears - drilling wastewater, and waste drilling mud, solid phase – bore mud [1], [2].

The bore mud is multicomponent mixture of substances. Components of the bore muds belong to III and IV classes of danger. Percentage ration of materials and chemical reagents can vary depending on the method of drilling, formation pressure, origination of reservoir formation. Density of the bore muds varies from 1.0 to 1.2 g/cm<sup>3</sup> [3].

Bore mud is fluid, paste-like mass of dark grey color with metal tint, oily by touch and with smell of oil. Density of the bore mud is determined by the density of bore mud and drilled rock. For the Western Siberia density of bore mud varies from 1.3 to 2.2 g/cm<sup>3</sup> [3]-[6][5].

Viscosity (opposite property of the fluidity) of the drilling cuttings is 0.1-4.5 Pa·s. Fluidity increases with the increase of water content and during the poor solution purification. Dehydrated bore muds lose fluidity and are easily milled into powder [5]. Researches of granulometric content have shown that sizes of bore mud particles are from 10 to 500 μm, and larger particles correspond to drilled rocks, while small one correspond to bentonites. The curve of particles distribution by the size has 2 maximums. One maximum has particles with a size 20-30 μm, another 200-300 μm [7].

The main objects of soiling during the drilling of wells is geological environment (underground waters), hydro and lithosphere (open reservoirs, bottom of water areas, soil and vegetation cover) [8].



Pollution agents of the bore muds having accumulated in the soil layer, lead to the loss of fertility: destroying of aggregates, appearance or strengthening of erosion processes, decrease of biological activity of the soil and its ability to self-purification. Alkaline mineralized waste drilling muds and bore mud containing oil and oil-products have the biggest danger. High mineralization and alkalinity of waste drilling muds and presence of liquid hydrocarbons in their content are the main factors of negative influence on their soil continuum [9],[10],[11].

Migration of toxic salts of the components (chloride ion, ions of sodium, sulphate-ions, hydrocarbonate ions) and oil products leads to amelioration of soil properties in horizontal as well as vertical direction: water-air mode of soil, concentration of soil solution increases, penetration of sodium ions to soil adsorption complex takes place, microflora is oppressed that makes soil inappropriate for the growth of plants. This leads to destruction of ecosystems established on this territory with the following pollution of the contiguous environments [12],[8].

Influence of the drilling cuttings on the natural objects not necessarily can be expressed in violation of ecological balance of biotopes of different trophic levels with their interaction with abiotic environment bearing mechanism of functional damages of the ecosystem [13].

## 2. Materials and Methods

Within the framework of this experiment, sample collection was carried out on the territory of well from the mud pit if Uvatskiy district of Tumen region [15][16].

Studies of bore mud samples took place on the base of the laboratory of Technosphere safety department. Oil products analysis of samples was carried out using fluid analyzer «Fluorat-02-2M» according to the methodology of Federal Environmental Regulatory Documents 16.1:2.21 [17]. Determination of chloride ions was carried out according to National Standard 26425 [16].

Laboratory researches for determination of germinating energy of seeds took place according to National Standard 12038 [18].

Variants of biological recultivation of the bore mud are presented in table 1.

**Table 1.** Variants of biological recultivation of the bore mud

Name of phytoculture	Variant	Component				
		BM	Phosphogypsum	Sorbent	Sand	Humic formulation «Rostok»
Festuca rubra / bromopsis inermis / poa pratensis	Control variant	+	-	-	-	-
	1	+	+	-	-	-
	2	+	+	-	-	+
	3	+	+	-	-	+
	4	+	+	-	-	+
	5	+	+	-	-	+
	6	+	+	-	+	+
	7	+	+	+	+	+

## 3. Results

For the evaluation of the possibility of perspective use of grain crops for biological recultivation of bore mud, seed of the plants were used: *Bromopsis inermis*, *Poa pratensis*, *Festuca rubra*.

Germinating energy and emergence rate of the seed material were demined in percentage terms. Result of analysis was taken as arithmetical mean of two replicaitons. The work contains averaged values of germination and emergence of experimental seeds, presented in the table 2.

**Table 2.** Averaged values of emergence rate and germinating energy

Evaluation criterion	Concentration of the bore mud, %	Culture		
		<i>Poa pratensis</i>	<i>Bromopsis inermis</i>	<i>Festuca rubra</i>
Average arithmetical mean of emergence	control	70	55	65
	5	80	50	65

Evaluation criterion	Concentration of the bore mud, %	Culture		
		<i>Poa pratensis</i>	<i>Bromopsis inermis</i>	<i>Festuca rubra</i>
rate, %	10	85	50	70
	15	90	70	65
	20	65	30	60
Average arithmetical mean of germinating	control	70	70	65
	5	95	60	70
	10	95	60	75
energy, %	15	90	70	65
	20	75	50	60

With the following increase of concentration of the drill fluid, seeds did not experience oppression since the drill fluid with different concentrations 5 %, 10%, 15%, 20% corresponds to the content of low level of pollution. Content of oil products is 0,15 mg/inch<sup>3</sup>, 0,30 mg/inch<sup>3</sup>, 0,45 mg/inch<sup>3</sup> and 0,60 mg/inch<sup>3</sup> correspondingly.

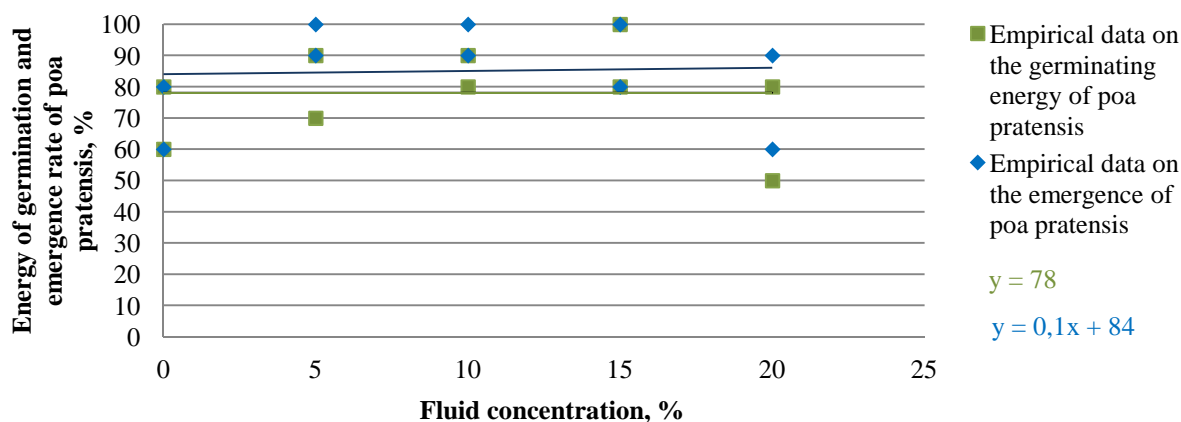
Germinating energy of poa pratensis under 5-14% pollution increases emergence rate of control sample by 10-20%, under 20% concentration there was observed phytotoxic effect on the growth and development of germs of poa pratensis (65%). High index of germinating energy of bromopsis inermis was observed under the 15% drill fluid and made up 70%. With the following increase of 20% concentration marked decrease of germinating energy took place. Germinating energy of festuca rubra under 5% and 15% pollution was on the level of control sample (65%), under the 20% concentration of the solution this value was 60%.

Poa pratensis showed more stable properties to pollution in comparison with bromopsis inermis. Bromopsis inermis had the lowest emergence rate in comparison to control sample. Under 5-10% concentration of drill fluid, emergence rate of bromopsis inermis decreased, concentration 20% has statistically significant influence on the growth of seeds of this culture, emergence rate made up 50%. The studies have shown that value of emergence in festuca rubra under the concentration of 5 and 10% were 70% ND 75% correspondingly.

Laboratory tests allow us to make conclusion about the possibility of selection and use of growth as cultures-phytomeliorants under small material consumption.

For better visual representation of received data there were made diagrams reflecting dependency of energy of germinating and emergence of seeds on drill fluid concentration (figure 1, 2, 3, 4, 5, 6). Intensity of this dependency is determined with a help of correlation factor ( $r$ ) - dimensionless number measured within limits  $-1 < r < +1$ . Under  $r=0$ , linear connection there is no relationship, under  $r=\pm 1$ , correlation relationship turns into functional one. Under positive value of  $r$ , the relationship is direct, under the negative value of  $r$  the relationship is reverse.

Influence of drill fluid concentration on the germinating energy and the emergence of poa pratensis is presented in figure 1.

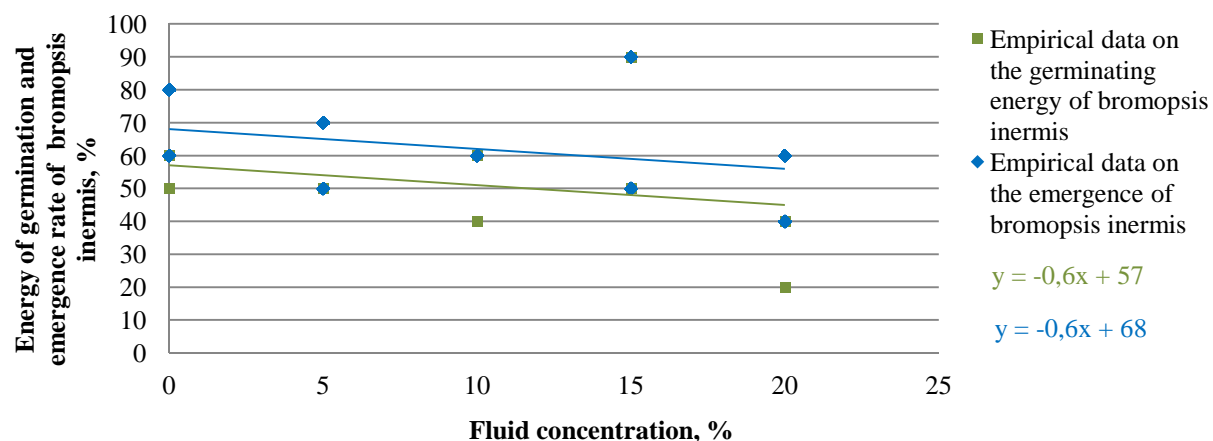


**Figure 1.** Influence of drill fluid concentration on the germinating energy and the emergence of poa pratensis

Correlation factor in dependency on drill fluid concentration (5,10,15,20%) to the germinating energy of poa pratensis was  $r = -0.478$  – reverse relationship.

Correlation factor in dependency on the content of drill fluid (5,10,15,20%) to the emergency rate of seeds was  $r = -0,887$  – strong reverse relationship.

Influence of drill fluid concentration of the germinating energy and the emergence of bromopsis inermis is presented in figure 2.

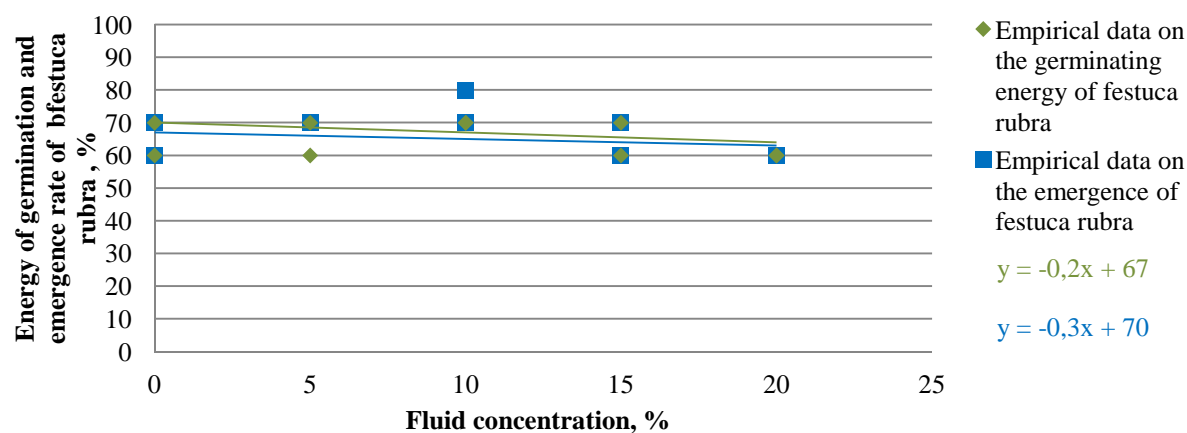


**Figure 2.** Influence of drill fluid concentration on the germinating energy and the emergence of bromopsis inermis

Correlation factor in dependency on drill fluid concentration (5,10,15,20%) to the germinating energy was  $r = -0,316$  – reverse average relationship.

Correlation factor in dependency on the content of waste drilling mud (5,10,15,20%) to the emergence made up  $r = -0,316$  – reverse average relationship.

Influence of waste drilling mud concentration on the germinating energy and the emergence of festuca rubra is presented in figure 3.



**Figure 3.** Influence of waste drilling mud concentration on the germinating energy and the emergence of festuca rubra

Correlation factor in dependency on the content of waste drilling mud (5,10,15,20%) to the germinating energy made up  $r = -0,632$  – reverse average relationship.

Correlation factor in dependency on the content of drilling mud (5,10,15,20%) to the emergence made up  $r = -0,800$  – strong reverse relationship.

The diagrams show that during the increase of drill fluid concentration, oppression of plant seeds takes place, i.e., germinating energy and emergence rate decrease. Bromopsis inermis is the most resistant to the toxic effect of drill fluid.

Important condition for carrying out of works on biological recultivation is assessment of bore mud state, including potentially dangerous, toxic and polluting substances.

When adding phosphogypsum into the bore mud, level of pH decreases from alkaline (10.5 U) to alkaline

7.6 U, decrease of pH is connected with the influence of acidity of phosphogypsum and neutralization of the bore mud. When adding phosphogypsum, sand, sorbent and humic formulation «Rostok» there was observed the lowest value pH – 7.6.

Oil products concentration in the sample of the bore mud was 2386.67 mg/kg. Values of oil products in the meliorated bore mud varied from 2370.06 to 2386.09 mg/kg. During adding of sand in the volume 0.2 in comparison to the mass of the bore mud, oil products concentration was 1546.96-1556.30 mg/kg. Laboratory researches on adding of sorbent to the bore mud, have shown that the degree of decomposition of oil hydrocarbons in the tests with its use (temperature  $T=20^{\circ}\text{C}$ , isolation 45 days) was 90%.

Concentration of chloride ions and sulphate ions in meliorated bore mud was  $70\pm 7$  and  $456\pm 46$  correspondingly. Decrease of these indices takes place at the expense of the replacement of cations  $\text{Na}^+$  to the cations  $\text{Ca}^{2+}$ , that contributes to the formation of water-stable structure with good filterability.

Results of the variants of biological recultivation of the bore mud are presented in table 3.

**Table 3.** Results of influence of bore mud recultivation variants on the plants-phytomeliorants

№	Variants	Names of cultures-phytomeliorants					
		Poa pratensis		Bromopsis inermis		Festuca rubra	
		Number of species, 5 p	Height of overground sprouts, cm	Number of species, 5 p	Height of overground sprouts, cm	Number of species, 5 p	Height of overground sprouts, cm
1	Bore mud (Control)	3	2.7	1	7.6	-	6.5
2	Bore mud + phosphogypsum	3	3.2	-	8.2	1	6.8
3	Bore mud + phosphogypsum + humic formulation «Rostok».	4	3.5	4	8.4	5	7.6
4	Bore mud + phosphogypsum + sand + humic formulation «Rostok»	5	3.9	3	9.8	2	8.3
5	Bore mud + phosphogypsum + sand + sorbent + humic formulation «Rostok»	5	4.3	5	10.7	4	9.6

When adding phosphogypsum, sand, sorbent and humic formulation «Rostok» into the bore mud, it has shown good emergence of cultures-phytomeliorants in comparison with other variants (93,3%). 100% emergence was observed in poa pratensis with height of overground sprouts 4.3 cm and bromopsis inermis with height of overground sprouts 10.7 cm. Under the same variant, emergence of festuca rubra was 80% with height of overground sprouts 9.6 cm.

#### 4. Conclusion

With the increase of concentration of waste drilling mud (15%, 20%), oppression of plant seeds takes place, germinating energy and emergence decrease. Depending on the content of drill fluid, the emergence and germinating energy of bromopsis inermis reverse average correlation relationship was observed, therefore, it can be concluded that it is more resistant to toxic influence of the drill fluid.

Adding phosphogypsum improves chemical and physical-chemical properties of the bore mud and provides conditions of seeds germination, growth and development of plants. Use of sorbent and humic formulation «Rostok» favorably influence plants development. At the same time, formation of viable phytocenosis with high values of phytomasses of vegetative overground sprouts is  $897.4-1162.8 \text{ g/m}^2$  (raw materials).

Use of sorbent in the process of utilization of the bore mud has shown that concentration of oil products in the ground made up 198.0-219.0 mg/kg.

Possibility of use of the presented technology for utilization of the bore mud under pit and no-pit methods of drilling with the following use of ground for recultivation of mud pits and the adjacent industrial and auxiliary

infrastructure disturbed soils of temporary and permanent draw-off with carrying out of biological stage of recultivation.

## References

- [1] Belov P S, Golubeva I A, Nizova S A 1991 *Ecology of production of chemical products from hydrocarbons of oil and gas. Textbook for universities*. (M.: Chemistry) p 256
- [2] Belov P S, Golubeva I A, Nizova S A 1991 *Ecology of manufacture of chemical products from carbons of oil and gas. Textbook for universities*. (M.: Chemistry) p 256
- [3] Ahmetshin M A, Andreeva N N, Pinyagin U P 1995 *Ways and means of achievement of balanced ecologically-economic development in oil regions of Western Siberia*. (Nizhnevartovsk.: Uralskiy rabochiy) p 62-63
- [4] Balaba V I, Kolesov A I, Konovalov E A 2001 *Ser. Safety of man and environment in gas industry*. (Moscow, IRC «Gazprom») p 32
- [5] Golubev E V, Soromotin A V 2010 Content and properties of drilling cuttings of Western Siberia *World of science, culture, education* **6-2** 319-320
- [6] Ryadinskiy V U, Soromotin A V, Deneko U V 2004 Content and properties of drilling cuttings of Western Siberia *TGU* **3** 51-55
- [7] Ryadinskiy V U 2006 Phase and granulometric content of drilling cuttings *Messenger of Tumen State University. Social-economic and legal researches* **3** 36-42
- [8] Yagofarova G G, Barahnina V B 2006 Utilization of ecologically dangerous drilling cuttings *Oil and Gas Engineering*. **2** 48-61
- [9] Skipin L N, Petuhova V S, Kustysheva I N 2015 Results of elements of technologies of biological recultivation of the bore mud. *Collection of materials of XV research and practice conference of young scientists, post-graduate students, applicants and undergraduates of TumGASU* 11-116
- [10] Skipin L N, Galamov A A, Gaevaya E V, Zakharova E V 2014 Technogenic influence of mud pits on the environment of the isle Yamal *Messenger of Krasnoyarsk State agrarian university* **11** 146-150
- [11] Skipin L, Petukhova V, Gaevaya E, Zakharova E, Mitrikovskiy A 2016 Comparative effect of different coagulants on physical properties of drill cuttings *Solid State Phenomena* **871** 233-241
- [12] Uzbekov F M, Motovilova L V, Mohov A E, Sokolov C A 2003 Detoxication of waste drilling muds and bore muds and their utilization as ameliorants under recultivation of disturbed soils *Protection of the environment in oil and gas complex*. **5** 15-18
- [13] Bulatov A I, Makarenko P P, Shemetov V U 1997 Protection of the environment in oil and gas industry. (Moscow, Nedra) p 483
- [14] Lushpeeva O A 2000 Complex of technological events directed at the decrease of the process of wells building on the environment. *State, problems, main spheres of development of oil industry in XXI century. Well boring: Conference report*. **III** 15-20
- [15] National Standard 17.4.4.02-84 1984 «Protection of the environment. Soil. Methods of selection and preparation of samples for chemical, bacteriological, helminthological analysis». (Moscow: Gosstandart)
- [16] National Standard 26425-85 1985 «Soils. Methods of determination of chloride ion in water extract». (Moscow: Ministry of agriculture of USSR)
- [17] FEDERAL ENVIRONMENTAL REGULATORY DOCUMENTS 16.1:2.21-98. «Quantitative chemical analysis of soils. Method of measurement of mass share of oil products in samples of soils and grounds by fluometric method using fluid analyzer «Fluorat-02»».
- [18] National Standard 12038-84 1984 «Seeds of agriculture cultures. Methods of emergence determination». (Moscow: Ministry of agriculture of USSR)