Monitoring of environmental studies during storage of drilling waste

I. N. Kustysheva[1*], and *A. D.* Kustysheva[1]

[1]Industrial University of Tyumen, 38, Volodarskogo, Tyumen, 652000, Russia

Abstract. Intensive exploitation of hydrocarbon resources and related processing products creates significant risks for vulnerable natural ecosystems, especially ecosystems of the Far North. This study is devoted to monitoring the environmental and radiation assessment of drilling waste, which is an important step towards their effective disposal. The article considers current problems arising during the disposal of drilling waste, as well as modern approaches to solving these issues. The main attention is paid to conducting a comprehensive assessment of the environmental and radiation state of drilling waste associated with the development of oil and gas fields. The purpose of this study is to formulate recommendations for the application of technological methods for processing drill cuttings for its subsequent use as an experimental building material for road surfaces.

1 Introduction

The development of technological solutions for the operation of oil and gas fields is gaining a large-scale character. However, the work carried out to extract hydrocarbon raw materials is accompanied by the formation of toxic drilling waste (production waste), which is formed in the areas of the well pad from oil and gas wells and is subsequently placed in drilling waste storage facilities. After analyzing a number of studies, it was found that at present, despite the modern period of oil producing enterprises, there is no universal way for the disposal and disposal of drilling waste. For the correct choice of drilling waste disposal option, it is necessary to study the physical and chemical composition, environmental and radiation assessment and their impact on the environment. Drilling waste can have a negative impact on the natural balance of ecosystems, which can lead to various changes in these complexes in the future. To prevent such adverse effects, it is necessary to neutralize drill cuttings or ensure their environmentally safe disposal. It should be noted that drilling waste contains various chemicals that can have a toxic effect on organisms living in ecosystems. Therefore, it is important to develop effective methods for monitoring the state of the environment in order to promptly identify and minimize potential threats. Also, the introduction of modern technologies for processing and reusing drilling waste not only helps to reduce their negative impact, but also promotes the efficient use of natural resources. The development of special standards and regulations for waste management in the oil and gas industry is also a priority for ensuring sustainable

* Corresponding author: kustyshevain@tyuiu.ru

development and environmental protection. The introduction of environmentally friendly technologies in the drilling process will help reduce the risks of pollution, creating safer conditions for both us and nature. [1-2]. The extraction of hydrocarbon raw materials in Russia has always been a prerogative direction in the economic development of the country. The Russian Federation is one of the leaders in hydrocarbon production in the world. [3-4]. During the extraction of hydrocarbon raw materials, environmental pollution is observed both in the territories of well pads and in areas occupied by drilling waste sludge collectors. Drilling waste generated as a result of drilling requires subsequent disposal and processing. There are technologies for processing drilling waste, both in Russia and abroad, which can be classified by methods into the following groups:

- Thermal (burning, thermal desorption).
- Chemical (precipitation, neutralization, solidification).
- Physical.
- Biological.
- Combined.

Globally, all methods of sludge disposal can also be divided into 3 groups:

- Re-injection of the mixture into underground reservoirs.
- Their use for the production of special construction mixtures.
- Disposal of sludge at special landfills [5-7]. However, the disposal and recycling of drilling waste is an expensive process. Previously, oil companies put all the sludge in special barns, where the remains were filled with soil and concrete. The result was the appearance of burials containing toxic elements, metals, petroleum hydrocarbons, which potentially threatened the environmental pollution of large areas. It is worth noting that to this day, most of the territories in Western Siberia where drilling waste storage facilities were located have not been reclaimed, and hydrocarbon production and exploitation activities are not being carried out. The purpose of this study was to monitor the implementation of ecological and radiation assessment of sludge from exploited oil wells from the Limutinskoye oil field. After conducting an environmental and radiation analysis, it will be possible to give recommendations to the subsoil user, or to dispose of drilling waste or use it to develop building material as road pavement.

2 Materials and methods

In The material for the study was drilling waste from well pads No. 1-3: which is a liquid oily mass of dark gray color, which has the smell of oil. It should also be noted the radioactivity of all mineral raw materials, which is due to the presence in the rocks of long-lived radionuclides (i.e., having very long half-lives) belonging to the families of uranium - 238, thorium - 232 and potassium - 40. Therefore, the recycling of drilling waste requires an environmental and radiation assessment, and then a similar assessment of the resulting building material. This is necessary to ensure that the use of this material will not have a negative impact on the environment: - regulation, that is, the definition of hygienic norms, standards, norms and rules, which are established in agreement with the state sanitary and epidemiological supervision; - production control (including input control) for ensuring radiation safety in the process of production, transportation, processing, storage and sale of products; - inspection control carried out by the state supervisory authorities for control over radiation safety (during scheduled inspections, special raids); - public control carried out by public associations, in accordance with Article 12 of the Law of the Russian Federation "On radiation safety of the population", which have the right to exercise public control over the implementation of norms, rules and regulation in the field of radiation safety [4, 7-13]. Responsibility for carrying out production control lies with the

management of the enterprise that extracts, transports, processes, stores and sells products. To control the concentration of radionuclides of natural and technogenic origin, devices with a spectrometric action for detecting them are used. With the introduction of GOST 30108-94 "Construction materials and products, determination of the specific effective activity of natural radionuclides", it is mandatory to study samples of building materials for the specific effective activity of natural radionuclides of radium-226, thorium-232 and potassium-40. All building products should be produced and used only if there is a sanitary and hygienic certificate, the obligatory requirement of which is the assessment of the radioactivity of building materials [3, 12]. According to radiation safety standards NRB-99/2009 (A_{eff}), the background state of radionuclides in materials that can be used in construction or are a by-product of industry, as well as in industrial waste, must be tested using special devices and equipment (radiometers, spectrometers).

$$A_{eff}=A_{Ra}+1.31A_{Th}+0.085A_K \quad (1)$$

Where, A_{Ra}, A_{Th}, A_K are the specific activities of radium, thorium, potassium, respectively, Bq/kg.

Each monitoring zone included five soil pits. One point sample weighing at least 1 kg was taken from each pit. Soil samples were packed in appropriate bags with accompanying labels, which indicated: the place and date of sampling, geographical coordinates, the number of the soil section, the name of the soil, the date.

3 Results and Discussion

The work was carried out at well pads (3 pieces) of the Limutinskoye field, where dosimetric monitoring of gamma radiation was carried out in the production area of storage of pump-compression pipes, various equipment of the oil and gas industry, in fuel storage areas, in work areas and utility rooms, on well pads and other production facilities. This is necessary to prevent radiation from entering the environment.. Such monitoring allows identifying potential sources of pollution and taking the necessary actions to eliminate them. In order to minimize such impact, it is possible to propose using filler in asphalt concrete compositions and producing cement-soil mixtures for road surfaces based on it. For research, samples of drill cuttings were taken at the Limutinskoye field (Figures 1-2).

Fig. 1. Drilling waste accumulator at the Limutinskoye field (bush No. 1).

Fig. 2. Drilling waste accumulator at the Limutinskoye field (bush No. 2).

Physical and chemical characteristics are also analyzed to conduct monitoring and evaluation. Such indicators should be determined in accordance with regulatory and legal documentation, for example, with the methodology for determining chemical indicators in soils intended for agricultural products. The determination of physico-chemical parameters is reproduced in accordance with well-known methods of laboratory research. To establish the compliance of the obtained materials with the requirements of the established regulatory documents, it is necessary to determine the physical and mechanical parameters of the obtained samples. To determine whether the drilling mud belongs to known mineral powders, a state standard was used, which regulates the level of chemical substances in drilling waste samples. These indicators are given in Table 1.

Table 1. Level of chemical substances in drilling waste samples.

Bush platform	**Level of chemical substances, mg/kg**			
	Chrome	**Lead**	**Copper**	**Manganese**
Drilling cuttings well pad No. 1	0.66	2.6	1.7	104
Drilling cuttings well pad No. 2	1.4	2.4	2.0	116

During the radiation safety studies, the recommendations and requirements stipulated by GOST 30108-94, which regulates the methods for determining the specific effective activity of natural radionuclides in building materials and products, were strictly observed. These studies are a necessary stage for indicating potential radiation risks associated with the use of drill cuttings, which are formed during hydrocarbon production. As part of the research work, measurements of drill cuttings samples were performed using high-precision spectrometric installations. This approach allows obtaining reliable and substantiated data on the content of natural radionuclides, including thorium, radium and potassium, which can affect the radiation situation both at the local level of the well pad and on the scale of the entire license area. These measurements were especially important for assessing the state of environmental safety of the territory. The results of the studies concerning the content of natural radionuclides in drilling waste samples are presented in tabular form (Tables 2-3), where the parameters of the specific effective activity are clearly indicated. Also, the illustration of the results in the form of graphs (Figure 3) allows for a visual assessment of the distribution of radionuclides and their concentration at the Limutinskoye field. These visual data are a key tool for analyzing and understanding the radiation situation and can be used to plan further reclamation actions. The results obtained and their values can contribute to the formation of recommendations for future activities on drilling waste management and minimization of environmental risks. Analysis and interpretation of

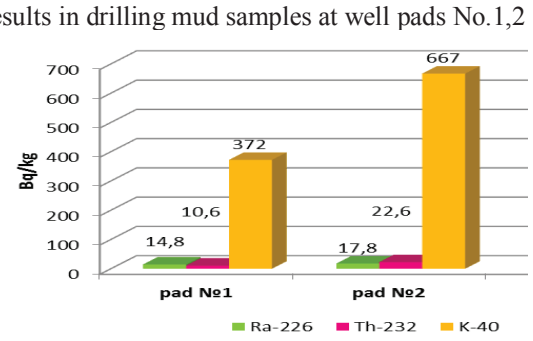
such data is necessary in the strategic planning of oil and gas companies, as well as in the field of environmental monitoring and environmental impact analysis.

Table 2. Measurement results with error in the sample drill cuttings at well pad No. 1.

No.	Measurement results with error, Bq/kg (Sample weight, 1000 g)						
	Unit of measurement	Ra-226	Unit of measurement	Th-232	Unit of measurement	K-40	A_{eff}
1	13.5	14.8 ± 3.9	11.0	10.6 ± 3.7	311	372 ± 80	60.3 ± 8.6
2	11.9		12.3		394		
3	16.8		7.9		386		
4	15.1		12.7		406		
5	16.6		9.0		364		

Table 3. Measurement results with error in the sample drill cuttings at well pad No.2.

No.	Measurement results with error, Bq/kg (Sample weight, 1000 g)						
	Unit of measurement	Ra-226	Unit of measurement	Th-232	Unit of measurement	K-40	A_{eff}
1	20.0	17.8 ± 3.9	22.7	22.6 ± 2.7	707	667 ± 99	104.1 ± 9.8
2	18.1		22.0		662		
3	19.0		21.9		600		
4	14.6		21.7		725		
5	17.1		24.9		642		



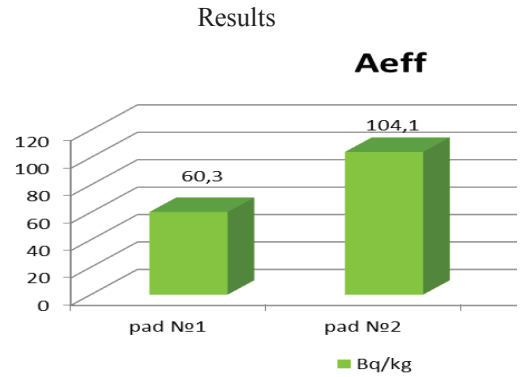


Fig. 3. Research results.

The results of the analysis showed that the highest values were noted in relation to potassium-40. The maximum concentration for this component was 667 Bq/kg at well pad No. 2. At another study site, potassium-40 concentrations varied in the range 357 Bq/kg, respectively [12–14]. The activity of thorium-232 and radium-226, in contrast to potassium-40, did not have significant indicators. The maximum concentration of thorium-232 in all the studied drill cuttings samples did not exceed 22.6 Bq/kg, while the minimum value was 9.6 Bq/kg. Radium-226 concentrations ranged from 14.8 to 18.4 Bq/kg, slightly below the activity of thorium-232. Criteria for deciding on the use of building materials are given in Table 5.

Table 4. Criteria for deciding on the use of building materials.

Indicator (A_{eff}), Bq/kg	Class material	Application area
to 370	I	All types of construction
370 to 740	II	Road construction within settlements and zones of promising development, construction of industrial facilities
740 to1500	III	Road construction outside built-up areas
1500 to 4000	IV	The issue of using the material is decided in agreement with the department.

It can be concluded that it is possible to use drilling waste for the development of building material, but it is necessary to ensure the environmental friendliness of the resulting product. It was proposed to use drilling waste for the development of experimental building material by processing it using a technological method. Thus, the conducted research has proven to the oil and gas company the economic and environmental efficiency and the possibility of obtaining additional profit from processing drilling waste to create an experimental building material, rather than simply disposing of it in furnaces. This approach not only reduces disposal costs, but also promotes more rational use of resources, which is important in the current ecologically unstable situation. In addition, the introduction of new recycling technologies allows for an increase in the diversity of building materials for various purposes of their use and promotes the development of innovative methods in the field of recycling.

4 Conclusion

The rapid development of the fuel and energy complex leads to the need to explore new hydrocarbon deposits, which rapidly entails an increase in the introduction of wells to search for oil and gas deposits. In this regard, the disposal of waste obtained during the drilling of various types of wells has been and remains an urgent problem faced by subsoil users in the process of carrying out their production activities [15-16].

Currently, methods are actively developing that not only ensure waste disposal, but also allow obtaining secondary products that represent additional value. However, the use of such innovative approaches requires additional research and modernization of existing technologies.

References

1. A.V. Vasiliev, Ensuring environmental safety in the urban district of Togliatti: a study guide, Publishing House of the Samara Scientific Center of the Russian Academy of Sciences, Samara, 201 (2012)

2. V.K. Salakhova, L.V. Rudakova, K.G. Pugin, K.Yu. Tyuryukhanov, Use of polyethylene waste contaminated with oil products in the production of asphalt concrete, Ecology and Industry of Russia, **27**, **10**, 16-22 (2023) DOI 10.18412/1816-0395-2023-10-16-22
3. GOST 51.01-06-85, Protection of Nature. Hydrosphere. Rules for the disposal of waste drilling and oil and gas production in the sea, Input. 1986-01-01, NIPI "Gipromorneftegaz", Moscow, 10 (1985)
4. E.B. Accountant, A.I. Vladimirova, Ecology of the oil and gas complex, State Unitary Enterprise Publishing House "Oil and Gas" Russian State University of Oil and Gas, I.M. Gubkina, Moscow, **2**, 416 (2003)
5. RD 39-133-94, Instructions on environmental protection when drilling wells for oil and gas onshore, Rosneft, Moscow, 46 (1994)
6. S. M. Yarantseva, Study of drilling cuttings utilization technologies, 2 (2014) http://earchive.tpu.ru/bitstream/11683 /31901/1/conference_tpu-2016C11_V2_p283-284.pdf
7. Sludge pit (sludge storage), http://www.geoplenka.ru/articles/oilindustry/shlamohranilischa/
8. A.I. Bulatov, Ecology during the construction and operation of oil and gas wells, A manual for university students, Enlightenment-South, M: Krasnodar, 603 (2011)
9. G. G. Yagafarova, V. B. Barakhnina, Utilization of environmentally hazardous drilling waste, Mountain Bulletin, **4**, 4
10. A. D. Abalakov, Ecological geology: textbook. allowance, Irkut Publishing House. state un-ta, Irkutsk, 267 (2007)
11. I. M. Yanin, The problem of neutralization of oil sludge, Bulatovskie reading, **4**, 252-254 (2017)
12. E. A. Pichugin, Assessment of the impact of drill cuttings on the environment, Young scientist, **9**, 122-123 (2013)
13. A.V. Vasiliev, O.V. Tupitsyna, Environmental impact of drill cuttings and approaches to their processing, Problems of Applied Ecology, 308 - 313 (2014)
14. V. A. Babkina, Electrochemical method of processing drill cuttings study of the chemical composition of drill cuttings after processing by the electrochemical method, Arctic: modern approaches to industrial and environmental safety in the oil and gas sector: materials of the International scientific and practical conference, Tyumen, November 29, 2023, Tyumen Industrial University, Tyumen, 234-237 (2024)
15. N.L., Vlasenko G.S., Akopova E.A. Trigubova, A.V. Borodai, Improving environmental safety in the treatment of drilling waste, Construction of drilling and gas wells on land and sea, 10 (2010)
16. E. V. Gaevaya, Justification of geoecological parameters of technogenic soils in the process of drilling mud disposal, Ecology of industrial production, **2** (**126**), 2-7 (2024) DOI 10.52190/2073-2589_2024_2_2