Study of change of hydrophysical properties of bore mud in process of its utilization into man-induced soil

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Abstract. The article considers the results of studies of the chemical and granulometric content and the factor of bore mud filtration in the process of its utilization. When the phosphogypsum is added, hydrophysical properties of the bore mud improve. At the same time, gradation of soil from the water-proof to weakly permeable takes place. This phenomenon is connected with recovery of filterability at the expense of ion-exchange reaction and a decrease of the silt fraction content in the bore mud. During the adding of phosphogypsum in the bore mud, pH decreased and made up 7.6-7.8 U. The decrease of the concentration of chloride-ions and sulphate-ions took place at the expense of replacement of Na^+ by cations of Ca^{2+} that contributed to the formation of the water-stable structure with good filterability. The content of total forms of heavy metals in man-induced soil was lower than MAC (APC) for the loams. Man-induced soil has a V class of danger for the surrounding environment.

1. Introduction

The process of wells construction is accompanied by application of materials and chemical reagents in a different degree of ecological danger [1]. During the hole drilling, the drilling fluid is used, which is necessary for removal of detrital products of rocks from the pit-face, cooling rock cutting tools, prevention and liquidation of complications, tailing-in. Completion fluid is additionally used for washing thread connections of drill pipes, for cleaning screens and also during washing equipment and production sites [2].

For the conditions of Western Siberia, 1 meter of mining gives from 0.2 to 0.6 m^3 of drilling cuttings. The lower index belongs to the technology with a larger degree of mud return after cleaning. For the wells with the depth of 2000 m, the volume of drilling cuttings for Western Siberia on average makes up 500 m^3 [3].

The bore muds used in the process of holes drilling can be used during the drilling of intervals for every production string and can have different content. Water content varies from 71 to 87%, content of aqua-gels, used as viscosifying agents, varies from 4 to 15%. The remaining part includes chemical reagents, intended for prevention of hydration process of clay rocks, improvement of rheological properties, control and stabilization of alkalinity, regulation of fluid loss, colmatation and weighting of the bore mud, improvement of stability of hole walls, hydrophobization of clays. The use of different components, included into the content of the bore mud, directly influences the properties of drilled rock which in the process of drilling is transformed into the bore mud [4]-[6].

Drilling cuttings are the colloidal solution of particles of clay, sand, chemical reagents and oil in water. pH, as a rule, corresponds to the alkaline condition and makes up 8.5-10.5. Among chemical compounds, drilling cuttings contain water (20-50%), oxides: silicon (40-60%), aluminum (10-20%), carbon (7-9%), iron (5-8%), calcium (2-5%), magnesium (1,5-3%), sodium (0.5-1%), potassium (0.4-2%), boron (0.3-0.5%), phosphorus (0,03-0,05%), manganese (0.03-0.1%) and other abovementioned elements, their sulphates and chlorides. In the content of drilling cuttings, amount of oil and oil products reaches 5%, surface-active reagent – 0.5% [7].

The bore mud is mass which can be from fluid to low-plastic, from black to light-grey, depending on the depth of mining with inclusion of various diameter, by characteristic's it's related to light loam or light clay. The bore muds have negative hydrophysical properties: total ash structure, low airing, low filterability etc. [8]-[10]

2. Materials and Methods

Within the framework of the current trial, sampling of the bore mud was carried out on the territory of cluster sites of Pokachevskoe and Urievskoe fields in KhMAD-Ugra according to the reference documents [11]. Studies of the samples of the bore mud and received man-induced soil for the determination of granulometric content and coefficient of permeability were carried out on the base of accredited analytical laboratory JSC «RAC», laboratory of physics, chemistry and mechanics of frozen soils and laboratory of the department of technosphere safety, according to the methods determined by GOST [12].

Analysis of samples on the content of oil products was carried out using fluid analyzer «Fluorat-02-2M» according to the method of Federal environmental regulatory documents 16.1:2.21 [13]. The chloride and sulfate ions were determined in accordance with GOST 26425 and GOST 26426, respectively [14], [15]. Determination of the content of cadmium, lead, zinc and copper in drilling muds was carried out according to the methods of MU 08-47 / 152 «Soil. Method for performing measurements of mass concentrations of cadmium, lead, zinc and copper by inversion voltammetry» [16].

The determination of arsenic was carried out in accordance with methodology guidelines 31-11/05 (methodology guidelines 31-11 / 05 Determination of zinc, cadmium, lead, copper, manganese, arsenic, iron and mercury in the soil) [17]. The determination of the mass fraction of total mercury was carried out on the mercury analyzer RA-915 + with the prefix RP-91C, in accordance with the technique of Federal environmental regulatory documents 16.1: 2.23 [18].

3. Results

Presence of sodium, stipulated by the presence of component of the control pH in the drilling fluids - caustic soda in the absorbed complex of the bore mud intensifies dispersion of colloid particles. This condition is accompanied by the series of negative physical properties of the bore mud: high water susceptibility, overcrust during the moistening and weighting of granulometric content [19].

In case of adding of ameliorant – phosphogypsum, cations of Na^+, rendering state of sol to the bore mud, are replaced to the cations Ca^{2+}, contributing to amelioration and formation of water-stable structure with increasing of filterability.

$$[\text{Bore mud}]_{Na}^{Na} + CaSO_4 = [\text{Bore mud}]Ca + Na_2SO_4$$

Decrease of the content of silt fraction takes place at the expense of diluting of volume of the bore mud by the specific weight of the waste of industrial production – phosphogypsum.

The results of studies of granulometric content of the bore mud using phosphogypsum, sorbent, sand and peat are presented in Table 1.

Table1.

Table1. Results of changes of granulometric content

№	Variant	Diameter of particles, mm*							Soil
		1-	0.25-	0.05-	0.01-	0.005-	<0.001	<0.01	characteristi

		0.25	0.05	0.01	0.005	0.001			cs
		Content, %							
		Pokachevskoe field							
1.1	Bore mud (control)	1.14	24.02	53.02	7.21	11.8	2.81	21.82	Light loam
1.2	Bore mud + phosphogypsum	4.35	21.06	54.02	9.1	9.42	2.05	20.57	Light loam
1.3	Bore mud + phosphogypsum + sorbent + sand	5.37	16.03	58.04	9.07	9.53	1.96	20.56	Light loam
1.4	Bore mud + phosphogypsum + sorbent + sand + peat	1.49	22.94	55.53	9.33	8.89	1.82	20.04	Light loam
		Urievskoe field							
2.1	Bore mud (control)	0.05	0.02	49.24	2.01	35.45	13.23	50.69	Light clay
2.2	Bore mud + phosphogypsum	0.02	0.02	49.98	2.75	35.5	11.73	49.98	Heavy loam
2.3	Bore mud + phosphogypsum + sorbent + sand	0.01	0.06	57.04	4.5	28.97	9.42	42.89	Heavy loam
2.4	Bore mud + phosphogypsum + sorbent + sand + peat	3.6	15.86	42.0	7.92	25.41	5.21	38.54	Medium loam

* - classification of the mechanical elements of soils according to N.A. Kachinskiy

In the bore mud (control) by the example of Pokachevskoe field, the content of fractions of the physical sand made up 78.18% that allows relating it to the light loam according to the table B.17 GOST 25100. The mass share of the silt fraction was at the level of 2.81 % [20].

In the control variant (drill cuttings) of the Urievskoe deposit, the content of the physical sand fraction is 49.3% by weight, which characterizes it as light clay. A significant portion of physical clay falls on the silt fraction - 13.23%.

A high content of clay fraction (particle diameter less than 0.001 mm) is characteristic of the illuvial horizon. In connection with the increased content of organic colloids (humus) in the fraction, it exhibits the greatest sorption ability, which indicates to a high physicochemical absorption capacity and, as a result, has negative physical and chemical properties.

In the bore mud, the content of the clay fraction is stipulated by the cuttings and the used drilling mud.

When phosphogypsum, sorbent, sand and peat were introduced into the drill cuttings of the Urievskoe deposit, gradation of the granulometric composition from clay to medium loam was observed, due to an increase in the physical sand content by 24.64% and a decrease in physical clay by 23.97%.

The results of the determinations of the coefficient and time of filtration are reflected in Figures 1 and 2.

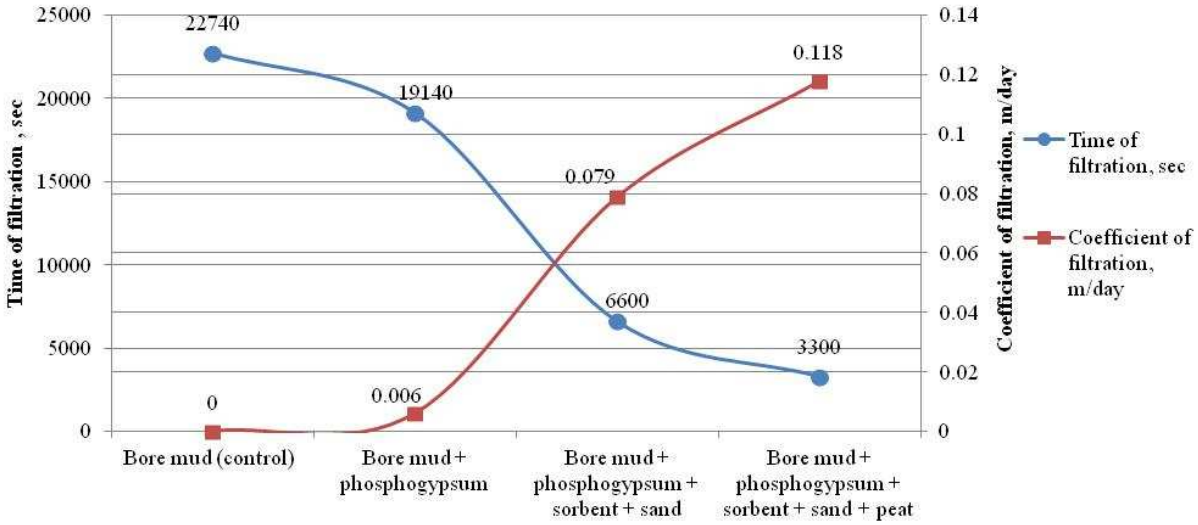

Figure 1. Coefficient and time of filtration of bore mud of Pokachevskoe field

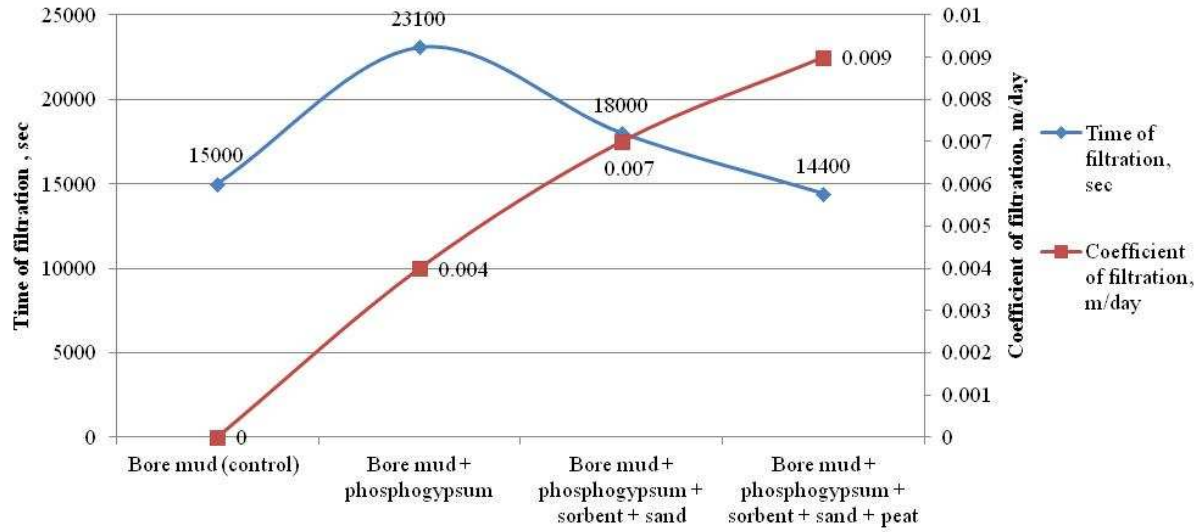

Figure 2. Coefficient and time of filtration of bore mud of Urievskoe field

The coefficients of filtration in the control variants of the drilling cuttings of the Pokachovkoe and Urievskoe fields are close to zero, i.e. there was no filtration, which in accordance with Table B.7 GOST 25100 refers to watertight soils [7].

The change in water permeability of the drilling mud at the Pokachevskoe deposit occurs in the second variant, due to the introduction of phosphogypsum, which is converted from waterproof to slightly waterproof, in contrast to the drilling mud of the Urievskoye field of the same variant. This is explained by the fact that a sample of drilling cuttings from the Urievskoe deposit belongs to a variety of light clays, with a prevalence of physical clay of 28.87% more relative to the drilling mud of the Pokachevskoe deposit. The change in the filtration capacity of the drill cuttings in the Urievskoe deposit occurs with the addition of phosphogypsum, sorbent and sand, while the filtration coefficient is 0.007 m/day and allows the technogenic soil to be classified as slightly water-permeable.

The highest filtration coefficient was observed in the latter variant, where phosphogypsum, sorbent, sand, peat were applied in the drilling mud of the Pokachevskoe and Urievskoe deposits, and amounted to 0.118 and 0.009 m/day, respectively.

During the disposal of drill cuttings, chemical and analytical studies of drilling cuttings and man-

induced soil, as well as industrial waste (phosphogypsum), were carried out.

Research of wastes of industrial production (phosphogypsum) was performed in an accredited analytical laboratory. The results of studies of phosphogypsum showed that the hydrogen index was 5.87 units (weakly acid medium), the content of gross forms of heavy metals (cadmium, cobalt, copper, nickel, lead, chromium, zinc, mercury) was below the detection threshold of methods determined by GOST. The concentration of arsenic in phosphogypsum was 0.58 mg/kg. The specific effective activity of natural radionuclides was 64.1 Bq/kg.

The content of total forms of heavy metals was below the MAC (APC) for light loam. The highest concentration was typical for arsenic in the Pokachevskoye field and was 4.29 ± 1.37 mg/kg, the lowest for mercury (0.0005 mg/ kg).

The content of heavy metals in drilling cuttings and man-induced soil (Urievskoye deposit) varied widely. The maximum concentration was observed in copper, with the introduction of components in drilling cuttings (36.67 mg/kg), content of this element was slightly reduced (35.06 mg/kg).

When phosphogypsum was introduced into the drilling mud, the hydrogen index was 7.6-7.8 units, in the control sample - 10.5 units. (Pokachevskoye field) and 11.0 (Urievskoye field). The introduction of the sorbent indicated its high sorption capacity in relation to oil hydrocarbons (exposure 45 days), the concentration of oil products was 116.83-138.67 mg/kg.

Reduction in the concentration of chloride ions and sulfate ions takes place at the expense of substitution of cations Na^+ for cations Ca^{2+}, which contributes to the formation of a water-resistant structure with a good filtration capacity. When phosphogypsum is introduced into the drilling mud, the hazard class for the environment is reduced from IV to V.

4. Conclusion

Negative hydrophysical properties reduce due to the introduction of waste of industrial production – phosphogypsum; aggregation and increase of filtration properties of man-induced soils take place. Due to additionally introduced components such as sorbent, sand and peat, the fraction of physical clay is diluted and the physical sand content is increased relative to the sample mass. When phosphogypsum, sorbent, sand and peat were introduced into the drilling cuttings, gradation of the granulometric composition from clay to medium loam was observed, due to the increase in the physical sand content by 24.64% and a decrease in physical clay by 23.97%. The change in the filtration capacity of drilling cuttings occurs with the addition of phosphogypsum, sorbent and sand, with a filtration factor of 0.007 m/day and allows the man-induced soil to be classified as weakly water-permeable.

The content of total forms of heavy metals in man-induced soil was below the MAC (APC) for clay loams. When phosphogypsum was introduced into the mud, the hydrogen index decreased and amounted to 7.6-7.8 units, while in the control sample there was 10.5 units. (Pokachevskoye field) and 11.0 (Urievskoye field). The introduction of the sorbent indicated its high sorption capacity in relation to hydrocarbons of oil, the concentration of oil products was 116.83-138.67 mg/kg.

Reduction in the concentration of chloride ions and sulfate ions is due to the substitution of cations $Na^+$for cations Ca^{2+}, which contributes to the formation of a water-resistant structure with a good filtration capacity. When phosphogypsum is introduced into the drilling mud, the hazard class for the environment reduces from IV to V.

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