Salvaging of waste drilling muds by means of injection and mechanical ways

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Abstract: Over the past decades, in the process of oil and gas production in Western Siberia, one of the most common methods of salvaging of waste drilling muds is the introduction of cement into the salvaging, followed by agitation by an excavator. This method does not ensure the uniform distribution of any detoxifier preparation and contradicts the logic in the field of excavator application. More than two hundred years, this machine belongs to a group of diggers, not mixers. This article presents modern methods of obtaining homogeneous mixtures, borrowed from the foundations, road and hydraulic engineering.

1. Introduction
The greatest danger for objects of the natural environment is the production and technological waste of drilling in the well construction process, which are accumulated and stored directly on the drilling site. The waste drilling mud is a drilled rock, which is flushed to the surface from the bottom of the well by the drilling mud. The rock separated from the drilling fluid is drill cuttings.

Drilling of wells is carried out mostly in sedimentary deposits, in which clay rocks are the most common. Their share is 65-80%. In their composition they contain a wide range of pollutants of mineral and organic nature, represented by materials and chemical reagents used for the preparation and processing of drilling muds, except from oil, oil products and pollutants of mineral nature.

The mineralogical composition of the waste drilling mud is determined by the lithological composition of the drilled rocks and can change significantly as the well deepens.

The chemical composition of drill cuttings depends on a number of factors: the composition of the drilling fluid, the used drilling mud, the physical and chemical properties of the rock, etc. The main components of the waste drilling mud, which can have a negative effect on the microflora of soils and other environmental objects, are oil, mineral salts (especially chlorides), surfactants and heavy metals.

The share of waste drilling fluids in drilled areas is up to 98%.

Waste drilling muds is an aggregate-stable colloidal system stabilized by reagents - surfactants (sodium carboxy methyl cellulose, rubber composition-2, sulfanole, higher fatty alcohols, etc.); they can vary over a wide range, which greatly complicates their clarification and purifying. The composition of waste drilling mud can contain suspended substances from 2500 to 25000 mg/l, oil and petroleum products from 50 to 150 mg/l and oxidizable organic matter (chemical oxygen demand) from 1000 to 3500 mg/l [2]. Drilling fluids also have a high content of hard metals.

2. Research
The proposed general list of works on the processing of salvaging with waste drilling muds consists of the following stages:

1. Field studies of the salvaging by remote and subsurface vertical exploration and chemical studies;
2. Construction of a technical site and development of measures to ensure local stability of technological machines;
3. Transportation and storage of materials and chemicals;
4. Technological operations for preparation of mixtures of chemical preparations and their introduction, distribution and mixing in the waste drilling mud salvaging;
5. Quality control of obtaining a homogeneous mixture by geo-radar survey and control drilling with sampling for chemical studies;
6. Control monitoring by vertical exploration through the estimated time of toxicity elimination.

3. Results and discussion

3.1. Field studies of waste drilling mud salvaging
The existing methods for studying soil masses are based on the study of cuttings taken during the drilling of wells. Therefore, the reliability of the data depends on the frequency of sampling and chemical analysis. This method does not allow to determine the qualitative and quantitative composition as well as homogeneity of waste drilling mud with a maximum degree of probability and accuracy, which in turn makes it impossible to select effective preparations for toxicity elimination and their dosage.

During the last 15 years geophysical non-destructive methods for studying ground masses have been used in construction practice. Remote and subsurface vertical exploration is one of the most promising geophysical methods (Figure 1). The principle of their action consists in the emission of electromagnetic waves and the analysis of their reflection from various boundaries. And remote vertical exploration to a depth of up to 15 meters can be carried out both with the help of space vehicles and drones. This method allows to organize the search for buried and hidden salvaging locations of waste drilling mud and to determine their approximate qualitative composition. And a subsurface vertical exploration with control sampling gives complete information on the composition of waste drilling mud. The analysis of the dielectric constant of the salvaging massif determines the homogeneity of the waste drilling mud, the location and presence of layers and interlayers as well as the basic physical parameters (Figure 2). This allows to select the optimal and effective methods of production technology, to manage the process of introduction and mixing components, as well as assess the quality of the performed work. For greater reliability, these data are refined based on the results of the control drilling.
Figure 1. Geo-radar survey.

Figure 2. Radargram of the longitudinal section of the waste drilling mud salvaging.
Geo-radar survey is performed in longitudinal and transverse directions. Dimensions of grids depend on the parameters of the salvaging and are from 1 to 5 meters. In the absence of passability on the surface of the salvaging the device moves on a sledge or in a boat at a speed of 1 to 5 km/h. The following parameters and properties of the salvaging product are determined by decoding:

- bundles and lenses in terms of density and mineral component;
- volumetric distribution of moisture,
- leakage of liquid outside the salvaging;
- Density-Moisture-Viscosity-Shear Stability diagrams.

3.2. Construction of a technical site and development of measures to ensure the local stability of technological machines
At this stage, works on the equipping the work site are performed: warehouses, cabins, workshops, personal hygiene equipment, access roads, etc. If there is no provision for accessibility of vehicles, inventory portable shields are installed to move the equipment along the surface of the salvaging.

3.3. Introduction and distribution (mixing) of compounds in the salvaging
The technological part is based on classical solutions from the field of foundation engineering, strengthening of soils in the road sector and hydraulic engineering construction [1]. In Fig. 3 classification processing technologies of waste drilling muds is presented.

3.4. Injection technology.
It is divided in turn into jet and pressure (cup) ones [2]. Currently, in the world and domestic practice, there are many injection methods for introducing chemical reagents and chemicals into soils to change their physical and mechanical properties. Injection technology was patented in 1794 by the French engineer S. Berigny. It is a kind of deep anchoring of soils by injection of treatment or fixing solutions through pre-drilled wells or injectors.

![Figure 3. Classification of processing technology of waste drillin mud.](image-url)
3.5. Jet-grouting technology.
It is based on the use of the energy of a high-pressure jet of a solution at a pressure of 40-100 MPa for the destruction of soil and its simultaneous mixing. The pressure is created by means of a monitor equipped with one or two nozzles through which a solution is fed into the ground in a direction perpendicular to the well axis. Simultaneously with the feeding of the solution, the monitor rotates and it moves along the well. There are three types of jet fastening, determined by the simultaneous use of various components:
- one-component - the jet of chemical solution is applied at a pressure of 40-60 MPa, the radius of the fixing zone in clay soils does not exceed 0.6-0.8 m;
- two-component - the jet of chemical solution is supplied in the air cage, the radius of the treatment zone is up to 3.0 m;
- multicomponent - the jet of water in the air cage is used for soil erosion, and the processing chemical solution is supplied with significantly lower pressure into the eroded cavity, the radius of the zone exceeds 5 meters. Injection pressure determines the energy of the jet and the radius of its action. The recommended value of injection pressure is 450 atm. (bar).

The equipment used to carry out the injection works is made by different, both foreign and domestic manufacturers and has a significant difference in technical and operational parameters. At the same time, the main technological units are drilling equipment, a mixing station, a solution pump and high pressure hoses.

Drilling equipment is used for wells of a certain diameter and depth for the installation of injectors.

![Figure 4. Drilling equipment: a) large-sized installation, b) transportable installation.](image)

3.6. Mechanical stirring.
When mechanical stirring, the blade body is inserted into the salvaging of the waste drilling mud with a simultaneous dosage of the compound and additives. During the rotation of the blades, the distribution of the compound and the formation of a homogeneous mixture occur. The feeding of the compound under dry and wet methods of treatment is carried out under pressure through a flexible pipeline directly into the working zone of the mixer milling cutter. Admissible technological parameters for a dry process of waste drilling mud treatment should be maintained within the following limits: binder consumption 100-400 kg/m³; the pressure in the hose inlet 0.2-0.4 kPa; the pressure in the hose outlet 0.2-0.5 kPa; rotation rate of the mixer milling cutter 100-200 rpm. Acceptable values of technological parameters when treatment of the waste drilling mud in the salvaging with the wet method: binder consumption 100-250 l/m³; pressure in the hose inlet 2.0 MPa;
pressure in the hose outlet 0-1.0 MPa; rotation rate of the mixer milling cutter 10-20 rpm; the lifting rate of the mixer milling cutter 0.1-0.5 m/s.

4. Conclusion
Technologies for treatment of the waste drilling mud with the use of methods of jet injection, mechanical and vibro-mixing with productivity from 20 to 1000 m³ per hour are developed. The use of remote and subsurface vertical exploration makes it possible to study in detail the waste drilling mud salvaging, carry out their quality control and monitoring.

References
[1] Rzhanitsin B A 1986 Chemical anchoring of soils in construction (Moscow: Stroyizdat) pp 42-45
[2] Voronkevich S V 2005 Fundamentals of technical land reclamation (Moscow: Scientific World) pp 272-6