ENVIRONMENTAL ASPECTS OF OFFSHORE ACTIVITIES IN ARCTIC

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ÖZET

Dünya çapında artmakta olan enerji talebi, dünyanın ilgisini nispeten daha az keşfedilmiş ve zengin hidrokarbon kaynaklarına sahip Arktik bölgesine çekmiştir. Bu çalışmada, Arktik bölgesinde yürütülen açık deniz faaliyetlerinin, güncel durumu, karşılaşılan zorluklar ve olası çevresel etkileri değerlendirilmiştir. Arktik iklim ve çalışma şartları açısından zorlu bir coğrafya olup bu bölgede açık deniz faaliyetleri icra edilirken buzlanma, yüksek maliyetli operasyonel gereksinimler ve entegre esnasında zorluklar ile karşılaşılabilmektedir. Bunun yanında faaliyetler esnasında petrol sızıntısı, su altı patlaması, atmosfere yüksek sera gazı salınımı, atık su deşarjları gibi önemli yan etkiler ortaya çıkmaktadır. Alınabilecek tedbirler kapsamında yeni ve çevre dostu teknolojilerin kullanımı, yerinde yakma, sıfır deşarj politikası, faaliyet öncesinde tüm olasılıkların değerlendirilebileceği hazırlık ve planlama faaliyetleri gerçekleştirilebilir. Arktik'in gelecek dönemlerde açık deniz faaliyetlerine daha fazla ev sahipliği yapacağı, bu maksatla çevresel etkilerin ve alınabilecek önlemlerin daha detaylı incelenmesi gerekli olduğu değerlendirilmektedir.

Anahtar Kelimeler: Açık deniz faaliyetleri, Arktik, Çevresel etki, Hidrokarbon kaynaklar.
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ABSTRACT

Increasing worldwide energy demand has drawn the world's attention to the Arctic region, which is relatively less explored and has rich hydrocarbon resources. In this study, the current status, difficulties and possible environmental impacts of offshore activities carried out in the Arctic region were evaluated. The Arctic is a challenging geography in terms of climate and operating conditions, icing, high-cost operational requirements, great energy demand for extraction and difficulties encountered during integration while performing offshore activities. In addition, important effects such as oil spills, underwater blasts, high greenhouse gas emissions into the atmosphere and produced water discharges may occur during activities. Within the scope of the measures that can be taken, the use of new and environmentally friendly technologies, in situ burning, zero discharge policy, preparation and well-planning before the activity can be carried out. It is considered that the Arctic will host more offshore activities in the future, and for this purpose, it is necessary to examine the environmental effects and the measures that can be taken in more detail.

Keywords: Offshore activities, Arctic, Environmental impact, Hydrocarbon resources.
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1. Introduction

The Arctic Ocean is the smallest and shallowest of the five ocean basins of Earth, mainly covered by sea ice in winter but with more than half of the area ice-free during the permanently summer season [1]. Arctic Circle is the most widely used indicator to define the Arctic area but also the less accurate as it does not take into consideration any climatological or other geographical variations. According to this indicator, Arctic is an ocean placed in the north of the Arctic Circle (above the latitude of 66° 33' 44") [2]. If climatology is taken into consideration, the definition commonly accepted in engineering practices, "Arctic" refers to those places where the average temperature for the warmest month of the year is less than 10 °C [3].

The expanding demand for the oil and gas drives the explorations of the petroleum to the Arctic region [5, 6]. In 2008, the United States Geological Survey has assessed the area north of the Arctic Circle by using a probabilistic geology-based methodology and concluded that 22% of world hydrocarbon reserves (30% of the world's undiscovered gas and 13% (412 billion barrels) of the world's undiscovered oil) within these areas, mostly offshore under less than 500 meters of water and approximately 84% of such sources is expected to be found in offshore areas [7, 8, 9, 10, 11, 12, 13]. Undiscovered natural gas is three times more abundant than oil in the Arctic and is largely concentrated in Russia. Oil resources, although important to the interests of Arctic countries, are probably not sufficient to substantially shift the current geographic pattern of world oil production [14].

In this study, it is aimed to explain the current status of offshore activities in Arctic and the challenges encountered, and to review the environmental impacts and the measures to be taken by compiling different studies.

2. Offshore Activities in Arctic

2.1. Current Status

The Arctic environment is responding very sensitively to global warming, and the Arctic Ocean sea-ice is decreasing at a pace exceeding scientific predictions. Currently, the increasing meltdown of summer polar ice in the Arctic Ocean encourages the Arctic nations to perform offshore hydrocarbon exploration activities [2, 15].

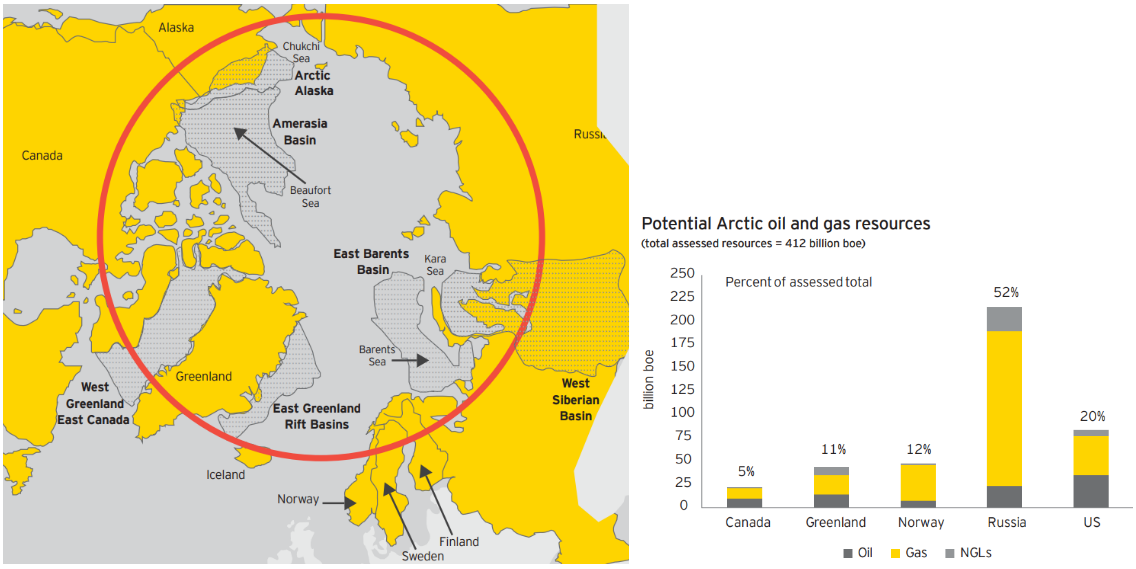

Figure 1. Probability of the presence of undiscovered oil/gas fields [9].

Figure 1 [9] shows the circumpolar Arctic region, the countries it includes, the most significant oil reserves, and the location of the Arctic Circle (see also in Section 1). Allocating the estimated resources/provinces to the nearest country (with “shared” provinces allocated equally), Russia is estimated to hold more than half of the total Arctic resources. Russia also holds the largest amount of natural gas resources, while the largest oil resources are in the US portion of the Arctic (Alaska). While Norway's offshore oil and gas reserves are beneath the North Norwegian and Barents seas, in Atlantic Canada, oil and gas activity occurs offshore the provinces of Newfoundland and Labrador, and Nova Scotia [17]. The largest oil and gas reserves in the Arctic are found in Russia. In Alaska there are six, in Canada eleven, and finally in Norway there is one large, discovered field [10, 18].

According to Novitsky et al. [19], offshore platforms can be divided into four groups based on operating depth: shallow (≤30 m), average depth (30-150 m), deep water (150-350 m), and ultra-deep water (≥350 m). Figure 2 shows various types of offshore structures and their operating depths. From a structural point of view, an offshore platform can be either fixed at the seabed or buoyant. Fixed platforms (fixed platform, compliant tower etc.), which are typically made of steel or concrete and are permanently anchored to the seabed. These platforms are more stable and less vulnerable to ice damage, but they are only suitable for use in relatively shallow waters. Buoyant platforms (tension leg platform, mini-tension leg platform, SPAR platform, floating production system, floating production, storage, offloading system) operate in deeper areas. These platforms are designed to move with the ice, allowing them to operate in shallow and frozen waters. The biggest challenge with buoyant platforms is the potential for ice damage, which can require significant maintenance and repair.

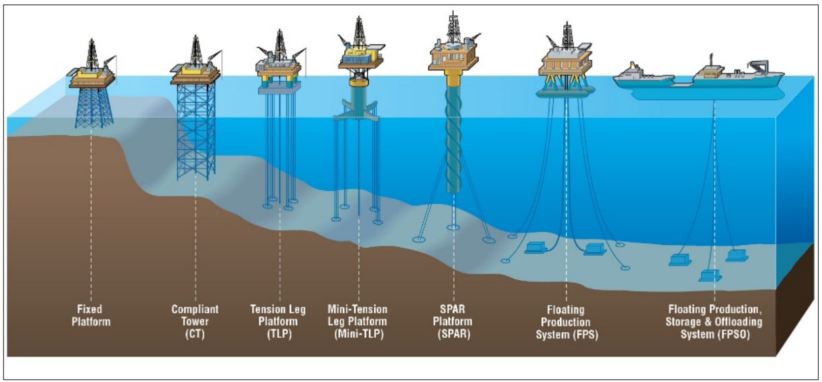

Figure 2. Types of offshore structures [60].

2.2. Challenges Encountered

Offshore activities in Arctic also bring a series of critical challenges to address:

Climate/Weather factors: The Arctic is characterized by a harsh climate with extreme variation in light and temperature, short summers, extensive snow and ice cover in winter, and large areas of permafrost [4]. The weather may deteriorate facility components at a higher rate, and delay operations, emergency and evacuation procedures. The remote and harsh environment is characterized by extreme waves, winds, storms, currents, icebergs, sea ice, and fog that hinder drilling operations and cause structural failures of critical offshore infrastructures. Moreover, these regions host unique ecosystems, and their preservation is a worldwide priority. For this reason, a comprehensive and systematic approach for risk analysis is necessary to prevent major accidents and comply with Arctic pollution control. Climate has considerable influence on the choice of design, operations, and maintenance [20, 21, 22]. From the past experiences, it is generally seen that bad weather causes loss of station keeping due to high winds and rough seas for floating structures and falling loads due to storms for fixed structures. Besides, high vulnerability to natural events of offshore infrastructure during transfer operations has resulted in numerous incidents [23]. Uncertainty on the influence of Arctic low temperature on offshore platform mechanical properties, which represents a topic for further investigation [6].

Icing: In his article, Barabadi et al. [24], emphasized that icing is a challenge for offshore structures and evaluated it by dividing it into two categories in general: atmospheric icing and sea spray icing. Atmospheric icing is defined as the processes where falling or drifting raindrops, refrozen wet snow, or drizzle form accretions on an object that is exposed to the atmosphere. Atmospheric ices are explained generally as hitting the deck of offshore structures; such as glaze (precipitating cold-water droplets), snow accumulation, rime (resulting from droplets in fog, sea smoke, or cloud drops), frost (direct transformation of water vapor to ice), sleet/ice pellets (accumulating loosely on horizontal surfaces such as decks, stairs, hatches, and helicopter landing pads). In the case of sea spray icing, the sea spray droplets are carried by the wind and hit objects in their way. Waves, volume of spray flux, and salinity of seawater are important factors that affect rate of sea spray. Sea spray accumulation occurrence is very rapid when there are high winds, low air temperature, and low sea temperature. Platform legs, bracing, blowout-preventer guidelines, mooring chains, marine risers, and flexible kill and choke lines in the splash zone 5–7 m above the sea are some potential areas for sea spray icing accumulation. Sea spray ice can reduce rig stability, damage rig structure due to changes in stress on structural components, cause slipping hazards, render deck cargo unavailable, disable winches, cranes, and antennas, cover windows, rescue equipment, hatches, firefighting equipment, valves, and radomes [15, 24].

Figure 3. Icing effects on offshore structures [15].

Great energy demand for extraction: The extraction of oil and gas resources requires greater amounts of energy for lifting fluid to the surface. The energy demand for lifting fluid to the surface in the Arctic is likely to be higher than in other offshore environments due to the cold temperatures and the need for additional heating and insulation. Besides, in Arctic, the cold temperatures can cause the viscosity of oil to increase, making it more difficult to transport and process. To reduce the viscosity, the method often used is extra heating. But, heating the oil can require a significant amount of energy, which can be expensive and potentially increase greenhouse gas emissions [25, 26].

High operational costs: Higher wages and salaries are required to induce highly qualified personnel to work in the isolated and inhospitable Arctic. Transportation of materials and equipment is extremely expensive (logistic challenges). The icepack can hinder shipment of personnel, materials, equipment, and oil for long time periods. Furthermore, long supply lines from the world's manufacturing centers require equipment redundancy and a larger inventory of spare parts to insure reliability [2]. Also in Arctic conditions, clean-up costs are likely to be significantly greater than in less remote areas with more developed infrastructure, and milder weather conditions [27].

Strict regulations: Following the Deep-Water Horizon oil spill in the Gulf of Mexico in 2010, regulations on offshore drilling have been tightened, thereby limiting access and increasing costs further [2]. However, although these regulations may seem harsh, it is an undeniable fact that they will be beneficial in reducing environmental impacts, as will be explained in the next sections.

Reliability and integrity challenges: Every offshore activity can have risks like; hull structural failures, riser system failures, mooring line failures, umbilical system failures and human failures by its nature [2].

3. Environmental Impacts of Offshore Activities in Arctic

3.1. Possible Hazards

Health effects of oil spills: New economic developments in the Arctic, such as shipping and oil exploitation, bring along unprecedented risks of marine oil spills [28]. Oil spill is the major threat for these kinds of activities. Over the past 100 years, 7 million tons of oil has been spilled into the global environment from over 140 major incidents in addition to an estimated 600,000 tons of oil released annually from natural seeps [29, 30, 31]. For Arctic, A 2013 BOEM analysis of oil spills in the North Slope area between 1971 and 2011 identified 10 spills larger than 660 tons, and 2 spills larger than 1,300 tons [61]. In the report that Eger et al. [32] prepared, the reasons of oil spills could be from process leak, blowout, riser/pipeline/subsea structure leak, object on collision course; damage to structure; leak during loading/offloading. Differences in temperature between Arctic and temperate systems may alter the physical behavior of oil [5], hence oil spills can have more severe effects to living creatures: They can have negative impacts on local food sources because of contaminants and toxic substances that accumulate in the food chain of animals consumed as traditional foods [33, 34]. They may cause a loss of coastal areas and/or subsidence of land, contamination of beaches and rocks negative impacts on wildlife, including the killing of mammals, fish stocks, seabirds and shorebirds and various marine resources. Loss of land may also be due to the handling of contaminated waste, or by setting up a quarry on land to store oil from beaches. Such quarries may cause risks to wildlife, especially birds that may mistakenly identify it as a water source [33]. It should not be forgotten that Arctic plants and animals need a longer time to recover from damage because oil breaks down more slowly under cold conditions than warmer environments [2, 35]. Also shallow water sediments may become contaminated due to oil spills, as well as coastal vegetation, which may accelerate rates of erosion, wetlands may be lost, in addition to damage to “deep-sea coral communities” and “seaweed habitats harboring deep-sea shrimp, crab, and lobsters” [33]. Besides animals, they have effects to human health indirectly: Unpleasant oil smells and/or smoke/air pollution from a fire are also likely consequences of oil spills [33]. The health risks from oil and gas extraction are not only through air pollution but also through contaminated drinking water sources with chemicals that lead to cancer, birth defects, and liver damage [4]. Arctic oil spill response is challenging because of extreme weather and environmental conditions; the lack of existing or sustained communications, logistical and information infrastructure; significant geographic distances; vulnerability of Arctic species, ecosystems, and cultures. Timely and effective response to oil spills requires containment, recovery and restoration [2]. Johannsdottir and Cook [33] highlighted that oil spill response viability varies greatly throughout the year, with the situation better during summer months (July to October), when most areas are ice-free. However, during winter months’, responses may not be as favorable. Location is another key aspect affecting likely response times. Oil spill responses are more favorable in the Bering Sea, Barents Sea, Norwegian Sea, Baffin Bay, Hudson Bay, and North Atlantic, while the situation is less favorable in other areas within the Polar region [36]. As a result, oil spills in ice infested waters are harder to deal with than open water, and that Arctic waters “might never recover from an environmental catastrophe like the one in the Gulf of Mexico” [37].

Harm to marine life due to underwater blasts: An underwater blast is accompanied by large amounts of air bubbles rising to the surface for a few minutes [38]. Underwater blasting can cause a range of impacts from the motile biota escaping the area of operation to lethal injuries or immediate death, the impacted animals ranging in size from fish larvae and small fishes to large marine mammals [38, 39, 40]. According to Kjesbu et al. [55], underwater blasts cause significant behavioral changes in cod and herring, leading to decreased feeding and increased stress levels. Additionally, underwater blasts can result in physical damage to marine organisms. In a study of beluga whales in the Beaufort Sea, researchers found that exposure to underwater blasts caused damage to the whales' auditory systems, leading to hearing loss and potential impairments in their ability to communicate and navigate [56]. Furthermore, the effects of underwater blasts on the Arctic ecosystem extend beyond direct physical harm to individual organisms. These blasts can also cause migration of marine species, leading to changes in population dynamics and potentially disrupting the delicate balance of the ecosystem. In a study of narwhals in the Canadian Arctic, researchers found that underwater blasts resulted in the animals shifting their migratory patterns and moving away from their usual habitats [57].

Underwater blasts and dredging's suspended sediments and effects to benthic communities: Studies of dredging activities have shown that spreading of suspended sediment takes place, e.g., near the surface or near the bottom, depending on the type of dredge being used [38]. These sediments mainly have effects to benthic communities. Benthic data is regularly collected worldwide to assess the environmental quality of marine ecosystems, by comparing proportions of species tolerant or favored by pollution, to species representative of unpolluted conditions. Arctic benthic communities are more vulnerable to petroleum compounds than those of temperate regions [41]. The reason could be that because Arctic region is characterized by low temperatures and a lack of sunlight, which results in slower rates of biodegradation and a longer persistence of pollutants in the environment [59]. This means that petroleum components are more likely to remain in the environment for a longer period of time, increasing the risk of exposure for benthic communities. In areas where the sediments at the seabed are polluted, operations such as underwater blasting and dredging could lead to the mobilization and spreading of the pollutants. In comparison it would seem that underwater blasting creates much more vigor and brings far more sediment into suspension and that this sediment becomes suspended at all possible levels throughout the water column. Blasting leads to a wider spreading of sediment, but that dredging leads to a wider spreading of the organic part of the sediment [38]. Barite and related compounds discharged at sea have an environmental impact on the benthos. Barite is a weight material used in drilling fluids, and barium and other heavy metals are found at high concentrations in it [41, 42]. Dredging of sediments has been shown to cause removal or destruction of the biota in the dredged material, coverage of the benthos in the vicinity of the site of operation by settlement of suspended sediment, and increased turbidity, resulting in decreased primary production of both phytoplankton and phytobenthos [38]. Besides, Roca et al. [43] demonstrated that high sedimentation rate can be the cause for a catastrophic, long-term impact on a nearby seagrass meadow and ecosystem.

Greenhouse gas emissions into the atmosphere: Oil and gas industry is one of the largest emitters of carbon dioxide [44]. Large power demand of offshore installations in the Arctic area is, in most cases, covered by their own gas, and greenhouse gas emissions from power production are high. Ice-protection techniques with a high consumption of energy have negative impacts on the sensitive environment and wilderness in the Arctic. The use of hazardous chemical ice protection causes degradation of the environmental quality; it also increases the produced waste and serious environmental consequences [24, 45].

Produced water discharges: Production of oil and gas generates large volumes of produced water. Produced water is a complex mixture of formation water (water trapped for millions of years in a geologic reservoir, condensation water and occasionally injection water) injected in the well to maintain production levels. It contains numerous dissolved and particulate organic and inorganic substances with a concentration largely depending on reservoir characteristics. These substances include inorganic salts, metals, radioisotopes and organic compounds, such as polycyclic aromatic hydrocarbons, alkylphenols [46, 47, 48]. Beyer et al. [49] examined the environmental effects of offshore produced water and it is summarized that the accumulated ecotoxicological knowledge of offshore produced water discharges. The discharges contain organic acids (64%), metals (25%), dispersed crude oil (4%), alkylphenols (1%), polycyclic aromatic hydrocarbons (0.3%), and many other constituents of environmental relevance. Monitoring surveys find detectable exposures in caged mussel and fish several km downstream from produced water outfalls. Besides, increased concentrations of DNA adducts are found repeatedly in benthic fish populations, especially in haddock. But is uncertain whether increased adducts could be a long-term effect of sediment contamination due to ongoing produced water discharges, or earlier discharges of oil-containing drilling waste. According to Camus et al. [5], Arctic marine species are not less sensitive than their temperate counterparts to artificial produced water. But according to Geraudie et al. [50], overall long-term effects of produced water discharges to the marine environment are likely to be small.

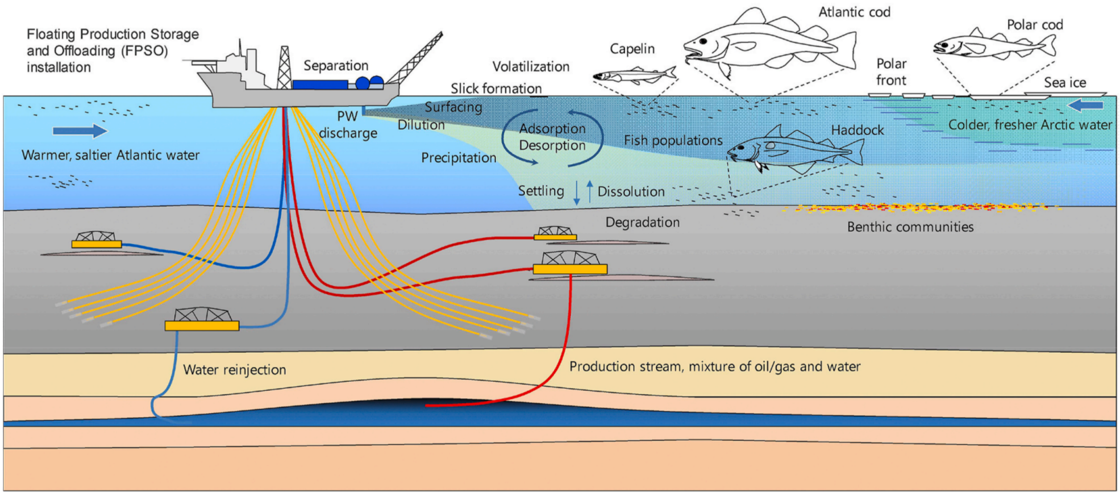

Figure 4. Produced water discharged from offshore oil and gas production and its effects [49].

Other effects: The accidents of Piper Alpha and the Gulf of Mexico, among other cases, show devastating outcomes, causing the semi-submersible platform's sinking, offloading, topside systems and helicopter accidents. It should not be forgotten that the similar disasters can happen in Arctic, too [22].

3.2. Precautions And Countermeasures To Be Taken

In-situ burning: The spilled oil not only harms the marine ecological environment, but it also can affect the shoreline ecological system and socioeconomic features, thereby endangering human health [51, 52, also see in section 3.1]. Once oil reaches or even strands on shorelines, cleanup and recovery are more difficult. The wind and atmosphere stability also play an important role in pollution dispersion. Lower wind and temperature inversion can seriously hinder the diffusion of pollutants. One of the widely used remediation strategies to prevent oil spreading is in-situ burning (also called controlled burning) when the oil is still floating on the ocean's surface in offshore areas. Several studies, laboratory research and field experiments have proven that controlled burning in ice-affected waters is efficient in oil spill response, and it has been successfully applied in Arctic regions [53].

The usage of modern technology: There are various types of available offshore structures operated successfully in the Arctic region, but most of these structures are still limited by water depths and are incapable of year-round operations in extremely harsh ice environments. Hence, the need for new concepts or improvements to produce a feasible, reliable, and economical structure that permits continual year-round operation for the Arctic offshore drilling and production of oil and gas. The suitable concept of the structure should possess high resistance to extreme ice loadings, high resistance to freeze and thaw, easy site installations, and short site construction time [6]. It should be taken into consideration that the offshore platforms powered by renewable energy, including solar panels and wind turbines, and equipped with a wastewater treatment system and other environmentally friendly features should be used for better future. Today more and more companies are turning to environmentally friendly practices and technologies to reduce their impacts on the region's fragile ecosystem. Here are just a few examples of environment-friendly offshore activities in the Arctic. One example of environment-friendly offshore activities in the Arctic is the use of advanced drilling technology. This includes the use of subsea blowout preventers, which can help to prevent oil spills, as well as the deployment of remote operated vehicles (ROVs) for inspection and maintenance activities. By using these advanced technologies, companies can reduce the risks of accidents and spills, helping to protect the environment and wildlife in the Arctic. Another example of environment-friendly offshore activities in the Arctic is the use of environmental monitoring systems. These systems, which use sensors and other technology, can help to monitor water quality, air quality, and other environmental factors in real-time. This can help to identify potential environmental impacts of offshore operations, allowing companies to take timely and effective action to mitigate these impacts. Additionally, many companies operating in the Arctic are adopting best practices and standards for offshore activities. This includes the development of comprehensive emergency response plans, as well as the adoption of strict regulations and guidelines for offshore operations. By implementing these best practices and standards, companies can ensure that their operations are conducted in a responsible and sustainable manner, minimizing their impacts on the Arctic environment [58]. Besides, in Newfoundland and Alaska platforms have been designed to be able to withstand floating icebergs, and in Norway (e.g. Snøhvit) subsea installations have made gas transportation safer [10].

Zero-discharge policy: Andrade and Renaud [41] explored the polychaete/amphipod data ratio along the entire extent of the Norwegian continental shelf (North to Barents Seas) to evaluate its performance, specifically for impacts related to petroleum activities, as an environmental indicator for oil and gas impacts. The Barents Sea is managed under a zero-discharge policy, that is, no chemicals, oils and/or wastewater can be discharged to sea. The results give encouraging evidence that operation under the zero-discharge policy, combined with subsea installation and processing on land, does not seem to affect benthic communities, at least to the same extent as in other areas where discharges are permitted, and permanent surface installations exist [41, 54].

New environment-friendly policies: The Arctic Council initiated a project, 'Emergency Prevention, Preparedness and Response' (EPPR) for oil spill risks and published a subsequent technical report on circumpolar oil spill response [33, 36]. The report discusses weather conditions in the Arctic, i.e. "effects of wind, waves effects of wind, waves, air temperature, wind chill, sea ice, superstructure icing, horizontal visibility, and daylight/ darkness" on particular oil spill response systems [36]. These systems are mechanical of vessels, ranging from 1 to 3 ships taking part in the recovery, dispersants from the vessel, aircraft or a helicopter, or in-situ burning techniques of vessels or helicopters. The Arctic Council's working groups and task forces, current and previous, are instrumental in initiating work that may reduce oil related risks in the region, as they are or have been focusing on issues such as telecommunication and connectivity, marine oil pollution prevention, preparedness and response, and search and rescue [35].

Preparedness and well-planning: The environmental impact of underwater blasting can probably be reduced considerably if the blast is timed favorably. If the desire is to reduce the far field environmental impacts such as spreading of organic material and fine-grained sediment, which might be carrying pollutants, then blasting should be carried out near slack tide, preferably in connection with neap tide, and when wind and waves are small. In addition, sediment is able to stay suspended at internal density gradients in the water column, periods should be preferred in which there is little input of buoyancy from freshwater or heating or when mixing of the water masses is strong. In arctic areas this is likely to happen during the fall where the freshwater run-off from land is ceasing and cooling from the atmosphere is increasing [38]. Another preparation is taking climate effects into consideration. For example, the extreme harsh environment where catastrophic hurricanes occur, requires a critical analysis of environmental loading on floating and fixed offshore structures at the operational phase [22].

Dispersants usage: Chemical usage (dispersants) during the clean-up phase of oil-spills may have positive effects, such as decreased amounts of toxic gases inhaled by clean-up participants [33].

4. Conclusions

In this study, environmental aspects of offshore activities in Arctic is examined. Increasing worldwide energy demand has drawn the world's attention to the Arctic region, which is relatively less explored and has rich hydrocarbon resources. Challenges during activities are classified as climate and weather factors, icing, great energy demand, strict regulations, reliability and integrity challenges. Environmental effects can be classified as health effects of oil spills, harms to marine life due to underwater blasts, underwater blasts and dredging's suspended sediments and effects to benthic communities, greenhouse gas emissions to Earth and produced water discharges. In order to prevent environmental impacts; in-situ burning and dispersant usage for oil spills, preparedness and well-planning to avoid accidents, the improvement of modern technology for harsh circumstances, and creating new environment-friendly policies can be used.

According to experts, we are ‘‘more than likely’’ to witness a substantial increase in oil and gas activities in the Arctic in the years to come, it should not be forgotten that the Arctic will become the center for oil and gas between 2030–2050 [10]. For this purpose, it is necessary to examine the environmental effects and the countermeasures that can be taken in more detail.

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