Ways of Drilling Wastes Utilization Using Ecologically Safe Materials

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Abstract. Handling of the industrial waste, including drilling waste is still one of the leading fields in the ecology area. The article considers utilization way of the bore mud consisting in application of safe components allowing getting of the ground suitable for the reclamation of disturbed lands. There was revealed that the content of physical clay \(d < 0.01\ mm\) in the control sample (bore mud) is 6.58\%, when applying the mixture of components in the bore mud. The decrease of physical clay is observed in the ground of A type (2 times) and B and C types (3 times). In the same time, in the grounds of all types, hydrophysical properties improve and gelation takes place. Composition of the studied total forms of heavy metals was on the level of maximum allowable concentrations for loam. Manganese concentration in the control sample was in the range from 69 to 93 mg/kg. Water extract from the grounds of all types has very strong influence on the test objects \((Daphnia magna Straus)\), class of hazard for the environment is IV.

1. Introduction
Handling of the industrial waste, including drilling waste is still one of the leading fields in the ecology area. Nowadays the main ways of drilling waste handling are thermal treatment and utilization (solidification, capsulation) with the following obtaining of production.

The accepted technologies of the bore mud utilization, as a rule, provides for the collection, accumulation and/or storage of the drilling waste in mud pits/temporary sectional tanks. However, despite such measures as dike of the mud pits, hydroisolation of their bottom and walls, the reliable protection of environment from the contamination with drilling waste is not provided [1,2].

Drilling waste is a colloidal solution of particles of clay, sand, chemical reagents and oil in water. The pH parameter, as a rule, corresponds to the alkaline medium and is 8.5-10.5. Among chemical compounds, drilling waste contains 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 above-mentioned elements, their sulfates and chlorides. As a part of drilling waste, the content of oil and oil products reaches 5\%, surfactants – 0.5\% [3,4,5,6].

In the process of well drilling the transformation of source raw material in the drilling waste takes place. As the result, liquid phase of the drilling waste forms – bore waste waters and used waste drilling fluid, solid phase – bore mud [7].
The bore muds are the fluid paste-like mass of dark-gray color with metallic tint. It is greasy by touch and has oil smell. Density of the bore mud is determined by the density of the drilling solution and drill cuttings. In the Western Siberia density of the bore mud varies from 1.3 to 2.2 g/cm$^3$[3].

Viscosity (opposite property of the fluidity) is 0.1-4.5 Pa·s. Fluidity increases with the increase of water content and in case of poor solution purification. Dewatered bore muds lose fluidity and ground easily into the powder [3].

The studies of granulometric composition have shown that size of the bore mud particles are from 10 to 500 mkm. Moreover, bigger particles correspond to the drilling cuttings and the small ones to bentonite. PSD curve has two maximums. One maximum corresponds to the particles with a size 20-30 mkm, another one – 200-300 mkm [3].

The main objects of pollution during the well drilling are geological environment (underground waters), hydro-lithosphere (open reservoirs, bottom of water areas, soil and vegetation cover) [8,9,10].

Accumulating in the soil layer, polluting components of drilling fluids lead to the loss of soil fertility: soil de-structuring, emergence or strengthening of erosion processes, decrease in the biological activity of the soil and its ability to self-cleaning. The most dangerous are alkaline mineralized waste muds and drill cuttings, the content of oil and oil products. The migration of toxic salts of components (ions of chlorine, sodium, sulfate ions, hydrogen bicarbonate ions) and oil products, both in vertical and horizontal directions, leads to deterioration of soil properties: the water-air regime of the soil is disturbed, the concentration of soil solution increases, sodium in MAC, microflora is inhibited, which makes the soil unsuitable for plant growth. This leads to the destruction of existing ecosystems on the territory, followed by contamination of adjacent environments [11,12].

Influence of the drilling waste on the natural objects can not only be expressed in toxic effect on the biosphere but also in disturbance of ecological balance of biotypes of different trophic level during their interaction with abiotic environment bearing the mechanism of functional ecosystem damages [13,14].

Nowadays various ways of bore mud utilization are offered based on the application of different technologies which finally lead to the forming of significant number of secondary wastes from the utilized bore muds which are in turn determine the necessity of planning of the independent ways of handling these wastes or to the forming of such production volumes which can’t be in demand and are placed in the environment or require unreasonably high financial costs.

2. Materials and Methods
Source raw material for the soil is bore mud forming:
   a) during the drilling of field wells and easers on the oil and gas deposits using the mud pits;
   b) during the drilling of field wells and easers on the oil and gas deposits using the temporary sludge tanks;
   c) during the drilling of field wells and easers on the oil and gas deposits by pit-free drilling.

The bore mud is mainly solid drilling waste and together with the drilling cuttings it includes all chemical compounds used for the preparation of the drilling fluids.

Materials used for the production of soil should correspond to the requirements of the effective regulatory documents. The choice of components and their number is stipulated by economic expediency, ecological properties of the obtained material and availability of the components.

Materials used for soil production:
- quarry sands, commonly mined in the following ways: hydraulic placement method; dry-powder method.
- astringent: Portland cement.
- aluminosilicate sorbents: glauconite; diatomite.
- meliorating material: gypsum; phosphogypsum.

Components of the soil and their ratio in it are selected in the course of laboratory studies on the basis of the results of chemical-analytical studies of the bore mud samples.
The resulting soil consists of types and includes the following components:

- Soil type A: meliorating material and aluminosilicate sorbents;
- Type B soil: reclaiming material, aluminosilicate sorbents, quarry sand;
- Soil type B: meliorating material, binder, aluminosilicate sorbents, quarry sand.

Laboratory and instrumental studies of the obtained soil during the utilization of the bore mud were carried out in an accredited testing laboratory [15, 16, 17, 18].

3. Results

The bore muds are the fluid paste-like mass of dark-gray color with metallic tint. It is greasy by touch and has mixed smell. Density of the bore mud is determined by the density of the drilling solution, drill cuttings and humidity.

Gross-composition of the bore mud: drilling cuttings – 75-85%; organic substances – 5-10%; water-soluble salts – 5-10%; weighting additives and betonites – 5-10%.

The main component of the bore muds – drilling cutting consists of the clay particles and sand (but in less volume) which determine its mechanical properties. When drying up (about 20% of humidity) the bore mud is solid and firm. During the further drying these pieces crack and disintegrate. Moistening leads to quick softening of pieces or the powder and change of mass into the viscoplastic and later fluid state.

Granulometric composition of the bore mud and obtained soil of different types is in the figure 1.

![Figure 1. Granulometric composition of the bore mud and obtained soil of different types.](image-url)

Content of physical clay ($d < 0.01$ mm) in the control sample (bore mud) is 6.58% when applying the mixture of components to the bore mud, we observe the decrease of physical clay in the type A soils by 2 times and in types B and C soils by 3 times. At the same time hydrophysical properties improve in all types of soils and gelation takes place.

Composition of heavy metals in the samples of bore mud and obtained soil of various types is given in the figure 2.
Figure 2. Composition of heavy metals in the samples of the bore mud and obtained soil of various types.

The content of the studied gross forms of heavy metals was at the level of maximum allowable concentrations for loam. The concentration of manganese in the control sample was 200 mg kg, while the value of this element in the utilized bore mud was in the range from 69 to 93 mg/kg. In the process of utilization of the bore mud, the aluminosilicate sorbent was introduced, which has a high sorption capacity with respect to manganese ions.

The prospect of using the sorbent is conditioned on its adsorption and cation-exchange properties, which allows it to be used to extract various harmful substances from the soil. Essential advantages of the sorbent, as well as some other crystalline aluminosilicates showing molecular sorption and ion exchange properties, are: wide spread occurrence, availability, cheapness, granular structure, heat resistance, radiation stability, an ability to chemically and structurally modify the technological characteristics of the mineral. In addition, this sorbent is characterized by high polyfunctionality.

Degree of toxic action of the bore mud depends on their content and properties which are mainly determined by the drilling cuttings characteristics [19]. The main danger of the drilling cuttings is in high content of hydrocarbons which are contained in the payout beds [20].

During the toxicology test, the representatives of hydrobionts Daphnia magna Straus were used. For the biotesting there was applied water extract from the bore mud samples in ratio 1:10. Criterion of the acute toxicity of the extract from daphnia is the death of 50% and more species testing in the samples in comparison with the control (cultivation water) during the period of 48 hours. By the results of carried out testing and water extract dilution factor the class of hazard of the bore mud was determined (table 1).

The test water extract from the bore mud has an acute toxic effect on the test objects (Daphnia magna Straus). The dilution factor of water extract of the bore mud, in which there is no harmful effect on the test object is up to 46.13 times, class of hazard for the environment – IV. Water extract from all types of soil has an acute toxic effect on the test objects (Daphnia magna Straus), the hazard class for the environment – IV, while the dilution factor of water extract of the bore mud, in which there is no harmful effect on the test object is up to 2, 7 times.
Table 1. Results of the studies of bore mud and soils biotesting.

| Name                  | pH, units, pH | Evaluation of the tested sample          | Water extract dilution factor of the waste at which there is no effect on the testing objects | Class of hazard for the environment |
|-----------------------|---------------|------------------------------------------|---------------------------------------------------------------------------------------------|-------------------------------------|
| Bore mud (control)    | 8.02          | Acute toxicity effect                    | 46.13                                                                                        | IV                                  |
| Soil of the type A    | 7.77          | Acute toxicity effect                    | 2.7                                                                                         | IV                                  |
| Soil of the type B    | 8.01          | Acute toxicity effect                    | 2.7                                                                                         | IV                                  |
| Soil of the type C    | 8.47          | Acute toxicity effect                    | 2.7                                                                                         | IV                                  |

4. Conclusion

The technology is based on the physical-chemical way of drilling wastes utilization by the applying of ecologically safe components directed to the improvement of physical-chemical, hydrophysical and mechanical drilling wastes that will provide decrease of man-induced influence on the natural environment. The soils obtained in the process of bore mud utilization are suitable for reclamation of the adjacent (adjoining) production infrastructure and supporting infrastructure, disturbed lands for temporary and permanent location of oil deposit.

5. References

[1] Uzbekov F M, Motovilova L V, Mokhov A E, Sokolov S A 2003 Detoxification of waste drilling muds and bore muds and their utilization as ameliorants for reclamation of disturbed soils Protection of the environment in oil and gas complex 5 15-18 pp
[2] Gaevaya E V, Bogaychuk Y E, Tarasova S S, Skipin L N, Zakharova E V 2017 Study of change of hydrophysical properties of the bore mud in the process of its utilization into man-induced soil IOP Conf. Series: Earth and Environmental Science vol 87 042004
[3] Golubev E V, Soromotin A V 2010 Composition and properties of drilling waste of Western Siberia World of Science, Culture, Education 6-2 ISSN 1991-5497 319-320 pp
[4] Gaevaya E V, Bogaychuk Y E, Tarasova S S, Skipin L N, Zakharova E V 2017 Utilization of drilling cuttings with extraction of ground for reclamation of disturbed soils IOP Conf.: Series: Earth and Environmental Science vol 87 042003
[5] Ryadinskii V Yu, Soromotin Yu V, Deneko AV 2004 Composition and properties of drilling waste in Western Siberia Tyumen: TGU 3 pp 51-55
[6] Ryadinskii V U 2006 Phase and granulometric content of drilling cuttings Tyumen: TSU 3 pp 36-42
[7] Belov P S, Golubeva IA, Nizova SA 1991 Ecology of production of chemical products from hydrocarbons of oil and gas Moscow: Chemistry p 256
[8] Fedorov O V, Dikunets V N, Zhegalin L P 2010 Reclamation - an incentive for self-cleaning (oil production) Technical supervision p 10
[9] Balaba V I, Kolesov A I, Konovalov EA 2001 Problems of ecological safety of the use of substances and materials in drilling Moscow: RPC Gazprom, Ser., Human and Environmental Protection in the Gas Industry p 32
[10] Lushpeeva OA 2000 A complex of technical and technological measures aimed at reducing the impact of the process of wells building on the environment Status, problems, main directions of the development of the oil industry in the twenty-first century Wells drilling: Coll. of rep., Scientific-practical conference 16 -17 February 2000 Part III pp15-20
[11] Yagofarova G G, Barakhnina V B 2006 Utilization of environmentally hazardous drilling waste Oil and gas case 2 pp 48-61
[12] 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 pp 233-241
[13] Solntseva N P and Pikovskiy Yu N 1980 Peculiarities of soil contamination during the oil production Migration of pollutants in soils and adjacent environments Leningrad: Gidrometeoizdat p 252
[14] Lozanovskaya I N, Orlov DS, Sadovnikova LK 1998 Ecology and Biosphere Protection in conditions of chemical pollution Moscow: Higher School p 287
[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 the USSR
[17] Federal environmental regulatory documents 16.1: 2.21-98 1998 Quantitative chemical analysis of soils Method for measuring the mass of oil in samples of soils and by using the fluorescent method Fluorat-02
[18] National Standard 12038-84 1984 Seeds of agriculture cultures. Methods of emergence determination Moscow: Ministry of Agriculture of the USSR
[19] Maistrenko VN 2004 Ecological and Analytical Monitoring of Persistent Organic Pollutants Moscow: BINOM, Knowledge Laboratory p 323
[20] Kryuchkov V N 2012 Assessment of the impact of drilling wastes on hydrobionts Bulletin of Astrakhan State University, Series: Fisheries 1 pp 61-65