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The Environmental Impact of Drilling Sludge and Ways of Their Utilization

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ABSTRACT
Drilling sludge formed in the process of drilling wells using a drilling agent on a hydrocarbon basis looks like soft pasty mass of black color, with a distinct smell of petroleum products. Oil-based drill sludge has a high oil and chloride ions content, identified excessive concentrations of chromium 2.67 times. According to the degree of accumulation of heavy metals, that were distributed in the following order: manganese (Mn) > zinc (Zn) > copper (Cu) > chromium (Cr) > lead (Pb) > cobalt (Co) > arsenic (As) > mercury (Hg) > cadmium (Cd). The results of the particle size distribution indicate a significant proportion of physical clay, which peaks for the silt fraction – 63.60 %. During the study of the waste drilling agent was found that it includes oil products which reached level of 9000 mg/kg, while the hydrogen index refers to a neutral medium – 6.5 pH. The evaluation of the toxic effect of drilling waste according to the test-results has an acute toxic effect on the environment (hazard class IV). The significance of the research indicates the relevance of environmental assessment of drilling waste for the optimal choice of their subsequent disposal.

Keywords: drilling sludge, petroleum products, industrial waste, hydrocarbon-based solution, toxicity, neutralization.

INTRODUCTION

The oil industry is characterized by an intensive impact on the environment, which inevitably causes its change. In the process of production, the existing environmental condition in the areas of industrial facilities is completely or partially violated. These changes are manifested in various combinations of negative phenomena, the most important of which are: the removal of forest land for the placement of objects; depletion and pollution of groundwater and surface water; flooding and waterlogging of worked areas; dehydration and salinization of soils; pollution by harmful substances and chemical elements of atmospheric air; hydrogeological and geochemical changes unfavorable for local ecological systems [Timofeeva S.S. 2018].

Oil and oil products as pollutants of subsoil and environment are evaluated mainly by the degree of toxicity and geochemical stability. When these petroleum products get into the soil, they downward under the influence of gravitational forces and spread in breadth under the action of surface and capillary forces. The speed of oil movement depends on its properties, soil properties and the ratio of oil, air and water in a multiphase moving system. Oil entering the soil, causing significant and sometimes irreversible changes: the formation of bituminous and saline, hydronization, cementation, etc. [Ryazanov. 2015, Golubev and Soromotin. 2010]

In the process of drilling oil wells there is consistent destruction of rocks, mainly drilling tools, followed by removal of the products of destruction with drilling agent. However, the removal of drilled rock (drill cuttings) is not the only purpose of drilling agent. In this connection, different solutions are used, different composition, properties and scope.

Currently, the practice of drilling with hydrocarbon-based solutions is increasing, used in drilling wells with complex profiles, providing stabilization of unstable, swelling or expanding rocks in the water environment, low accident rate during drilling.

The main technical construction of the accumulation of these types of waste is a slurry barn. A sludge barn is a construction as a part of a well pad intended for centralized collection of oil well drilling waste (drilling mud, waste drilling agent and drilling waste water) in order to prevent the ingress of harmful substances into the environment. Sludge barns occupy an area of up to 2500 m^2 with one drilling rig and have a different volume depending on the number of wells on the bush, depth and duration of drilling [Gaevaya et al. 2017a, Skipin et al. 2014].

The main types of impact on the objects of the environment during the accumulation and placement of drilling cuttings in slurry barns are: direct impact associated with the «alienation» of land; penetration of the liquid phase of drilling waste into the soil, with poor waterproofing of slurry barns or the flow of the liquid phase of drilling through the top of the embankment; change in relief and violation of the component structure of landscapes associated with the padding of slurry barns; violation of the micro relief, surface runoff; deformation of the soil and vegetation cover; destruction of the vegetation cover; groundwater pollution; changes in the existing hydrological conditions due to drainage [Skipin et al. 2015].

To date, one of the methods of disposal of drill slurries on a hydrocarbon basis is neutralization with the use of installations such as UZG-1M or their analogues. This method consists of the thermal disposal of sludge at a temperature of 800–900 ˚C to obtain secondary products. The neutralizing effect while drilling slurries utilization is reached due to oil products evaporation (burning out); vapour of oil products burns and nonflammable inert materials (components) in the form of sand, soil are released. Sand, neutralized soil as building material is used in reclamation and construction works.

The disadvantages of this method are: additional removal of the territory for placing the plant for neutralization; air pollution with exhaust gases; additional introduction of clean soil into the drilling wastes in order to ensure its greater density and improve the operation of the installation.

This article presents the analysis of drilling waste – liquid phase (waste drilling agent) and solid phase (drilling mud), which are the products of transformation of mining with the use of hydrocarbon-based drilling agent [Tarasova et al. 2017]. Liquid waste is a colloidal system based on hydrocarbons where solid particles of drilled rock and other organic compounds that are part of drilling fluids are suspended. Drilling sludge formed in the process of drilling wells, using hydrocarbon-based drilling fluid, is soft pasty mass of black color, with a distinct smell of petroleum products [Tarasova et al. 2018]. Drilling cuttings have negative water-physical properties: complete structureless, low aeration, weak filtration capacity, etc. [Gaevaya et al. 2017b, Skipin et al. 2016a]. This direction in the field of waste management of drilling on a hydrocarbon basis is poorly studied, and therefore the question arises about the choice of methods for handling these types of waste.

In this regard, the purpose of the research was the environmental assessment of drilling waste on a hydrocarbon basis for the development of nature-saving technology aimed at minimizing the negative effects on the environment.

MATERIAL AND METHODS

In the course of the study, tests were carried out on the basis of the laboratory of the Department of Technosphere safety of the Industrial University of Tyumen, an accredited testing laboratory, in accordance with the methods included in the state register of quantitative chemical analysis techniques.

To determine the compliance of drill cuttings samples to the soil variety the laboratory tests were carried out using a laser particle analyzer «Analysette 222» Micro Tec Plus.

The concentration of heavy metals in the samples of drilling mud and spent drilling mud was determined by the following methods: atomic absorption spectrophotometry, inversion voltammetry, flame atomic absorption spectrometry [Federal environmental regulatory documents 31–11/05. 2005, Federal environmental regulatory documents F 16.1:2.2:2.3.36–02. 2002, Federal environmental regulatory documents 16.1:2.3:3.10–98. 1998].

Determination of hazard classes of the test objects was carried out to assess the intensity of acute toxic effects on biological test objects Daphnia magma Straus and Chlorella vulgaris Beijer [Federal environmental regulatory documents 14.1:2:4.12–06. 2006, Federal environmental regulatory documents 14.1:2:3:4.10–04. 2004].

RESULTS

According to the obtained particle size distribution of drill slurries, is presented in Figure 1, there was a prevalence of fine dust and silt fraction, which allowed to identify the slurry to the gradation of the clay heavy [National Standard 25100. 2011].

A significant proportion of physical clay accounts for the silt fraction – 63.60%, a high content of silt fraction (particle diameter less than 0.001 mm) are typical for the alluvial horizon. The agent content of the mud fraction in the drill cuttings is due to the drilled rock and the hydrocarbon-based drilling agent used.

In the composition of the drill cuttings oil-based notes increased chromium content of 2.67 times in compare with maximum concentration limit (roughly allowable concentration) for soil clay groups. It is well-known that chemical contamination of soils with heavy metals is the most dangerous type of degradation of soil cover, since the self-cleaning ability of soils from heavy metals is minimal, soils accumulate them firmly [State regulatory 2.1.7.2511.2009, Public health regulations 42–128–4433–87. 1988]. Thus, the soil becomes one of the most important geochemical barriers for the majority of toxicants on the way of their migration from the atmosphere to the ground and surface waters. In this aspect, chromium is the brightest representative of this group of chemical elements, the migration characteristics of which, the ability to bioaccumulate and biomagnify are not only the basis of the characteristics of the xenobiotic profile of biogeocenosis, but, also, determine the picture of chronic (delayed) and acute toxic effects.

The cadmium content was at the level of the established maximum permissible concentration (MPC) and corresponded to 5 mg/kg. The maximum value was observed for manganese and amounted to 332 mg/kg, which did not exceed the maximum permissible concentrations for this element. The content of other heavy metals was below the established standards. By the degree of accumulation of heavy metals in descending order were distributed in the following sequence: manganese (Mn) > zinc (Zn) > copper (Cu) > chromium (Cr) > lead (Pb) > cobalt (Co) > arsenic (As) > mercury (Hg) > cadmium (Cd) (Table 1).

In the study of the effect of drilling fluids on hydrocarbon-based components of the natural environment, chemical and analytical tests were carried out to characterize the possible negative impact on the environment. The content of gross forms of the heavy metals in the sample of drilling mud is presented in Table 2.

The concentration of the heavy metals in most variants was below the limit of detection of existing techniques. Arsenic average values were 1.9 mg/kg, chromium – 22 mg/kg and zinc – 35 mg/kg. There is no regulatory document for the definition of MAC of this type of drilling waste and, therefore, it is not possible to assess the level of pollution with heavy metals.

In determining the chemistry of salinity drilling waste by anionic composition – are chloride salinity. The content of oil products in drilling sludge and drilling mud are 1800 and 9000 mg/kg,

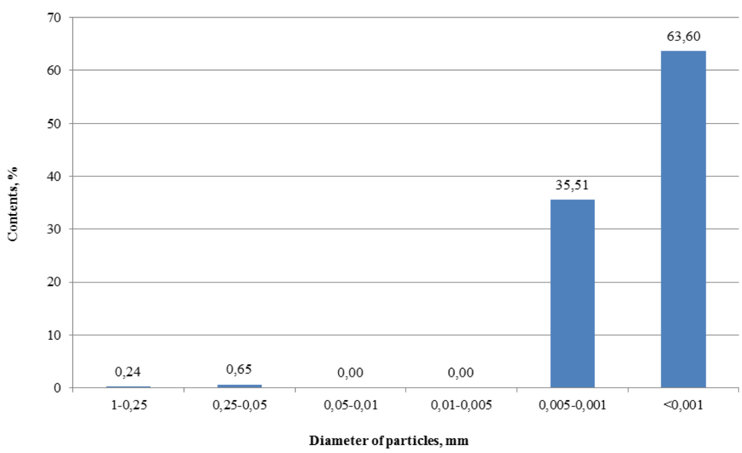

Fig. 1. Particle size distribution of drill slurries

Table 1. Content of gross forms of heavy metals in drill cuttings samples

Indicator	Unit	Test results, mg/kg	Maximum permissible concentration, mg/kg
Cadmium	mg/kg	<0.10	2.00
Cobalt	mg/kg	<5.00	5.00
Manganese	mg/kg	332.00	1500.00
Copper	mg/kg	23.00	132.00
Arsenic	mg/kg	2.87	10.00
Nickel	mg/kg	<50.00	80.00
Mercury	mg/kg	0.24	2.10
Lead	mg/kg	<10.00	130.00
Chromium	mg/kg	16.00	6.00
Zinc	mg/kg	29.00	220.00

Table 2. The content of gross forms of heavy metals in the sample of drilling fluid

Indicator	Unit	Test-results. mg/kg
Cadmium	mg/kg	<0.1
Cobalt	mg/kg	<5.0
Manganese	mg/kg	<200
Copper	mg/kg	<20
Arsenic	mg/kg	1.90
Nickel	mg/kg	<50
Mercury	mg/kg	<0.10
Lead	mg/kg	<10
Chromium	mg/kg	22
Zinc	mg/kg	35

Table 3. Chemical analysis of drilling wastes

Indicator	Unit	Object of research	
		Drilling sludge	Drilling mud
Petroleum products	mg/kg	1800	9000
Sulfate-ion (water-soluble form of anions)	mg/kg	140	25
Phosphate-ion (water-soluble form of anions)	mg/kg	<3.0	4.10
Chloride-ion (water-soluble form of anions)	mg/kg	4049	1734
Hydrogen index	unit of pH	7.31	6.5

respectively. The pH value refers to the neutral environment and amounted to 7.31 pH units, of 6.5 pH units, respectively (Table 3). The degree of toxic effects of drilling waste on the components of the environment, due to the high content of petroleum products and salts (Table 4).

CONCLUSIONS

At present, the issue of development of non-waste and low-waste, environmentally-friendly technologies for disposal of drilling waste (drilling sludge) based on physical and chemical methods by introducing natural mineral components (sorbents) with a high sorption capacity in relation to petroleum products and heavy metals is acute.

The results of studies of drilling waste on a hydrocarbon basis indicate an increased content of petroleum products and chloride ions, belong to the IV class of danger and have an acute toxic effect on the environment. The significance of these studies shows the relevance of environmental assessment of drilling waste for the optimal choice of their subsequent disposal.

Table 4. Evaluation of the toxic effect of samples of drill sludge and drilling mud spent on test-objects

Object of research	Test-object	Dilution factor. times	Evaluation of the test sample	Hazard class to the environment
Drilling sludge	*Daphnia magna Straus*	6.30 (The harmless factor of dilution) 1.00 (Average lethal dilution factor)	An acute toxic effect	IV
	Chlorella vulgaris Beijer	12.53		
Waste drilling agent	*Daphnia magna Straus*	31.60 (The harmless factor of dilution) 2.40 (Average lethal dilution factor)	An acute toxic effect	IV
	Chlorella vulgaris Beijer	15.49		

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