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Monitoring the Environment and Recycling Approaches for Managing Oil and Drilling Waste

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ABSTRACT

The annotation explores the key aspects of monitoring soil pollution during the treatment of drilling and oil waste in the Kyzylorda region. The authors conducted experimental studies on drilling and oil waste processing to assess their environmental impact. The study utilized various materials, including drilling cuttings, liquid drilling wastes (such as drilling wastewater and waste drilling fluid), oil-contaminated soil, and oil sludge. Diverse methods and technologies were employed for the processing of drilling and oil waste. The experimental setup included a drilling cuttings processing plant, three maps for curing and averaging drill cuttings, two trenches for settling and drying liquid drilling wastes, and a composting site for oil-contaminated soil. The processing site facilitated the treatment of drilling cuttings, oil sludge, and oil-contaminated soil, with the aim of producing a material suitable for road construction. The environmental monitoring revealed the efficacy of the undertaken measures in mitigating the adverse environmental impact.

1. INTRODUCTION

The problem of drilling waste management at oil producing enterprises, especially in terms of their high-quality neutralization, utilization and prevention of environmental pollution due to the ingress of toxic substances from oil production into the environment, continues to be extremely acute for both oil producing companies and attracts increasing public attention. The widely used, but insufficiently reliable use of such methods of disposal of drilling waste and oil sludge as their burial on fertile soils and in water protection zones without their appropriate processing, ensuring the environmental safety of waste, is a serious threat to nature and human life and requires direct state participation in control processes. for the disposal of drilling waste from oil producing enterprises [1].

The aim of this study is to investigate and assess the environmental impact of oil and drilling waste in the Kyzylorda region. The primary goal is to develop effective waste recycling technologies that not only reduce environmental pollution but also have practical applications, such as the production of road construction materials. The study employs both modern and time-tested approaches, ensuring the relevance of the research in light of recent global trends.

In foreign and domestic practice, the tasks of environmental protection, rational used of natural resources and resource conservation are acute. For these purposes, research is being carried out aimed at improving technologies, created specialized equipment, identifying new approaches to the organization of environmental management, in particular, waste management and their integrated processing. New approaches are designed to change the priorities of ongoing and planned work, considering them as an important component of the overall process of ensuring environmental safety. The policy in the field of waste management is mainly focused on reducing the amount of waste generated and on developing methods for their maximum further processing and disposal. Opportunities for optimization in this area of activity lie in the development and implementation of a new strategy for handling oil products and oily waste. This approach meets the new technological and economic requirements, handling of oil products and oily waste, prevention and timely elimination of the consequences of accidental spills of oil and oil products.

The greatest danger to the natural environment is represented by industrial and technological drilling waste, which is accumulated and stored directly on the territory of the drilling rig. In their composition, they contain a wide range of contaminants of mineral and organic nature, represented by materials and chemicals. There are up to 68 kg of polluting organics per 1m of waste, not counting oil and oil products and pollutants of a mineral nature. The percentage ratio between the components of the sludge can be very diverse depending on the geological conditions, the technical condition of the equipment, and the culture of production. The problem of liquidation of pit oil sludge is currently not completely resolved, which is due to a number of factors. Therefore, this issue is of particular relevance in the framework of environmental safety [2].

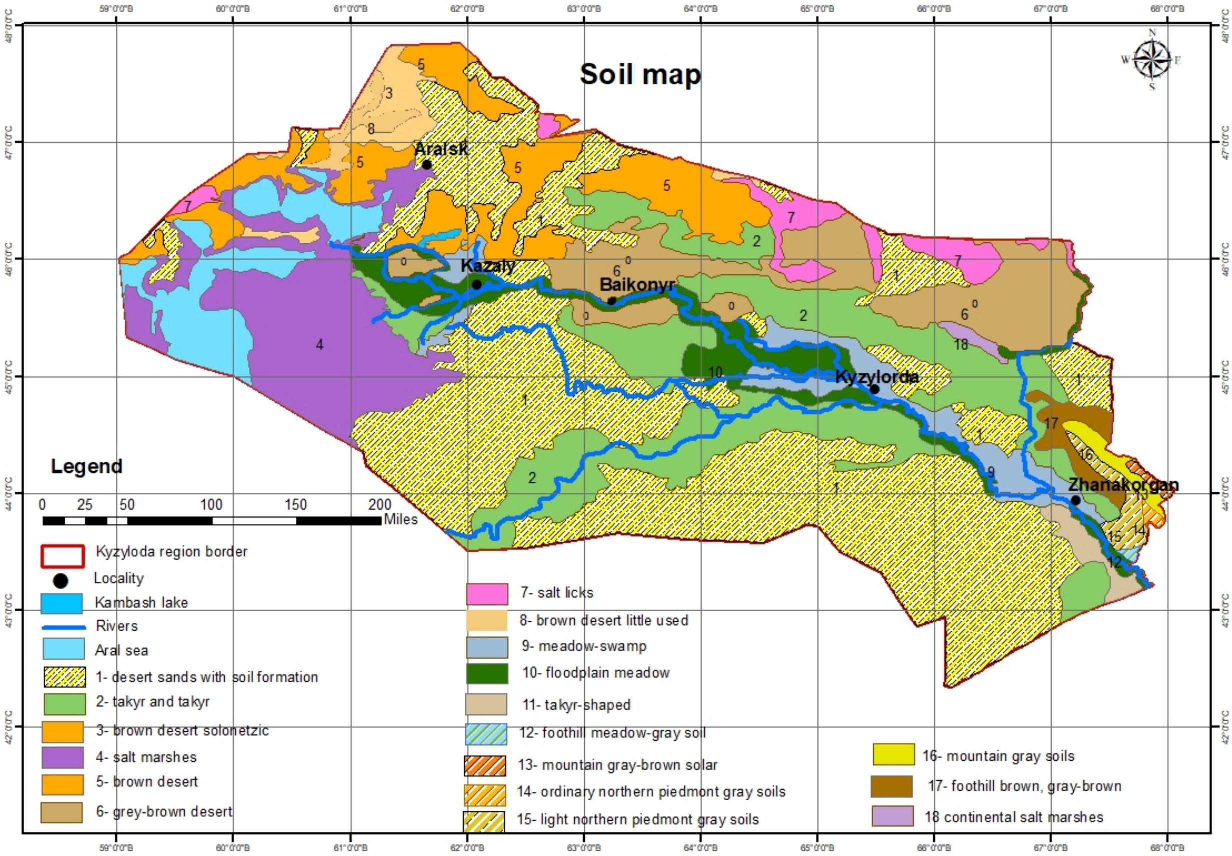

Figure 1. Soil map of Kyzylorda region

The study area is located to the east of the Aral Sea in the lower reaches of the Syrdarya River, mainly within the Turan lowland (altitude 50-200m). On the left bank of the Syr Darya there are vast expanses of hilly-ridged sands of the Kyzylkum, cut through by the dry channels of the Zhanadarya and Kuandarya; along the right bank there are elevations (Egizkara, 288m), sandy areas (Aryskum and others), shallow basins occupied by takyr-like solonchaks (Darialy and others) [3]. In the north-massifs of hilly sands (Small Badgers and the Aral Karakum; Zhuankum). In the extreme southeast, the northwestern spurs of the Karatau ridge enter the Kyzylorda region (height up to 1419m) (Figure 1).

The study was carried out jointly with Daulet Asia Company LLP, the main activity of which is the processing of drilling waste, oil production and oil refining in equipped maps with the production of road construction materials. The site for processing drilling and oil waste, temporary storage of industrial waste is located at 147km of the Kyzylorda-Kumkol highway of the Syrdarya district of the Kyzylorda region.

2. MAIN PART

Environmental monitoring monitors the level of pollution of atmospheric air, water basin, soil, meteorological, hydrological observations [4].

The main goal of environmental monitoring is to provide the enterprise with reliable information about its impact on the components of the natural environment. To achieve this goal, the following tasks were set and completed:

- obtaining data on quantitative indicators of the state of the natural environment by testing its various components;
- assessment of the state of environmental components;
- analysis of the release of pollutants into the environment and recommendations for reducing the impact of the enterprise's activities to an acceptable level (if necessary) [5].

Environmental safety is ensured by compliance with relevant environmental measures, the main of which are:

- constant monitoring of all types of impact and emissions into the environment;
- regulated movement of vehicles;
- reclamation of disturbed lands;
- promotion of nature protection;
- compliance with fire safety rules;
- compliance with the rules of safety and protection of health and the environment;
- training of service personnel and technical means for organized actions in emergency situations.

All technological processes (namely: exploration, drilling, production, collection, transportation, storage and processing of oil and gas) under certain conditions can disrupt the natural ecological situation. An analysis of the consequences of emergencies during all types of work in the oil and gas industry indicates the involvement in most cases of the human factor, with the possible exception of natural and man-made factors (for example, storms, deterioration of pipelines due to corrosion). Oil, drilling fluid, sludge, wastewater containing various chemical compounds can have a dangerous effect on air, water, soil, flora and fauna, and humans. During the development of deposits, the most active impact on the natural environment is carried out within the territories of the deposits themselves, the routes of linear structures (primarily main pipelines), and in the nearest settlements. This leads to disruption of vegetation and soil cover, surface runoff and microrelief of the territory. As a result, there are shifts in the thermal and wet regimes of the soil stratum and a significant change in its general condition, often with irreversible consequences. The main pollution during onshore drilling is associated with the spill of oil and oil products (diesel fuel, lubricating oils, etc.), with chemical reagents used to reduce the viscosity of clay drilling mud, acid treatments, etc. [6].

Let us consider in more detail the impact of drill cuttings on the environment. Since rock (60-80%), organic matter (8-10%), water-soluble salts (6%), oil, various reagents, etc. are present in the drilling cuttings, the main impact on the environment will be pollution of natural environment objects with chemical reagents, mineral salts and oil products. Oily waste is a specific type of waste. In small quantities, they do not have a noticeable impact on the environment, and in large concentrations they become an ecological disaster [7]. The complexity of the disposal of oily waste by incineration is explained by the fact that in this case toxic gases are emitted into the atmosphere, the amount of which is many times higher than the standard values. Therefore, the most common method is landfilling. But this method is ineffective from an ecological point of view, since the processes of soil self-purification without human intervention are extremely slow [8]. In particular, this is due to the fact that at low temperatures, and in the studied latitudes the negative temperature is observed from November to March, bioprocesses slow down or stop altogether [9].

The most negative impact on the geo-ecological system is produced by oil, oil products, oil and drilling sludge. Drilled cuttings, due to the complex mineral composition, the content of oil, oil products and toxic polymer additives: CMC (carboxymethylcellulose), SSB (sulfite-alcohol stillage), PAA (polyacrylamide) and others, are capable of contacting natural complexes, their moisture, atmospheric precipitation, underground and surface waters to have an uncontrollable negative impact on the established natural balance of local bio- and agrocenoses with the unpredictable behavior of these complexes in the subsequent time [10].

Liquid drilling waste-drilling waste water (DW) and waste drilling fluid (WDM)-a water-clay emulsion contaminated with drilling reagents residues and oil.

Drilling waste water (DWW) is formed in the process of settling drill cuttings in sludge collectors, flushing the wellbore from clay mud. The effluents are contaminated with clay particles, formation water, drilling fluid residues. DWW are collected together with cuttings in ecological tanks, where primary settling takes place (particles of cuttings settle). The liquid part from the surface of the reservoir is pumped out by vacuum machines and delivered to the landfill, where the effluents are placed for settling in storage trenches. After purification from suspension (clay), treated effluents are used for dust suppression in road construction and for other technical needs at the landfill.

Oil-containing wastes (NSO) are divided into oil sludge and oil-contaminated soil according to the content of oil and water.

- oil sludge is formed during the cleaning of oil storage tanks, cleaning of pipelines, scraper receiving chambers and represents a water-oil clay sediment;
- oil-contaminated soil in case of accidents and spills of oil, n/products.

It provides for control over the content of oil and n / products before and after waste processing, as well as radiation and environmental control of materials used in the construction of landfill facilities, and waste entering the landfill.

Methods

In recent years, various technological solutions aimed at the disposal of drilling waste have been introduced into production by oil producing enterprises. However, there is no unified method for processing oil sludge for the purpose of neutralization and disposal [11].

The choice of drilling waste disposal method is made taking into account many factors, including: drilling technology, equipment and machinery at the well pad, local conditions, the presence and remoteness of sand, sapropel, peat quarries, nearby production and waste, the availability of electricity and fuel, the design of the slurry barn, the requirements of environmental authorities. As a rule, not one, but several technologies are used. If in the southern regions, for the disposal of drilling waste, it is sufficient to perform centrifugation and separation more carefully, and take the resulting product to agricultural land for reclamation, then in other cases this process is associated with high costs and technical difficulties. However, despite all the problems, new methods of drilling waste disposal are being introduced into practice, old, proven methods are being improved. A number of research and design organizations are involved in the development of regulations for the disposal of drilling waste [12].

In world practice, the following methods of processing oily waste are currently used.

1). Thermal method: burning in open barns and furnaces; drying; pyrolysis; thermal desorption; electrical processing.

2). Chemical method: hardening by dispersion with hydrophobic reagents based on quicklime or other materials.

3). Biological method: biodegradation by introducing (mixing) oily waste into the arable layer of the earth; biodegradation using special strains of bacteria, biogenic additives and air supply [13].

4). Physical method: gravity sedimentation; separation in a centrifugal field; separation by filtration; extraction.

5). Physical and chemical method: the use of specially selected surfactants (demulsifiers, dispersants, wetting agents, etc.), auxiliary substances that affect the change in the state and colloidal structure of suspended particles in the oil and water phases [14].

At present, enough methods and technologies for processing oil sludge have been developed, but they have not received wide practical application. A limited number of disposal methods are used, mainly biological and thermal. One of the reasons for this limitation is the lack of knowledge of the component composition of oil sludge in relation to the justification of the choice of processing method, as well as the practical absence of separate collection of oil-contaminated soils depending on the amount of oil products, which in turn makes the measures taken less effective. Ultimately, preference is given to those technologies that achieve maximum economic efficiency and minimum time when an indispensable condition is met-these technologies must ensure the cleanliness of the generated waste in accordance with current environmental standards [15].

Utilization of oil sludge by the mechanical method is carried out using decanter units. Decanters are horizontal centrifuges designed for centrifugal separation. Such installations help to separate mechanical impurities, oil and water phases. Also, decanters are divided into two-phase-separating liquid and mechanical impurities, and three-phase-separating two liquids and mechanical impurities, below is an example of the stages of operation of a three-phase decanter [16].

As is known, oil sludge consists of hydrocarbon and water phases, the essence of utilization by the physicochemical method is the separation of these phases. The recycling process by the physicochemical method is as follows:

- heating of oil sludge at a certain temperature regime;
- destruction of water-oil emulsion with the help of special reagents (demulsifiers);
- acoustic vibrations, emulsion separation;
- introduction of flocculant - adhesion of mechanical particles.

The essence of the chemical disposal method is dispersion, that is, emulsification using chemical solvents. For emulsification of oil sludge, low-boiling paraffin hydrocarbons, a wide fraction of light hydrocarbons, can be used.

Advantages of the method:

- high efficiency;
- the final product can be used in road construction.

The essence of the biological method is the use of special strains of bacteria for the disinfection of oil sludge. Biological products are applied directly to contaminated soil or water. Bacteria convert petroleum hydrocarbons into simpler compounds, accumulate organic products and involve them in the carbon cycle. This method can be used when soil and water are contaminated with oily waste.

Advantages of the method:

- the smallest costs;
- low environmental impact.

Technological process of drilling waste processing:

To prevent environmental pollution, drilling without pits is envisaged with the transfer of drilling waste for processing at specially equipped landfills. Drill cuttings are separated from the drilling fluid and accumulated in tanks installed at the drilling site. From the sludge collector, after pumping out the settled drilling fluid, the sludge is shipped to vehicles and taken out for processing [17].

The processing of drill cuttings by the physicochemical method makes it possible to obtain soils for use in road construction when backfilling the subgrade. Drill cuttings with a moisture content of 60-50% are delivered by road to the averaging and curing maps, where the drill cuttings pile up with a gradual filling of the map area. During drying, the sludge is mixed with a motor grader for the purpose of averaging (acceleration of the oxidation of the organic part) with a layer thickness of 0.5 to 0.8m.

Upon reaching a moisture content of 10-12%, the waste that has undergone aging and averaging is loaded by a forklift into a vehicle and transported to the place of use.

The duration of the drying process depends on natural factors: temperature, humidity of the atmospheric air and the organization of transportation, as well as the volume of formation of drilling waste to be processed. In summer, when intensive drying occurs, the cards can be divided into sections with the device of rollers from dried drilling waste [18].

Platform for equipment UPBSH 10 S.

The UPBSh-10S equipment is designed for mixing drill cuttings and oil-contaminated soils with cement, sand, perlite, lime, and other substances and makes it possible to obtain stable conglomerates.

The unit is equipped with 4 hoppers, each with its own screw controlled by a regulator, which allows the mixing of sludge with 3 different components. All 4 augers supply materials to the main mixing unit, which mixes the supplied components to a homogeneous medium and unloads from the plant using a long auger into a concrete pit [19]. From where the finished product is shipped to a/transport and delivered to the place of use, as shown in Figure 2.

Figure 2. Equipment UPBSh-10S

Processing drill cuttings using technological equipment (UPBSh-10S) and cement (binder) allows you to speed up the process of sludge averaging, obtain a granular product for use in road construction, as well as for the preparation of paving stones (paving slabs) with the addition of a coloring pigment.

A brief technological process for the preparation of paving stones from recycled drill cuttings.

Table 1. HCO recycling methods

Physical and Mechanical	- HCO Flushing with Hot Water Followed by Centrifugation and Oil Separation
chemical method	- treatment of HSO with solvents with the separation of dissolved oil; - oxidation of oil hydrocarbons to bitumen due to intensive heating and oxygen purge of atmospheric air
biological method	- destruction of oil by bacteria (bioremediation) and conversion of heavy hydrocarbons into a form assimilable by plants (biocompost)

For the manufacture of paving stones (paving slabs) you will need plastic molds, a metal sheet and an improvised vibrator on the base. The mixture for pouring is used as a base - recycled sludge, in which the composition contains cement (if necessary, the technology may require the secondary addition of cement and other hardening elements) + mineral pigment (dry paint) to give an aesthetic color. The inner surface of the mold is lubricated with used engine oil. Drying will be carried out in a protected place from direct sunlight.

Technological process of oily waste processing

Processing of NSO is carried out by physical-mechanical, chemical and biological methods. HCO recycling methods are shown in Table 1.

In practice, a combination of different methods is used, depending on the area of use of treated waste.

Curing and averaging of wastes with the oxidation of oil hydrocarbons to bitumen is a combination of physical and chemical methods.

Purification of HCO with the addition of oil-destroying bacteria in the form of a liquid substrate and active mixing-biological and physical methods of purification [20].

The methods employed in this study were selected based on their environmental efficiency, cost-effectiveness, and technological feasibility in the specific climatic and geographical conditions of the Kyzylorda region. The data collection process included quality control at each stage, as well as precise procedures for soil and water sampling. Analytical equipment used to measure pollutants was calibrated to ensure accuracy [21].

In this study, modern analytical instruments were used to measure the oil content, heavy metals, and other pollutants in soil and water [22]. Sampling was conducted at regular intervals, and rigorous methodological approaches were applied to ensure the accuracy of the obtained data. Calibration protocols were followed for the instruments, which enabled high measurement precision.

3. RESULTS

The results of the study indicate that the proposed waste recycling technologies can be applied in other regions facing similar environmental challenges. These technologies have the potential to influence waste management practices at the regional level and contribute to the development of environmental policy. A comparative analysis with studies from other regions was conducted to confirm the uniqueness and effectiveness of the methods implemented in Kyzylorda.

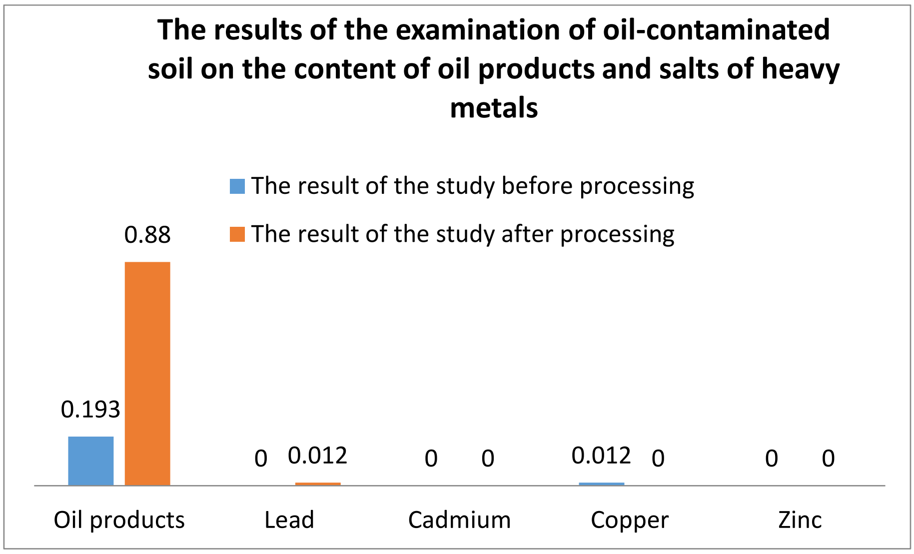

Figure 3. The results of the examination of oil-contaminated soil on the content of oil products and salts of heavy metals

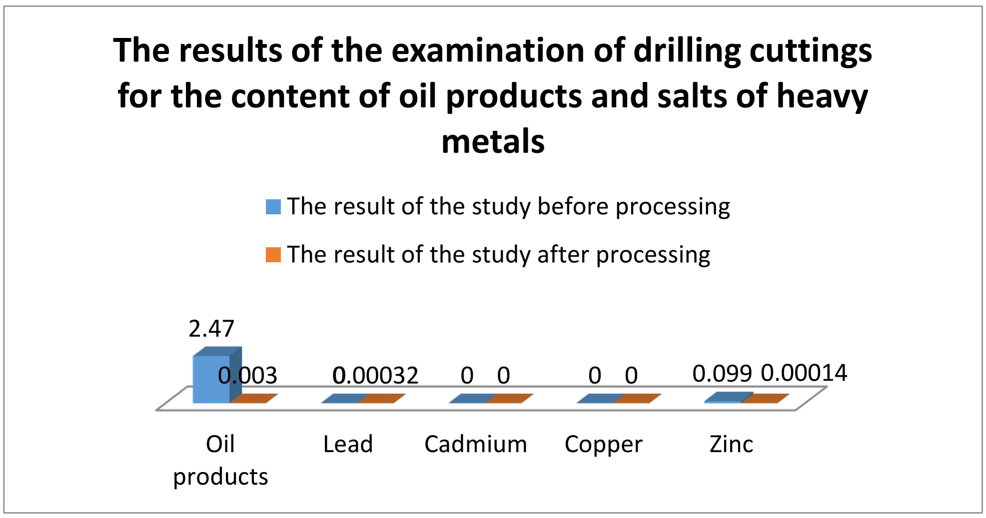

Figure 4. The results of the examination of drilling cuttings for the content of oil products and salts of heavy metals

Table 2. Summary table of incoming and outgoing material and raw material flows entering for processing

Industrial Site	Site	Name of Waste Received for Processing	Amount of Waste Received, T/Year (m^3/year)	Units of Measurement	Name of Products Received	Number of Products Received	Units of Measurement
Plot	Drilling waste site	Drill cuttings	72 000(45000)	т (м^3)	Road building materials	54500	t
	Recycling map	Oiled soil	30,000 (42,000) (oil content ≤12%)	t (m^3)	"Black Soil"	18850	t
	Map-sump	Oil sludge	30,000 (42,000) (oil content ≥12%)	t (m^3)	insulating material	34584,1	t

We carried out environmental monitoring for various indicators, the presence of oil products, lead, cadmium, copper and zinc in the soil. The results of the examination of the oil-contaminated soil for the content of oil products and salts of heavy metals showed an excellent result in reducing the content of heavy metals in the processed soil, as shown in Figure 3.

Based on the results of the examination of drill cuttings for the content of oil products and salts of heavy metals, it can also be said that before and after processing, these main indicators decreased in quantity, as can be seen in Figure 4.

As a result of oil and drilling waste, we get recycled finished products. The resulting products are shown in Table 2.

The accuracy of measurements and potential sources of errors were thoroughly examined. All measuring instruments were calibrated, minimizing uncertainty in the data. This ensures a high level of reliability in the research findings and their interpretation.

Recent advancements in environmental monitoring technologies include the use of real-time monitoring systems, advanced data processing methods, and remote sensing to detect oil spills and soil contamination. These innovations will be beneficial for improving future oil waste monitoring and management processes.

Environmental and safety concerns

The long-term sustainability and safety of the proposed waste disposal methods have been analyzed, taking into account the potential risks of soil and air pollution. The study outlines strategies to minimize these risks, including continuous monitoring and remediation efforts in compliance with international environmental safety standards.

4. CONCLUSIONS

During the environmental monitoring for soil pollution during the processing of oil and drilling waste, which we conducted in the Kyzylorda region, we revealed a decrease in the content of heavy metals in the studied soils. This allows us to conclude that after the processing of contaminated soil with oil products and heavy metals by various technologies, the environmental load on the environment and the ecosystem was reduced, and the soil stopped degrading, which gives hope for the restoration of this ecosystem.

Our research on oily waste disposal consisted of three stages: 1) material preparation, 2) waste processing and 3) sorting of finished products into places of use.

For the study, drilling cuttings were used, liquid drilling wastes, which include drilling wastewater and waste drilling fluid, oil-contaminated soil and oil sludge. Various methods and technologies have been used to process oil and drilling waste. A site was used to place a drilling cuttings processing plant, 3 maps of curing and averaging of drill cuttings, 2 trenches for settling and drying liquid drilling wastes, and a composting site for oil-contaminated soil for the experiment. Drilling cuttings, oil sludge and oil-contaminated soil were processed at the drilling and oil production waste site. The processing of drilling waste has been carried out to obtain a product used in road construction.

As a result of the environmental monitoring, the effectiveness of the work carried out to reduce the negative environmental impact on the environment was established.

The study demonstrated the effectiveness of the proposed oil and drilling waste recycling technologies, significantly reducing the environmental impact. Specifically, the reduction in heavy metal and petroleum product concentrations in the soil provides hope for the restoration of the region's ecosystem. The proposed technologies have the potential for broader application in other regions and could serve as a foundation for further research in oil waste processing.

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