Using the Resource Potential of Drill Cuttings in Road Construction

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Abstract. The article discusses one of the national environmental problems - a negative impact on the environment from improper placement of drill cuttings. The main source of pollution is oil products, chemical reagents added to drilling mud and heavy metals that are part of drill cuttings. Methods for the treatment of drill cuttings, which consist of burial, neutralization and disposal are presented. A more promising and cost-effective method is the disposal of drill cuttings. A disposal method was chosen, consisting of the use of dried drill cuttings as a mineral powder for the preparation of asphalt concrete mixture. Samples of drill cuttings from different fields of Russia were selected. Laboratory studies of drill cuttings samples were carried out and the results of the content of heavy metals, physical and chemical indicators, physical and mechanical indicators of asphalt concrete samples were given. During the research it turned out that the content of heavy metals does not exceed the established norms, the physical and chemical indicators have exceeded the established standards, the physical and mechanical indicators of asphalt concrete samples comply with the requirements of regulatory documents.

1. Introduction
Waste received from the activities of industrial enterprises, with its long-term placement form a technogenic load on environmental objects. In order to reduce the negative impact, it is necessary to improve the technological processes to obtain the target products and modernize the waste management methodologies [1,2]. Reducing the volume of waste generation is achieved by using the
resource potential of waste in the technology of obtaining materials in demand on the market. Previous studies show that the waste of various industries in their physical and mechanical properties are not inferior to natural raw materials [3,4].

One example of such waste is drill cuttings (DC), which is formed during the activities of oil and gas companies. DC is a water suspension, the hard part of which consists of products of destruction of rocks of the face and walls of the well, products of abrasion of the drill and casing, clay minerals (when washed with clay mud). DC is formed when drilling wells and at the same time is a source of significant environmental pollution [5,6]. Russia is actively conducting drilling operations in many regions: the Orenburg Region, the Khanty-Mansiysk Autonomous Area, the Yamalo-Nenets Autonomous Region etc. About 300 thousand tons of such waste is generated annually and more than 95 million tons of DC have been accumulated.

The mineralogical composition of the DC depends on the lithological composition of the rock being drilled and changes as the well deepens and the place of mineral extraction. The granulometric composition of the DC is determined by the type and diameter of the rock cutting tool, the mechanical properties of the rock, the properties of the washing liquid [7].

The average composition of DC includes the following components: water - 25%; drilled rock - 60%; chlorides - up to 0.5%; heavy metals - 6%; drilling mud reagents - 8%; other compounds - 0.5%.

Storage of DC is carried out by a granary or sumless method. Land plots are seized to locate them, and flora and fauna around the repositories are destroyed. The polluting agents contained in DC are washed into the ground by atmospheric precipitation and then transported to the rivers by groundwater. As a result, there is a depression and suppression of organic life, changes in the composition of biocenoses.

Currently, the responsibility for the disposal of DC lies with the oil and gas companies themselves. But it often happens that companies violate the requirements for safe storage of the DC and place waste on unprepared environmental sites (quarries, ravines), which creates a negative impact.

2. Environmental impact assessment

Analysis of the scientific literature has shown that the main negative impact is due to oil products, drilling mud reagents and heavy metals that are part of DC.

The authors [8,9] in their works reflected the negative impact of petroleum hydrocarbons on the flora and fauna due to their ability to accumulate in the organs of animals and plant tissues. When they enter the aquatic environment, the physical and chemical parameters of water change. Under the influence of sunlight, the light fractions of hydrocarbons evaporate, polluting the atmosphere.

As the authors [10,11] found out, the danger is represented by toxic substances added to the drilling mud in the form of various chemical reagents. Reagents are needed to reduce the water loss of the reservoir, to reduce the viscosity of the solution, to ensure the ability of thermal stabilization. Among the reagents can be distinguished defoamers, inhibitors, hydrogen sulfide scavengers, stabilizers. Toxins migrate to the ground due to precipitation and, then, groundwater is carried into the rivers. As a result, there is a depression of aquatic life, a change in the composition of biocenoses.

The authors [12,13] note that chemical compounds of heavy metals, such as chlorides, sulfates, nitrates (CrCl₂, MnCl₂, CoCl₂, NiCl₂, ZnCl₂, CdCl₂, 2Cu(NO₃)₂, PbSO₄) are well soluble in water, which forms a negative effect on the hydrosphere due to changes in the chemical composition of water. Also, heavy metals form a negative impact on living organisms due to their ability to accumulate in the organs of animals.

Thus, DC have a complex negative impact on humans and natural ecosystems. One of the practical tasks is to minimize the negative impact of DC on the environment.

3. Reducing the negative impact of DC on the environment

As world experience shows, methods of handling DC are based on three main areas: burial, neutralization, and recycling [14]. More progressive and cost-effective is recycling - the secondary use of waste in different areas of production.
In this regard, recently oil and gas companies are focused on the transition to sumpless drilling. At the same time, DC is not placed in a sludge barn, but is utilized - used in technologies for producing target products. For example, the authors [15,16,17] investigate the possibility of using DC in concrete as a partial replacement of cement. The maximum compressive strength of concrete samples containing 20% DC was set, and adding a mixture of fly ash and silicon dioxide will increase the compressive strength by 40%.

In their works, the authors of [18,19] reported on obtaining glass ceramics by melting DC at a temperature of $1300^\circ$ C with the addition of sodium oxide and calcium oxide. The resulting material has high strength and hardness, which makes it attractive for use in construction.

In [20, 21] the author considers the reuse of stabilized hardened DC for the production of feed in acidic soils. DC was treated with a 5% dose of cement and reused in granular form for growing feed, elephant grass after mixing with uncontaminated form.

4. Experiments

In connection with the given task of minimizing the negative impact, laboratory studies of DC were conducted to determine the physicochemical parameters and the content of heavy metals. Samples of drilling cuttings were used at several fields of the Russian Federation: No. 1 - Khanty-Mansiysk Autonomous Okrug, No. 2 - Orenburg Region, No. 3 - Yamalo-Nenets Autonomous Okrug.

The content of heavy metals in DC samples is presented in table 1:

| Name                      | Cadmium | Chrome | Nickel | Cobalt | Plumbum | Cuprum | Manganese |
|---------------------------|---------|--------|--------|--------|---------|--------|-----------|
| DC sample No. 1           | less than 0,2 | 0,89±0,27 | 3,6±0,9 | 1,8±0,4 | 2,8±0,7 | 2,3±0,6 | more than 100 (207) |
| DC sample No. 2           | less than 0,2 | 1,8±0,4 | 0,60±0,18 | less than 4 | less than 5 | 2,0±0,5 | 23±4 |
| DC sample No. 3           | less than 0,2 | 1,1±0,27 | 2,3±0,6 | 0,96±0,29 | 1,8±0,5 | 0,62±0,19 | 112 |
| Permissible value         | 1,0 | 6,0 | 4,0 | 5,0 | 6,0 | 3,0 | 600,0 |

Analysis of the results of laboratory studies found that there is no excess of standards for the content of heavy metals in mobile form.

Aqueous extracts from DC samples dried at $105^\circ$ C to constant weight were also prepared to determine chemical parameters. The research results are presented in table 2.

Water extract from samples of DC exceeds the LPC values (limit of permissible concentrations) in terms of COC (chemical oxygen consumption), oil product, dry residue, rigidity, magnesium and calcium ions, chlorides.

In order to reduce the negative impact, it was proposed to use the DC resource potential in the construction of roads.

The grain composition and content of dust-clay particles were determined according to GOST R 52129-2003 “Mineral powders for asphaltic concrete and organomineral mixtures” to determine the belonging of DC to known mineral powders. As a result of the analysis of the particle size distribution, it was obtained that according to the requirements of GOST R 52129-2003 samples 1 and 2 of DC according to the MP-2 classification - powders from non-carbonate rocks, solid and powder industrial wastes are suitable as mineral powder.
Table 2. Results of quantitative chemical analysis.

| Defined characteristics | Units       | Analysis results          | Limit of permissible concentrations |
|-------------------------|-------------|----------------------------|-------------------------------------|
|                         |             | DC sample No. 1 | DC sample No. 2 | DC sample No. 3 |                          |
| pH                      | un.pH      | 7,0 ± 0,05     | 6,9 ± 0,05     | 7,8 ± 0,05     | 6,5-9,0                  |
| Chemical oxygen index   | mgO₂/dm³   | 580 ± 23,0    | 1300 ± 65,0   | 444 ± 22,2    | 30                      |
| Oil product             | mg/dm³     | 1,5 ± 0,30    | 4,4 ± 0,88    | 2,70 ± 0,9    | 0,05                    |
| Dry residue             | mg/dm³     | 620 ± 62,0    | 1590,0 ± 159,0| 1800 ± 180,0  | 1000                    |
| Rigidity                | Mmol-eq/dm³| 11,5 ± 0,56   | 60 ± 3,0      | 23 ± 1,15     | 10,0                    |
| Calcium ion             | mg/dm³     | 154 ± 7,7     | 800 ± 40,0    | 306 ± 15,3    | 180,0                   |
| Magnesium ion           | mg/dm³     | 46 ± 2,3      | 240 ± 12,0    | 92 ± 4,6      | 40,0                    |
| Chlorides               | mg/dm³     | 452,6 ± 25    | 1411,1 ± 70,6 | 1650 ± 82,5   | 300                     |

Further, a study was conducted according to GOST 9128-2013 “Asphaltic concrete and polimer asphaltic concrete mixtures, asphaltic concrete and polimer asphaltic concrete for roads and aerodromes. Specifications”. Samples No. 1.2 of the asphalt concrete mix with samples of DC No. 1.2, respectively, were formed as a mineral powder. Asphalt samples are presented in figure 1. Component composition of asphalt mix: sand - 12%; rubble - 46%; crushing screenings - 38%; drill cuttings - 4%; bitumen - 5.3% over 100%.

Figure 1. Asphalt samples.

The resulting asphalt mixture refers to type B, grade II, dense. Tests were conducted to determine the values of average density, compressive strength, water resistance, water saturation, residual porosity, porosity of the mineral part of hot mix asphalt concrete. The research results are summarized in table 3:
Table 3. Indicators of physical and mechanical properties of asphalt samples.

| Name                                      | Units     | Requirements GOST 9128-2013 | Asphalt sample No. 1 | Asphalt sample No. 1 |
|-------------------------------------------|-----------|-----------------------------|----------------------|----------------------|
| Average density                           | g/cm³     | -                           | 2,39                 | 2,43                 |
| Compressive strength at a temperature of 50⁰ C, not less, for asphalt concrete | MPa       | 1,0                         | 1,39                 | 1,02                 |
| Compressive strength at a temperature of 20⁰ C, not less, for asphalt concrete | MPa       | 2,2                         | 2,59                 | 2,59                 |
| Water resistant, not less:                | index     | 0,85                        | 0,88                 | 0,96                 |
| Water saturation                          | %         | 1,5-4,0                     | 1,89                 | 0,8                  |
| Residual porosity                         | %         | 2,5-5,0                     | 4,4                  | 3,2                  |
| Porosity of the mineral part of hot mix asphalt concrete | %         | 14-19                       | 17                   | 15                   |

According to the results of the study, asphalt concrete sample No. 1 meets the requirements of GOST 9128-2013, asphalt concrete sample No. 2 meets the requirements of GOST 9128-2013, except for the water saturation indicator - the value is less than the lower limit of the requirement.

5. Conclusion

The formation of DC is a nationwide environmental problem that requires a mandatory solution. Oil products, drilling mud reagents and heavy metals entering the DC have a negative impact on the environment.

A progressive and cost-effective way to dispose of DC is to obtain on their basis of environmentally friendly secondary products that can be used in various fields of production.

Laboratory studies of DC were carried out and the possibility of using the resource potential of DC as a mineral powder in an asphalt concrete mixture was studied. The obtained samples of asphalt meet the requirements of GOST 9128-2013. Thus, DC can be used as a mineral powder in the asphalt mix.

6. References

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Acknowledgments
The team of authors wishes to express gratitude to the staff of the Department of Environmental Protection and the staff of the Department of Highways and Bridges of the “Perm National Research Polytechnic University” for providing assistance in carrying out laboratory research. The authors also wish success in scientific activities.