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Drill Cuttings Disposal Efficiency in Offshore Oil Drilling

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Abstract: The relevance of the study lies in the fact that with the depletion of conventional oil and gas reserves and an increase in the global demand for hydrocarbons, the focus of the industrial sector is gradually shifting towards the resources of the Arctic, which have tremendous potential for development. However, the current industrial policy has to take into account the concept of sustainable development, or harmony between economy, ecology, and society. Therefore, the extraction of raw materials must obey the principles of the circular economy, which aims to generate closed-loop cycles that maximize the use of the resources extracted and minimize waste generation so as not to destroy fragile ecosystems. It is necessary to drill wells for the discovery of a hydrocarbon deposit on the shelf, which entails the generation of a tremendous amount of complex waste., The use of disposal methods for drilling cuttings, which must be disposed of economically and with environmental reliability, is required to solve the problem. This study compares two methods of disposing of drilling waste. Statistical modeling results and a review of the literature show that the most effective method from both economic and environmental points of view is the thermomechanical cleaning of cuttings on site. This article discusses the advantages and disadvantages of both methods. It also evaluates drilling waste management prospects and opportunities for Russian offshore fields.

Keywords: drill cuttings; waste management; offshore drilling; oil and gas fields; exploratory wells; Arctic region; circular economy

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1. Introduction

The dimensions along which the oil and gas industry is currently evolving are set by the paradigm of sustainable development. This kind of development strives to meet the needs of the present while preserving the integrity of the environment and society, which the well-being of present and future generations depends on [1]. Against this backdrop, the oil and gas industry keeps playing a crucial role in providing for the needs of humanity as hydrocarbons are still in demand. According to the forecasts provided by Shell, oil and natural gas will constitute a major share (58% in 2030, 51% in 2040, and 40% in 2050) of the global energy mix until 2055 (Figure 1), after which fossil fuels will become gradually replaced by renewables (wind and solar). Nuclear power will also increase its share.

Due to growing pressure from regulators, investors, and consumers [2,3], who force oil and gas companies to reduce both waste and the carbon intensity of their products, the sector needs to revise and redefine its traditional business strategies. In view of this, some authors [4,5] propose to develop the Arctic hydrocarbon fields along the modern trend of carbon footprint reduction by using the extracted natural gas as a source for producing hydrogen and ammonia and the associated impurities as a raw material in gas-to-chemicals processes. Moreover, due to the lack of centralized power supply in remote areas of Russia, such as the Arctic region, it makes sense to implement projects for the small-scale production of liquefied natural gas [6].

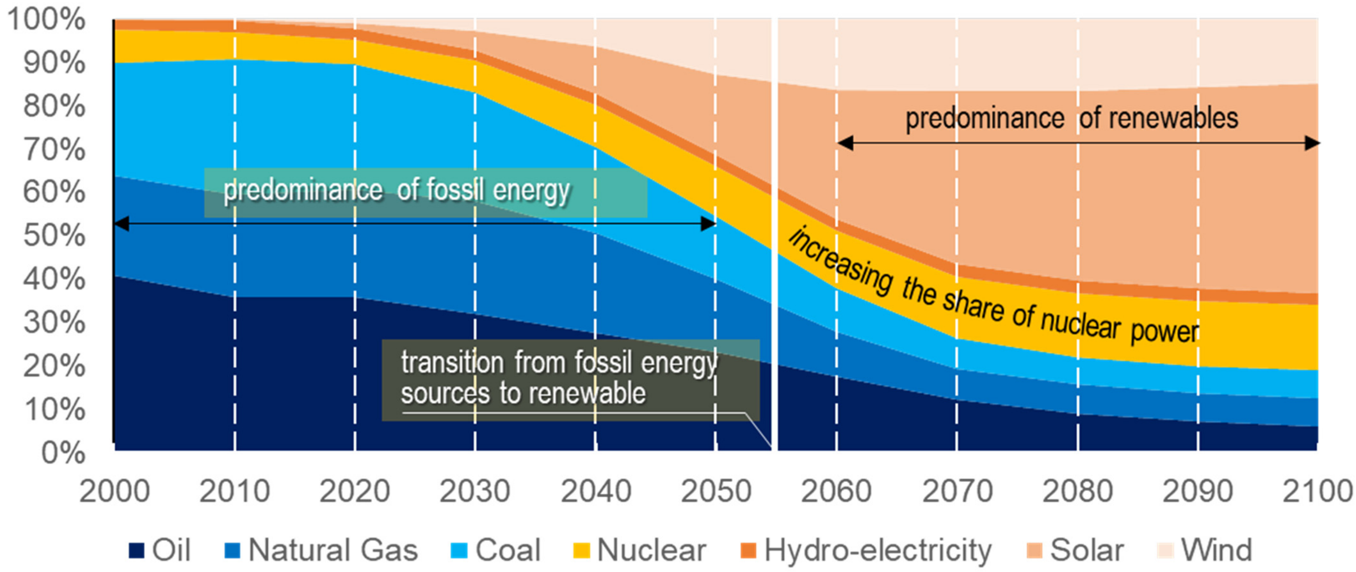

Figure 1. Energy production by fuel type. Adapted from [7].

Any hydrocarbon development project involves the generation of a significant amount of drilling waste that is difficult to dispose of and process due to its complex composition [8]. Nevertheless, the implementation of corporate waste management systems is a necessary and important element in the development of a closed-loop economy [9].

The purpose of this study is to compare two drill cuttings disposal methods used in offshore exploration drilling and identify the most effective one.

This study has the following objectives:

- To conduct a review of the literature regarding drilling waste disposal options to identify the most effective ones in offshore exploration and production and assess recycling prospects;
- To determine the initial data and methodology for calculating drill cuttings volume and associated transportation costs;
- To compare the results and identify the advantages and disadvantages of the drilling waste disposal methods under analysis;
- To assess the prospects of using these methods in offshore drilling in Russia.

2. Literature Review

2.1. Current Situation

While the interest in fossil fuels has not waned, the coronavirus pandemic has slightly reduced the volumes of prospecting, exploration, and development drilling. In 2021, drilling volumes fell to 25.9 million meters, or 5.13%, compared to the pre-pandemic year of 2019 (Figure 2).

Despite this, Rystad Energy predicts that drilling volumes will gradually increase, and the growth rate will depend on the price of oil on the market (Figure 3).

The data show that the oil prices have been fluctuating over the years and are strongly influenced by the global political situation. Nevertheless, over the past 2.5 years, the oil price showed a positive trend, making many well construction projects lucrative. Between 2022 and 2025, the number of wells will be in the region of 55,000, growth will be mostly driven by drilling wells for hard-to-recover reserves (shale hydrocarbons), and the share of offshore wells will be between 3 and 4%.

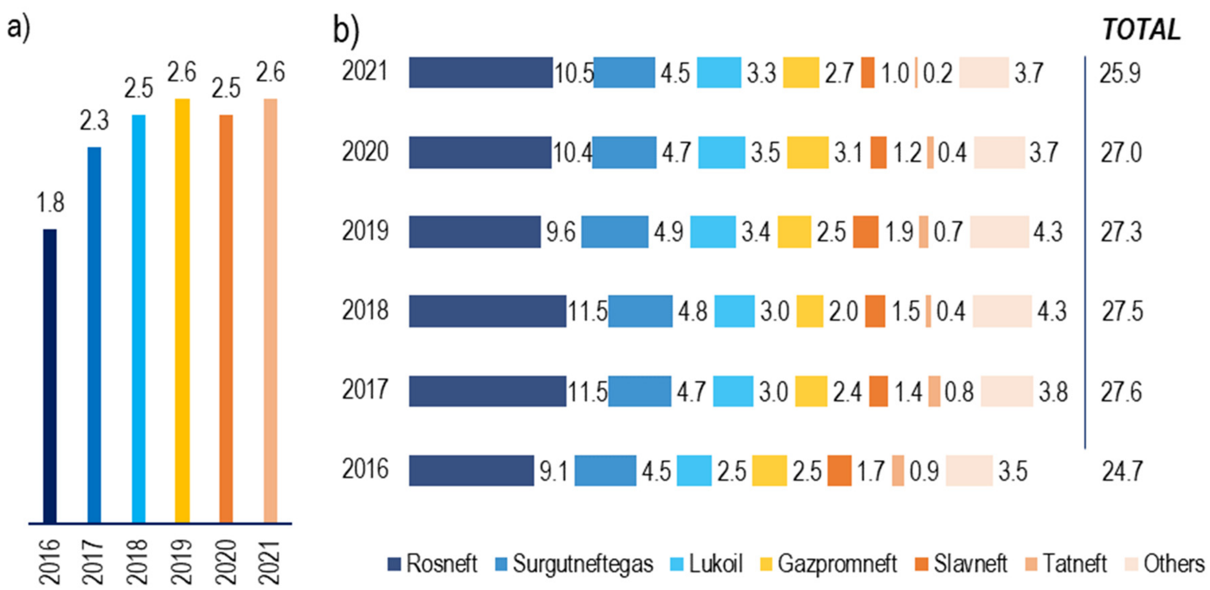

Figure 2. Drilling indicators from 2016 to 2021: (**a**) the costs of prospecting and exploration drilling for hydrocarbons, billion USD without VAT; (**b**) production drilling by companies of the Russian Federation, million m [10–16].

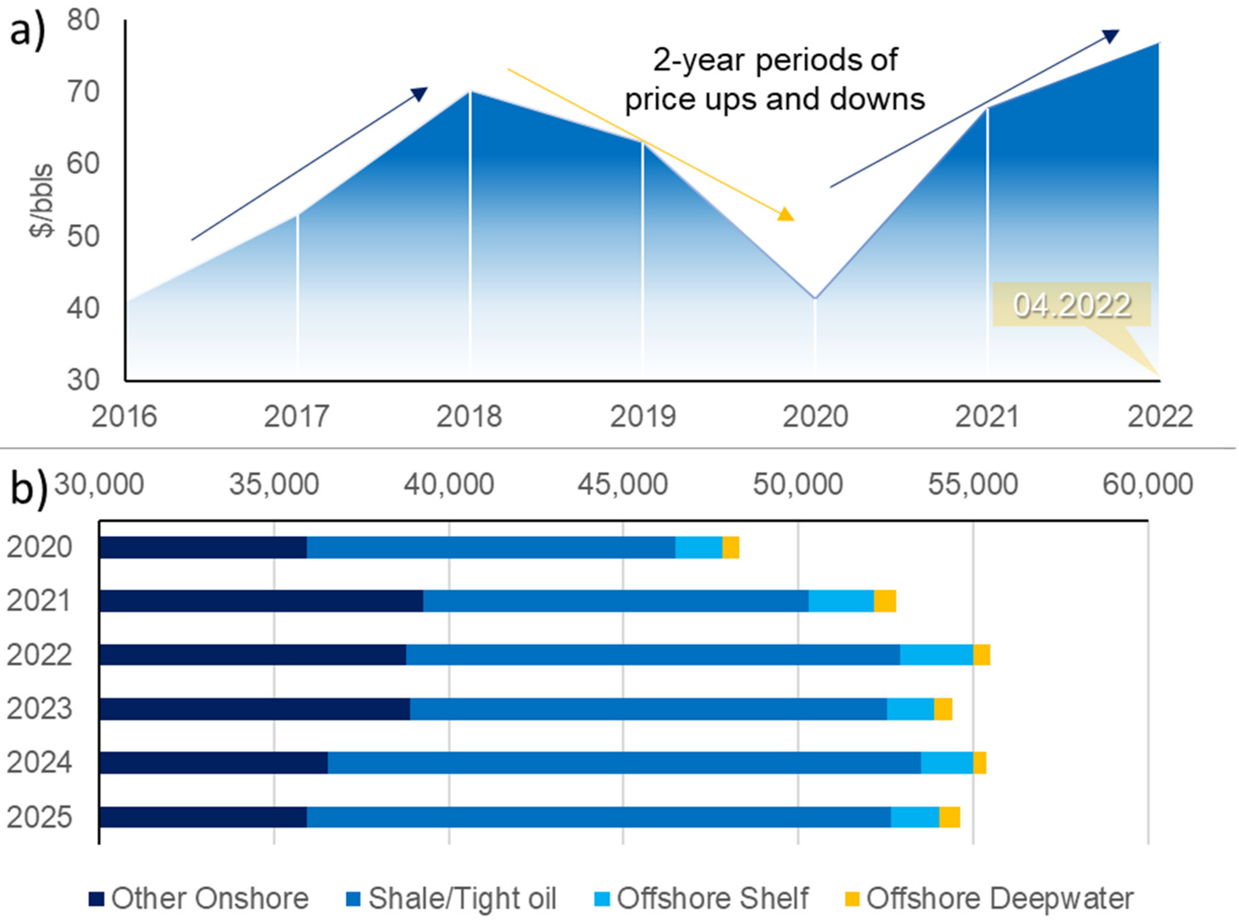

Figure 3. The cost of oil and changes in drilling volumes: (**a**) the cost of Urals oil according to VYGON Consulting; (**b**) global changes in well drilling and completion, pcs. [17,18].

2.2. Options for Drilling Waste Disposal

In the early days of the oil and gas industry, humanity did not think about the ecological damage caused by discharging drilling waste into the environment without any primary treatment aimed at neutralizing hazardous components [19]. Later, it was revealed that both ecosystems and humans suffer from hazardous chemical components that the drilling mud contains. Negative effects include the death of organisms [20], as well as conditions and symptoms in humans such as dermatitis, nausea, cough, and irritation of the skin and mucous membranes [21,22]. Therefore, the safe disposal of drill cuttings requires greater attention around the world.

Waste disposal has always been an integral part of the exploration, development, and operation of oil and gas fields, especially considering the enormous amount of waste generated. According to the analysis by S. Rana [23], one well produces 1000 to 5000 m^3 of drilling waste. Data given in [24] show that corporate waste management systems considerably influence both environmental and financial aspects and the corporate image. However, it should be clearly understood that an effective waste management system is an ongoing process that involves reviewing the system already in place and introducing new approaches to managing the waste produced in a more rational and environmentally sound manner.

According to [25], waste management methods can be divided into biological (decomposition of waste into non-toxic components by bacteria and fungi) and non-biological, such as landfill disposal, cutting reinjection (CRI), stabilization and encapsulation, and thermal treatment (incineration, gasification, desorption, evaporation, pyrolysis). The methods listed above have advantages and disadvantages. CRI requires that drill cuttings are milled and mixed with drilling mud to produce a slurry, while the injection process entails such risks as waste leakage because of the high pumping pressure and loss of valuable oil components [26]. While being low-cost and using simple technology, biological methods can take months or even years to implement [27]. Some authors [28] suggest reusing the used drilling agents by means of the vibroacoustic method.

There are two key methods of offshore drilling waste management. The first is the so-called Skip and Ship method [29], which implies loading waste into a skip (some container or tank) and transporting it to the shore. The second is in situ disposal. The choice of one method largely depends on the distance between the deposit and the onshore infrastructure and the depth of water [30].

Apart from these methods, there are phytoremediation [31], microwave heating [32], and supercritical extraction [33], but they have not been discussed or used much.

It should be noted that there is an opportunity for waste valorization, especially if the traditional landfilling method is not used. According to the information in [8], the thermomechanical treatment of drill cuttings (TCC) can recover some valuable products (Figure 4). This process contains the following coherent steps [8]. Drilling waste from the drilling mud recirculation system with the cuttings enters the feed hopper. Further, this waste is fed to the mill using a hydraulic pump. The mill grinds solids and generates kinetic energy due to friction, which is converted into heat. The mill is heated to a certain temperature (oil evaporation temperature). Oil and water evaporate, and solids from the cyclone are sent to the screw conveyor. In the cyclone, oil and water vapors are purified from solids. Further, oil is extracted from the vapors in the oil condenser without condensation of water, while the vapor temperature is cooled to about 105 °C. This enables oil to condense while the rest of the steam-containing water enters the steam condenser. In the steam condenser, cooling occurs up to 40 °C, and after that, the condensate enters the gravity separator, where it is separated into oil and water.

The drilling of seven offshore wells in Cyprus between 2013 and 2019 produced 10,922 tons of waste; 783 tons of oil, 5897 tons of saline water, and 4241 tons of solid residues were recovered from this waste.

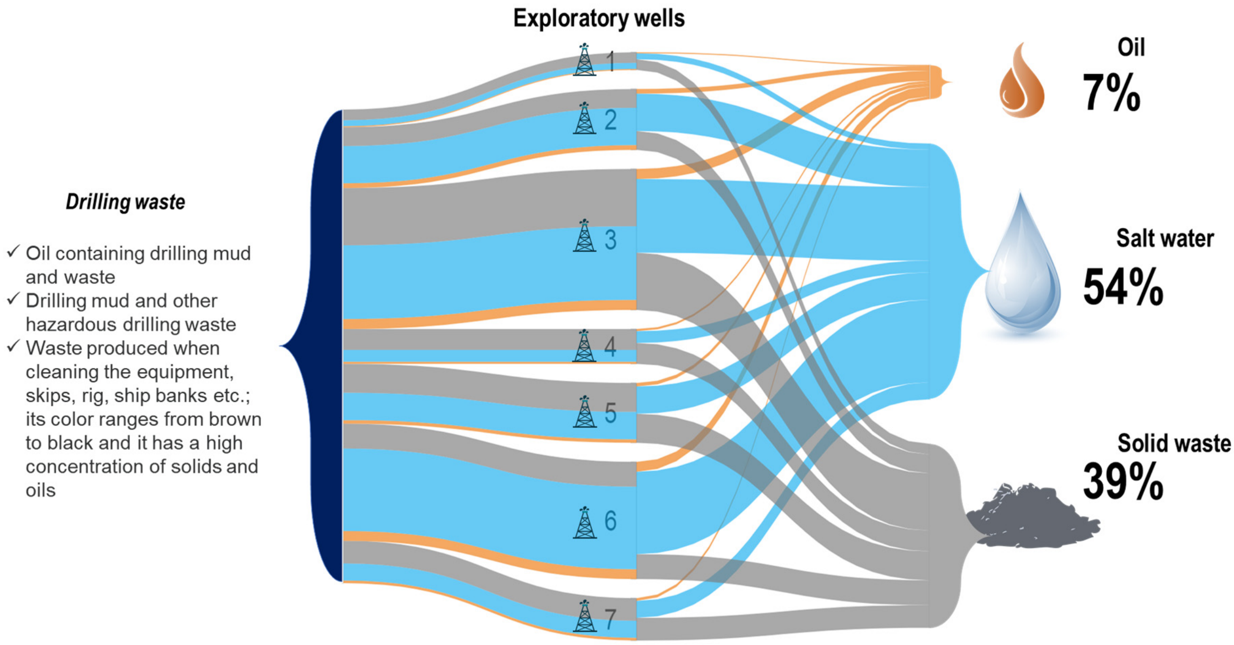

Figure 4. Valuable products obtained after thermomechanical cuttings cleaning at offshore exploration wells in Cyprus. Adapted from [8].

Some researchers have suggested that solid residues could be used in asphalt and concrete production. For example, the research discussed in [34] analyzed drill cuttings from an oil well located on the continental shelf of Nova Scotia (the Atlantic part of Canada). In the course of the research, it was revealed that up to 20% (by weight) of the drilling waste from this particular sample could be used, but the percentage depends on waste properties, especially on the size of grains and their strength. Years later, Foroutan M. et al. [35] also proved that the use of drill cuttings as a controlled low-strength material for cement manufacturing is possible because the strength properties of concrete do not deteriorate when the percentage of drill cuttings is properly calculated. Vlasov A. et al. [36] found out that the use of drill cuttings as a mineral powder in asphalt concrete production in quantities up to 7% by mass can provide physical and mechanical properties of the product corresponding to the national standard GOST 9128-2013.

3. Materials and Methods

Based on the literature review conducted in the field of drilling waste management, an algorithm for choosing one or another method of drilling sludge disposal in offshore conditions was compiled. It is necessary to collect the initial data to determine one or another method:

- Geological: mineralogical composition of rocks, fluid properties, reservoir conditions of occurrence (reservoir pressure, abnormally low or abnormally high, presupposes the basis the drilling fluid will be selected on), the presence of layers suitable for drilling an absorbing well;
- Geographical: the main condition is the distance from the deposit to the shore;
- Ecological: proximity of fragile ecosystems and specially protected areas;
- Legislative: restrictions on environmental standards are prescribed in the regulatory framework of each state;
- Climatic conditions: ice conditions, duration of the drilling slot period.

So, each condition reflects the initial data (Figure 5).

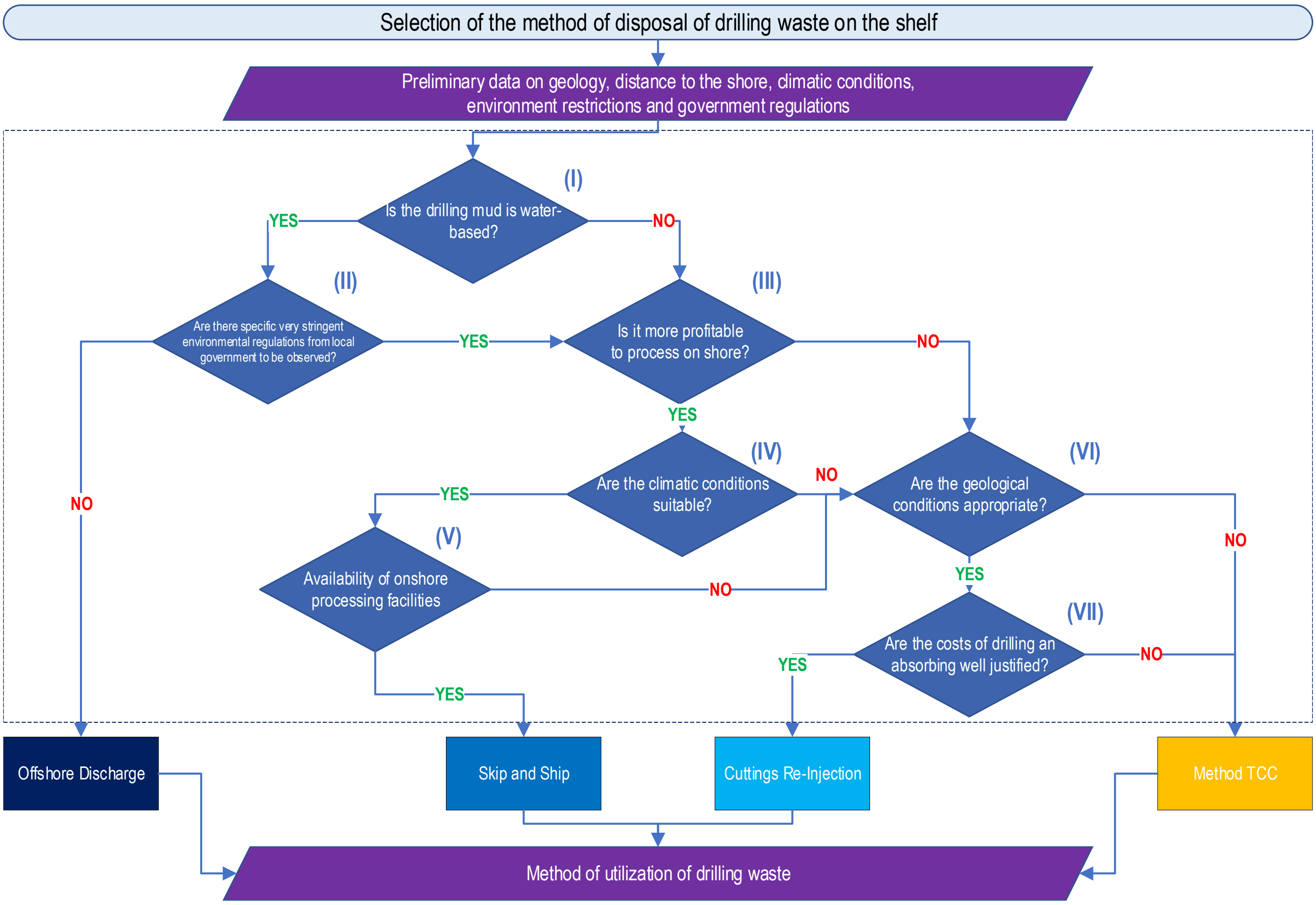

Figure 5. Algorithm of selection of the method of drilling waste disposal.

- (I) *On what basis will be the drilling mud?* According to the source [37], there are three types of drilling fluids: oil-based, water-based, and pneumatic. The water-based solution affects the environment to a lesser extent, and after the Cuttings Dryer System, it is possible to discharge the resulting waste into the waters.
- (II) *Are there very stringent, specific environmental regulations from the local government to be observed?* In any case, in order to discharge drilling waste into the sea, it is required to purify them to environmental standards adopted by the state in environmental protection regulations. For instance, different countries use their own specific requirement or technical specification related to drilling discharge and waste management [20].
- (III) *Is it cost-effective to process waste onshore?* The Skip and Ship method is well-known and quite simple to implement compared to other methods of waste disposal on the shelf [8].
- (IV) *Are the climatic conditions suitable?* The Skip and Ship method is subject to restrictions under difficult climatic conditions; for example, if the deposit is located in Arctic waters, then it is necessary to take into account the ice conditions.
- (V) *Are there any waste processing facilities nearby?* After transporting drilling waste ashore, it is required to deliver them to the nearest processing point. In the absence of such structures, the method is rejected.
- (VI) *Are the geological conditions appropriate?* If there is an absorbing reservoir for drilling a well for drilling waste, it is possible to avoid the purchase of expensive equipment for its processing, and waste-free drilling also occurs since the volumes of waste are injected into the well and do not affect the environment.

- (VII) *Are the costs of drilling an absorbing well justified?* Drilling an absorbing well is an expensive process. This type of disposal will be justified in the case of production drilling and not exploration (during which one or, less often, two wells are drilled).

Thus, this algorithm helps in selecting one or another method of utilizing drilling waste. In this study, we tested (III) the condition of the algorithm where it is more profitable to recycle drilling waste. Further, following the algorithm, the CRI method is excluded since only one well is drilled per exploration operation.

For the purposes of this study, we will consider two drilling waste management options according to the algorithm (Figure 5). Option 1 is the Skip and Ship disposal of drill cuttings. Option 2 is on-site disposal. The efficiency of drilling mud processing will be considered the same for both options. A conceptual representation of the methods is shown in Figure 6.

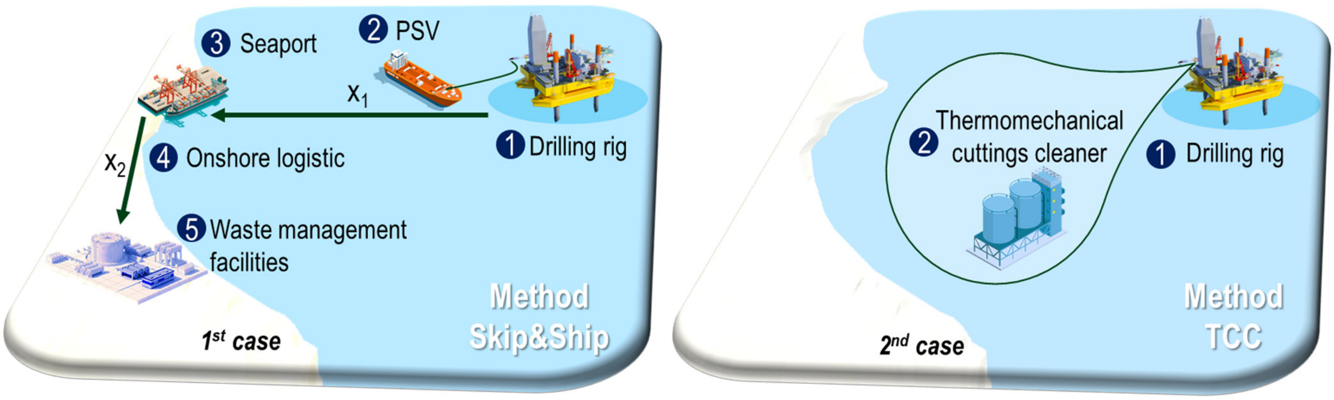

Figure 6. Two cases for waste management.

Let us suppose there is a hydrocarbon field A at a certain distance from the coast (x_1) and the depth of the sea is a variable. A vertical exploration well is being drilled as part of a prospecting and exploration project. The choice of the number of casing strings depends on the geological conditions of well drilling (reservoirs with different drilling conditions, reservoirs with abnormally high or abnormally low pressures, and intervals with lost circulation) and also on the technological requirements of the operator [38]. The design of the exploration well intended for offshore use consists of five casing strings: conductor, surface casing, first intermediate casing, second intermediate casing, and production casing (Table 1) [39].

Table 1. Casing design of the exploration well (field A).

Casing String	Drill Bit Diameter, mm	Casing Collar Diameter, mm	Outside Casing Diameter, mm
Conductor	914.0	804.0	762.0
Surface casing	660.0	533.4	508.0
1st intermediate casing	444.5	365.1	339.7
2nd intermediate casing	295.3	269.9	244.5
Production casing	215.9	194.5	177.8

The casing diameter and the parameters of the cone bit are defined according to GOST 632-80 and GOST-20692-2003. The results are demonstrated in Table 1.

Once the borehole design is determined, the volume of rock drilled in m^3 can be found according to the guidance RD 39-3-819-91 using Formula (1):

$$V_r = \sum_i V_{ri} = \frac{\pi}{4}\left(10^{-3} \cdot \lambda_i \cdot D_{\mathrm{dbi}}\right)^2 \cdot L_i, \quad (1)$$

where V_r—total volume of rock drilled, m^3; V_{ri}—ith volume of rock drilled, m^3; λ_i is the average cavity coefficient in the drilling interval i; $D_{\text{db}i}$ is the drill bit diameter, mm; and L_i is the design depth of casing, m.

The cavity coefficient λ is equal to the ratio of the volume of the caverns to the apparent volume of the sample. According to [40], the cavity coefficient varies from 1.1 to 2.5 depending on the depth of the formation. In this research, we take the values of the λ depending on the drilling intervals: λ_1 = 2.5, λ_2 = 1.3, λ_3 = 1.3, λ_4 = 1.2, λ_5 = 1.1.

Option 1 requires calculating sea transportation costs, which include heavy fuel and personnel costs. A PSV (platform supply vessel) is used as the vessel transporting the drilling waste. In oil and gas production practice, such vessels are expensive for companies because of their high operating costs [41]. The task of reducing these costs by optimizing vessel speed and taking weather conditions into account can be solved by partial integer programming [42].

For the calculation, we use vessel data from [43] and the methodology proposed in [44]. The total fuel volume in tons for the PSV is equal to the following:

$$Q_F = 10^{-3} \cdot q \cdot N \cdot \eta \cdot (T_1 + T_2), \tag{2}$$

where q is specific fuel consumption, kg/kWh; N is installed power, kW; η is the share of consumed power; T_1 is the total time taken to move the vessel, h; T_2 is the time taken to load or unload drilling waste, h.

The total time taken to move the vessel is as follows:

$$T_1 = \frac{2S}{v} \cdot n, \tag{3}$$

where S is the distance from the port to the field, km; v is ship speed, km/h; n is the number of shipments during the well drilling period.

Drilling waste discharge loading and unloading time is as follows:

$$T_2 = \frac{V_{\text{r}}}{v_{\text{dis}}}, \tag{4}$$

where v_{dis} is the discharge rate, m^3/h.

Fuel costs are calculated as follows:

$$C_F = Q_F \cdot p_F, \tag{5}$$

where p_F is fuel costs TSO, \$/ton.

Staff costs are

$$C_P = \left(T_{mar} + T_{tr} + T_{pr}\right) \cdot p_P, \tag{6}$$

where T_{mar} is the time taken to marine operations, days; T_{tr} is the time taken to transport to the processing site, days; T_{pr} is the time taken to process waste, days; p_p is personnel costs per day, \$/day.

The marine operations' time is

$$T_{mar} = T_1 + T_2. \tag{7}$$

The time taken to transport to the processing site hinge on some factors: the capacity of the trucks, the volume of waste, and the distance between the seaport and the production site. To simplify our model, let the T_{tr} is 1 day in average.

The process operations' time is

$$T_{pr} = \frac{V_{\text{r}}}{24 \cdot v_{pr}}, \tag{8}$$

where v_{pr} is process rate, m^3/h.

Having found offshore transportation costs, it is necessary to calculate onshore transportation costs (transit from the port to the waste treatment plant), the cost of drilling waste disposal itself, and downtime costs caused by weathering [45].

Under option 2, there are no offshore or onshore transportation costs because the drilling waste is disposed of on-site, so there is no need for a ship, and downtime costs are also eliminated. The main cost items are the purchase and installation of equipment, the personnel involved, and the energy required for processing [46].

The data for cost-benefit analysis were gathered from open sources and are presented in Tables 2–4. The well depth and the distance from the shoreline to the exploration site were taken from data by Wood Mackenzie on offshore projects in Russia (Table 2).

Table 2. Data on Russian offshore projects.

Field	Depth of Exploratory Wells, m		Distance from the Shore, km		Depth of Sea Level, m	
	from	to	from	to	from	to
Prirazlomnoye	2412	4495	60		20	
Pobeda	2350		>500		1	335
Neptun, Triton	2700	3000	30	55	62	80
Shtokmanovskoye	2484	3153	550		300	350
Vladimir Filanovsky	1650	2600	10		100	120

Source: created by the authors, data from [47].

In our research, we take the distance from the deposit to the shore as the average (141 km) according to the values given in Table 2.

The key regulatory document for producing marine fuels is ISO 8217. In Russia, GOST 32510-2013 is also used [48]. A fuel density of 991 kg/m^3 was used in the calculations. The cost of marine residual fuel is 693 \$/ton [49].

Drilling intervals for each well casing section are shown in Table 3.

Table 3. Depth of columns and wells.

Casing String	Interval Depth, m		Source
	from	to	
Conductor	90	120	[38]
Surface casing	400	700	[50]
1st intermediate casing	800	1100	[50]
2nd intermediate casing	1300	2000	[50]
Production casing	2350	4495	[47]

To make calculations precise, we used data for several vessels with different operational parameters (Table 4): capacity, discharge rate, installed power, vessel speed, and specific fuel consumption.

Table 4. Platform supply vessel data.

Platform Supply Vessel	Capacity, m^3	Discharge Rate, m^3/h	Installed Power, kW	Vessel Speed, km/h	Specific Fuel Consumption, kg/kWh
Baltic	257	159	625	14.8	0.15
Cabral	441	228	2811	22.2	0.25
Resolute	798	136	2850	17.2	0.26
Defiance	970	75	3945	18.5	0.24
Demerara	1085	75	4873	15.9	0.18

Source: created by the authors, data from [43].

4. Results

Geological conditions are pivotal in deciding how the field will be developed. They include reservoir thickness, type, filtration properties, depth of occurrence, and the degree of hydrodynamic connectivity. The field development system depends on them, including the plan of field development with reservoir pressure maintenance and oil recovery enhancement (systems, the number of and the relationship between production and injection wells, and the distance between them) [51,52]. Geological risks are extremely important to assess because they are associated with unproven hydrocarbon reserves, and dealing with them puts the economic indicators of the entire project at risk [53,54].

As mentioned above, the well design depends directly on the geological structure of the hydrocarbon deposit. Using the ranges of casing depths shown in Table 3, let us estimate the volume of rock drilled using statistical modeling (Monte Carlo method), which eliminates uncertainty and gives the highest probability of determining the desired value [55]. The result is shown in Figure 7.

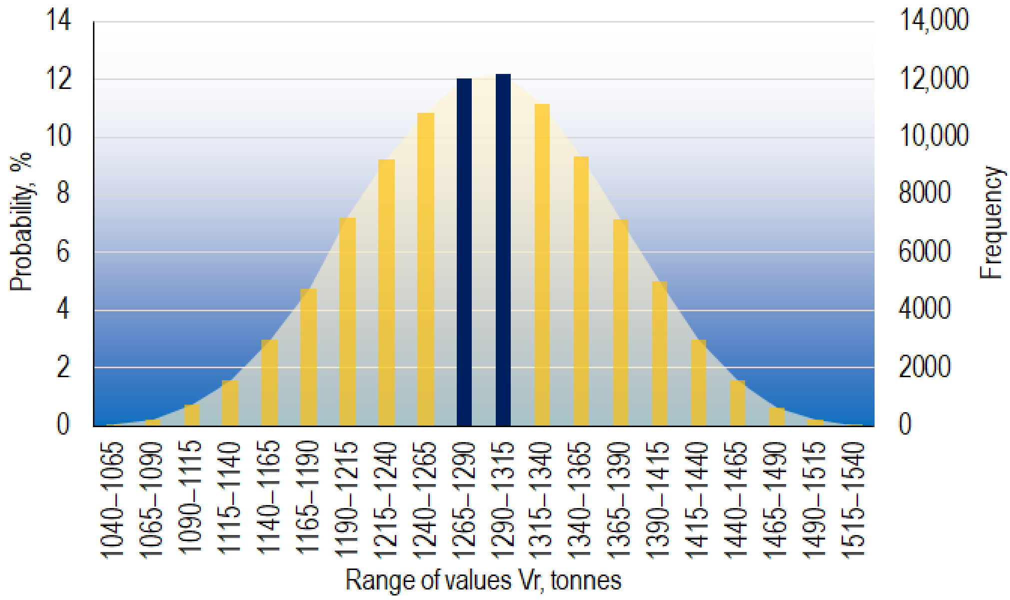

Figure 7. Search for the volume of drilled rock by the Monte Carlo method.

The parameters L_c, L_{sc}, L_{1ic}, L_{2ic}, L_w in the model were set using the RANDBETWEEN MS Excel function. The average (most likely) value is 1290.1 t, and the standard deviation of the sample of 100,000 values is 77.7 t.

The resulting value correlates with the drilling waste values discussed by the authors of [8], namely, from 406 to 3252 tons of drill cuttings with an average value of 1549 tons.

Offshore transportation costs were found using open-source data (Table 5). On average, the cost of transport from the platform to the port is USD 125,974 (not including possible downtime due to weather and vessel leasing).

Table 5. Calculation of offshore transportation costs.

PSV	Quantity of Shipments	Total Discharge Time, h	Ship's Travel Time, h	Fuel Volume, Tones	Fuel Costs, USD	Personnel Costs, USD	Total, USD
Baltic	5	8.0	19.0	8.2	6751	174,510	181,261
Caspian	3	5.6	12.7	26.1	18,078	110,843	128,921
Resolute	2	9.3	16.4	26.5	18,354	108,755	127,109
Defiance	2	16.9	15.2	38.1	26,414	116,411	142,825
Demerara	2	16.9	17.7	39.0	27,029	119,352	146,381

Source: created by the authors, data [43,56].

The next step after calculating offshore transportation costs is to find onshore transport costs as well as the costs related to downtime due to weather. Waste can be transported from the port to the processing site by either rail or road [57]. These costs can be calculated using the literature (Table 6) [58].

Table 6. Results of a comparison of drill cuttings disposal methods by cost items.

Cost Item	Skip and Ship, USD	TCC, USD	Source
Construction and installation work	-	166,087	[46]
Equipment costs	-	332,173	[46]
Offshore transportation costs		eliminated	
Fuel	19,325	-	calculated
Personnel	125,974	-	calculated
PSV hire	316,356	-	[41]
Onshore transportation costs	145,299	eliminated	[57]
Downtime due to weather (10% of offshore transportation costs)	46,166	eliminated	[44]
TOTAL	563,183	498,260	

To quantify the risks, we compiled a sensitivity analysis to compare the two methods. Assuming that the cost of the TCC method is constant, we estimate the possible economic effect of using the Skip and Ship method depending on the variable initial indicators: daily wage rate, PSV hire, distance to the shore, and waste volume. The analysis step is 10%. The resulting indicator will be the total cost of the method (Figure 8).

Figure 8. Sensitivity analysis of Skip and Ship method.

Costs are most sensitive to changes in the PSV hire and daily wage rate. Only with a reduction in the PSV hire by about 19% will it be more profitable to use this method compared to TCC. Costs are the least sensitive to the volume of waste generated and the remoteness of the deposit from the shore.

As can be seen, drill cuttings disposal on-site using thermomechanical cuttings cleaning is USD 64,923 more cost-effective for the given parameters. These results must be viewed critically, as there are uncertainties in the data collected. Some parameter values may be overestimated due to insufficient data, or cost values may be taken from different time frames (i.e., the concept of the time value of money must be used to estimate costs, as in any project [59]).

5. Discussion

Despite the effectiveness of the TCC method and a large number of patent developments, it has not found widespread application in Russia. However, in the Yurkharovskoye gas condensate field, thermomechanical cleaning is used to decontaminate drilling waste with the subsequent use of the resulting products as components for road construction in the field [60].

There are advantages and disadvantages to each of the drilling waste disposal methods (Tables 7 and 8).

Table 7. Advantages and disadvantages of the Skip and Ship method [61].

Advantages	Disadvantages and Limits
• Elimination of future environmental liabilities on the drilling platform • No impact on seabed organisms • Beneficial in areas with nearby protected areas and fragile ecosystems • Well-known and simple technology	• More CO_2 emissions due to fuel consumption by ships and dry bulk traffic • High risk of spillage during sludge transport • No sludge treatment, which may result in harm to the environment • Operating costs are highly dependent on sludge volumes and distances between sites • Harmful effect on the personnel • Weather influences economic efficiency • Necessity for permanent environmental monitoring • Necessity for waste treatment capacity

Table 8. Advantages and disadvantages of the TCC method [8,25].

Advantages	Disadvantages and Limits
• Smaller volumes of waste to be disposed • Generation of commercially viable products in the cleaning process • Reuse of recovered products • Reduced environmental impact due to the closed-loop nature of the facility and minimization of CO_2 emissions • Reduction of operating costs	• High capital costs • Highly skilled personnel required • Requires close monitoring of resulting products

The Skip and Ship method can only be economically advantageous if there is close proximity to onshore infrastructure and hazardous waste treatment facilities. As for the TCC method, some authors claim that it is not profitable for businesses that plan to drill a single exploration well. This study proves the contrary.

It is also necessary to evaluate the possibility of applying one or another method to specific hydrocarbon fields on the Russian continental shelf depending on their location (Figure 9). For example, for the fields of the Arctic shelf (Shtokman and Pobeda), it is necessary to take into consideration climatic conditions apart from ecological and production limitations [62,63], which makes the use of the Skip and Ship method limited (for example, due to ice conditions or the impossibility of building processing plants caused by permafrost degradation) [64]. For the Sakhalin, Neptune, and Triton offshore fields, the TCC method can be used since there is no production capacity for processing drilling waste, or the CRI method can be applied, as in the case of Sakhalin-1, Sakhalin-2, and Prirazlomnoye projects. The Skip and Ship method best fits Vladimir Filanovsky, a field in the Caspian Sea, due to its proximity to the port and the availability of waste processing facilities.

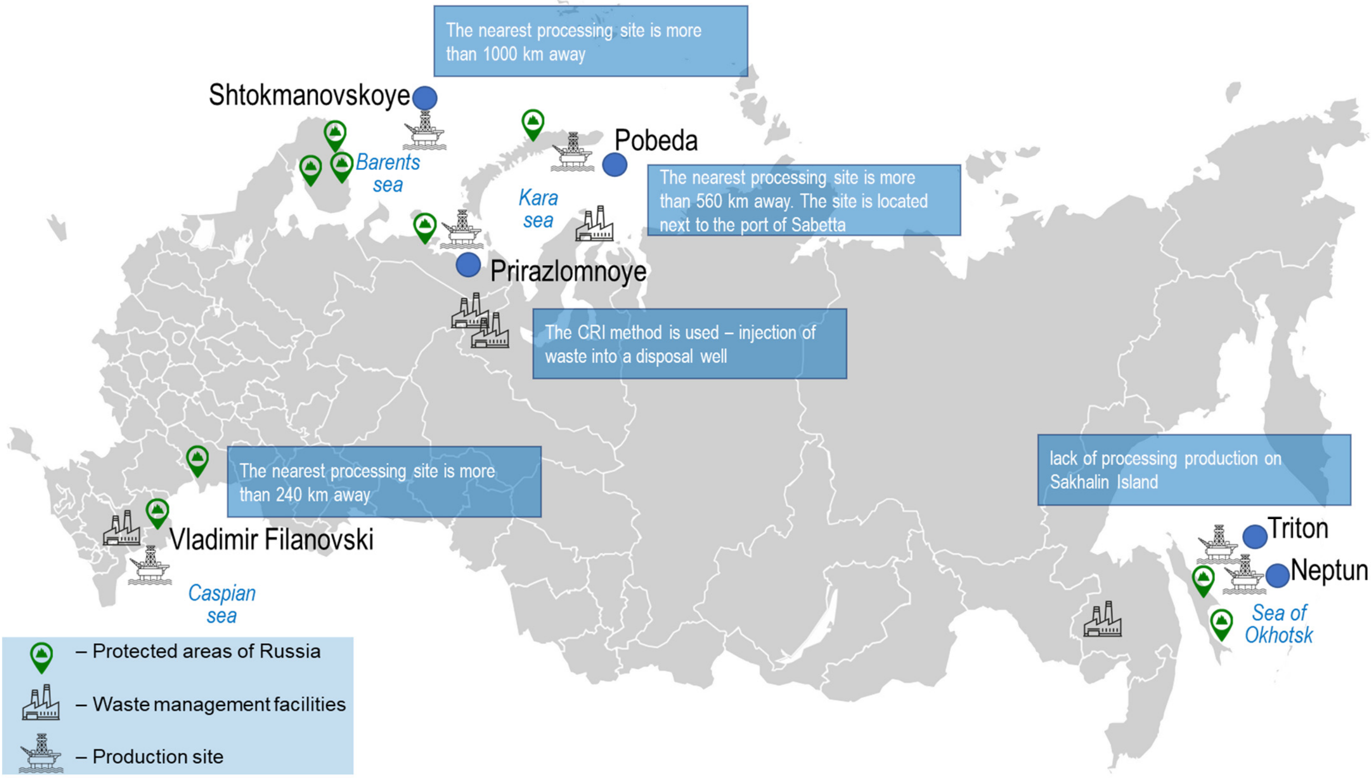

Figure 9. The availability of production facilities and the proximity of specially protected areas to some of Russia's offshore fields. Adapted from [65].

6. Conclusions

Well drilling volumes have not decreased over the years, resulting in growing amounts of drilling waste that can contain various elements, such as heavy metals, inorganic salts, and hydrocarbons. Each of these elements has a deleterious effect on the environment. Therefore, the timely and environmentally sound management of drilling waste is essential for the oil and gas industry. Numerous studies have been conducted that prove the effectiveness of various methods of drilling waste treatment, and each has its advantages and disadvantages. Consequently, oil and gas companies are faced with the issue of selecting the best drilling waste management system for their operations.

Implementing improved drill cuttings management techniques can have a positive economic effect, as cuttings can be reused in the asphalt industry. Some methods make it possible to reuse drilling mud for the next well, and recovered hydrocarbons can be utilized either for the company's own needs (as a fuel) or for those of the consumer.

As the geological conditions of any field are unique and the lack of data creates uncertainties in calculations, it becomes necessary to use mathematical modeling. The results obtained must be critically assessed based on the quality of the data collected. Nevertheless, the methodology enables us to evaluate drilling waste disposal options in different hydrocarbon reservoir conditions.

According to our study, using thermomechanical cleaning on-site can save cuttings disposal costs and reduce the environmental impact.

In future studies, we plan to estimate the environmental effect of minimizing CO_2 emissions by rejecting the use of the Skip and Ship method and breaking down cost items to produce better calculations of offshore and onshore transportation costs and energy costs associated with processing. It is also planned to identify the reasons why such an attractive drill cuttings disposal method has not been used much in Russia and propose options for its implementation at a corporate level.

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