ENVIRONMENTAL IMPACTS OF THE OFFSHORE DRILLING ACTIVITIES IN THE BLACK SEA

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ÖZET

Çalışmanın ana hedefi Karadeniz'de yürütülen sondaj faaliyetlerinin olası çevresel etkilerini ve oluşabilecek sorunları değerlendirmektir. Çalışma iki kısımdan oluşur: Birinci kısım Karadeniz'de halihazırda mevcut olan kirlilik durumudur. Bu kirlilik durumu, açık deniz sondaj faaliyetleri özelinde incelenmiştir. Ek olarak, Karadeniz'de sondaj yapılan bölgelerin sondaj sonrasında nasıl etkilendiğine de değinilmiştir. İkinci kısım ise sondaj faaliyetlerinin denizlerdeki genel çevresel etkileridir. Bu çevresel etkiler; üretimden kaynaklı su, sondaj sıvıları ve sondaj deliği için kesme atıkları özelinde üç ana başlıkta incelenmiştir. Sonrasında bu başlıklar, Karadeniz'deki açık deniz sondaj faaliyetleri kapsamında incelenmiştir.

Anahtar Kelimeler: Sondaj, Karadeniz, Açık Deniz, Çevresel Etki

ABSTRACT

The main aim is to evaluate the environmental effects and potential problems of drilling activities in the Black Sea. The work consists of two parts: The first part focuses on the current pollution situation in the Black Sea, specifically offshore drilling activities. It is also mentioned about the effects of post-drilling in the Black Sea. The second part is the general environmental effects of sea drilling activities. These environmental effects were examined under three main headings: Produced water, drilling fluids, and cutting wastes. Afterwards, they were examined within the scope of offshore drilling activities in the Black Sea.

Key Words: Drilling, Black Sea, Offshore, Environmental Impacts

1. Introduction

Since the 18th century, with the development of technology and industry, there has been a serious increase in energy demand worldwide. The invention of steam engines and the development of ignition systems revealed industrial facilities, and then the concept of fuel and natural gas consumption emerged. Especially in the last century, technological developments have facilitated access to the seas. Accordingly, to meet the increasing energy demands, states have sought new energy sources. For this purpose, drilling activities are carried out on the sea with the help of different types of platforms such as jacket platform, gravity type platform, tensioned platform, and semi-submersible platform. Especially Central America and the Middle East seas are the places where these activities are carried out most commonly. The oldest offshore drilling activity to produce oil in history took place in the state of Ohio in the USA. Around 1891, the first submerged oil well was discovered in Grand Lake St. Marys, by drilling the freshwater with the platforms built on stilts [1]. Wells were improved by small local companies such as Bryson, Riley Oil, German-American and Banker's Oil [1]. Today, offshore drilling activities are carried out in many parts of the world such as the Gulf of Mexico, Caspian Sea, Red Sea, Persian Gulf etc. One of these locations is the Black Sea. The starting point of this study is the statement that Turkey has discovered natural gas reserves in the Black Sea. The main purpose is to address the environmental problems that will be created by this exploration and subsequent drilling activities and to raise awareness to cause as little damage to nature as possible.

Within the scope of the study, firstly, the natural structure of the Black Sea and the current pollution situation were briefly mentioned. It has been mentioned that this pollution has many social, economic, and natural causes. In addition, it is explained that the Black Sea is in a structure that is suitable for pollution due to its geographical location and surroundings. The effects of ongoing drilling activities in such an environment and the effects of potential discoveries in the coming years are mentioned. Afterwards, a study examining the case located offshore Romania, where the oldest offshore drilling activity area in the Black Sea, is mentioned. The findings of this study were presented considering the proximity of Romania offshore to Sakarya Gas Field, which is Turkey's drilling field, examining the results is valuable. As an additional, another study made by E. A. Mazlova etc., a case that is simulating a borehole off the coast of a small coastal city in Russia was examined. Especially in that study, the effect of drilling activities on benthic organisms was examined (mentioned in part 2.2.2).

In the second part, environmental problems caused by offshore drilling activities are mentioned. These problems were examined under three main headings: (1) Produced Water (PW); (2) drilling fluids and chemicals; (3) cutting waste. These three headings are detailed and the environmental destruction they cause is briefly mentioned. Firstly, the environmental effects of PW in the sea are explained. A brief evaluation of water-based, oil-based, and synthetic-based PWs as structural components has been made. Secondly, drilling fluids and chemicals intended to protect the borehole were mentioned. The ecotoxicological effects of these chemicals on the living habitat are mentioned. In addition, examples of frequently used chemicals are given. Finally, drilling cutting wastes are mentioned. The heaps of these wastes on the seafloor are mentioned and brief information is given about the chemicals they contain, taking into consideration that these chemicals are generally like the drilling fluid chemicals.

2. Pollution of the Black Sea

2.1 Geography and pollution of the Black Sea

In the last century, the Black Sea has undergone significant changes caused by human activities. More than 160 million people live in the Black Sea catchment area, placing extraordinary demands on its resources. Waste from small and large cities where human activities are present is the main cause of pollution. Considering the waste coming from these settlements' flows into the Black Sea; some of them come directly from the coast, but most of them flow relentlessly through the Danube, Dnieper, and Dniester rivers, which are the principal rivers of the region [2]. Therefore, future trends will largely depend on man-made threats. The other major threat is many large ships or oil tankers. Finally, the adverse effects of the fishing industry and the tourism activities are destroying the natural life in the Black Sea and its impact area.

The area of the Black Sea is approximately 421,600 km^2. This area is more than half of Turkey's area. This size makes the Black Sea one of the largest inland marine environments in the world. Besides, it is the most isolated inland sea from the World Ocean. Most of the total volume of seawater is contaminated with hydrogen sulfide, which is unsuitable for life. This amount is estimated to be 547,000 km^3. Its only connection with the rest of the world's oceans through the Marmara Sea and the Mediterranean is the narrow Istanbul Strait. In addition, it is connected to the Sea of Azov (via the Kerch Strait) in the Northeast [3,4]. Of course, this connection is a blind connection since it does not lead to the oceans. The Black Sea is in a geography where the sunshine duration is relatively low due to its location. Besides, it is surrounded by geography where many freshwater springs flow into the sea. Due to these two factors, it is a sea with low salinity. Because it has only one exit, which is through the Istanbul Strait, the Black Sea has a closed basin characteristic as seen in Figure 1. In addition to its natural structure, the fact that it is surrounded by countries that left the Soviet Union, which missed the 20th-century technology and industrial revolution, also increases the pollution level of the discharges to the sea. There is serious pollution in the discharge of countries [3, 4, 5]. Considering all these, the Black Sea can be easily polluted due to its natural structure.

Figure 1. The Black Sea river basin [5].

2.2 Pollution caused by offshore drilling activities

This paper, it is aimed to examine the pollution of the Black Sea in terms of offshore drilling activities. Therefore, detailed information and examples of pollution caused by different reasons are not included. In this part of the article, the pollution of offshore drilling activities has been examined in the Black Sea region. In addition, the findings of previous studies on this subject are also mentioned.

2.2.1 Potential and existing hydrocarbon resources in the Black Sea

The northwest corner of the Black Sea corresponds to the Romanian offshore. This region was the only proven, developed, and produced oil region in the Black Sea until the beginning of the 2010s [6]. Production started about 40 years ago. In 2009, more than 30,000 barrels of oil and/or equivalent per day could be produced from the reservoirs in the pre-Oligocene (Cretaceous-Eocene) period [6]. Pre-Oligocene reservoirs are also known to be productive in several other hydrocarbon regions of the Black Sea. These regions are the Gulf of Odessa, off Bulgaria and Turkey [6]. But it was thought to be efficient only for dry gas. Recent developments have proven that all developed hydrocarbon fields in the Black Sea may be even more widespread.

Since the 2000s, Georgia has been working on the potential to explore hydrocarbon resources off the coast of Batumi. There are four seepage areas within an area of approximately 20 km^2 off the coast of Georgia. These have been named the Batumi seepage, the Pechora Mound, the Iberian Mound, and the Colkheti Leak. The waters in these seepage areas show characteristic differences in elemental concentrations and isotope signatures of oxygen, hydrogen, strontium, and chlorine. These characteristic differences are thought to be caused by deposits with oil and hydrocarbon potential [7]. In addition, there are active gas seepage, near-surface authigenic carbonates and gas hydrates in all seepage sites [7]. In the light of all this, Georgia hopes to reach its hydrocarbon resources.

Turkish Petroleum Corporation (TPAO) announced in August 2020 that it has found 405 billion m^3 natural gas in the Western Black Sea Region. The newly found reservoir was discovered in the Tuna 1 borehole (Figure 2), which is in the activity area that TPAO named Sakarya Gas Field (it corresponds to 150 km offshore of Zonguldak province). As stated before, the initial idea of this study is to determine the environmental effects that may be encountered for this and subsequent discoveries [8].

Figure 2. Location of Tuna 1 well [8].

2.2.2 Examples for the environmental issues of offshore drilling in the Black Sea

Romania is at the forefront of the countries that carry out offshore drilling in the Black Sea (as mentioned in section 2.2.1). The environmental effects of drilling activities on Romania's maritime jurisdiction (exclusive economic zone) are examined in a study [9] and the findings will be mentioned below. The Romanian offshore field is located close to the Sakarya gas field in the Western Black Sea, where the Republic of Turkey is drilling. It would be appropriate to evaluate the study from this perspective as well.

Romania has a long history of oil and gas production. Research activities for hydrocarbon deposits off the coast of Romania (on the Black Sea continental shelf) began in the early 1970s [10]. Offshore oil and conventional gas production in this region have decreased since 1976 and 1986, respectively. Romania had some disagreements with Ukraine after the collapse of the Soviet Union. One of these disagreements concerns the delimitation of the continental shelf and exclusive economic zone in the Black Sea [9, 10]. Since the conflict ended in 2009, Romania has expanded its offshore exploration activities [11]. The first deep-water wells Domino-1 in the Romanian sector of the Black Sea were opened in early 2012. According to preliminary estimates, it is thought that the reserve amount will reach 84 billion m^3 of gas [9, 11].

Considering all these issues, Romania is an important example that needs to be examined. Because the most reliable historical information can only be about the Romanian offshore area. In addition, it is very important that it has been active again recently and that it has been actively drilling for a long time. Thus, the Romanian case provides a suitable field of study for the different scenarios that may arise. The main purpose of the study by Ţigănuş et al. [9] is to determine the total petroleum hydrocarbon content (TPH) in the Black Sea offshore of Romania during the offshore exploration activities between the period of February and June 2015. TPH concentrations in seawater samples collected from 3 separate locations (200 to 1,625 m depth) were measured later by ultraviolet fluorescence spectroscopy. Petroleum hydrocarbons were found to be present in all samples. The detected concentrations were observed to be highly variable as observed in Figure 3 [9]. In addition, it has been mentioned independently from the previous natural situation before the drilling activity in the study that TPH concentrations in the study area followed a constantly increasing trend during the 5 years as stated in Figure 4 [9].

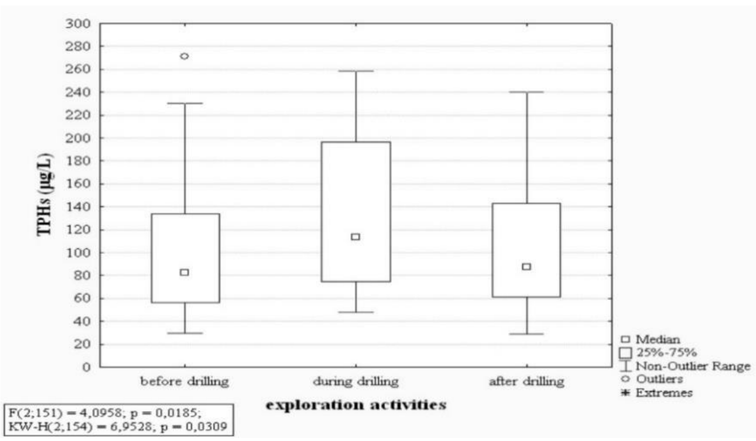

Figure 3. Romanian Sector's TPH change in 5 months [9].

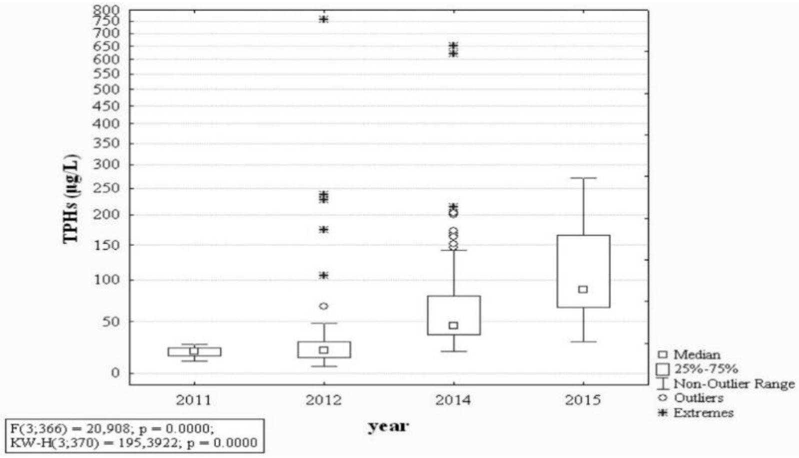

Figure 4. Romanian Sector's TPH change in 5 years [9].

Another study by Mazlova et. al. [12] was related to Tuapse, which is a small city on the Black Sea coast of Russia. This study aimed to examine the effects of the tailings of the Tuapse borehole located off the city. The researchers who carried out the study simulated the marine environment through experimental methods. They aimed to examine the effect of modelled drilling wastes on planktonic and benthic organisms [12]. Part of the findings of the study is summarized in Table 1.

Table 1. The effect of drilling wastes on planktonic organisms [12].

Species	**Genus**	**Duration**	**Concentration**	**Effect**
Phaedactylum Tricornutum	Diatom	96 hours of incubation	20 mg/litre drilling waste	Maximum effect
Daphnia Magna	Water flea	No data	Above 1 g/litre drilling waste	Acute lethal effect

Other findings of Mazlova et.al. are as follows: (1) Delayed effects such as fertility decline and maturation and growth retardation due to the short-term effect in the increased turbidity area were identified. (2) Mollusks (mussels) resisted the impact of drilling wastes, but their physiological state had deteriorated significantly. (3) In real conditions, such a concentration can only be obtained near the waste disposal site. Therefore, the levels of these effects are at the highest level that can occur on living things [12].

3. Environmental impacts of the drilling activities

Drilling activities carried out in the open sea are deeply affecting the underwater ecosystem. These effects can be evaluated in many ways. However, 3 main components are the main sources of the environmental problems: Produced water (PW), drilling fluids used to protect the borehole and the cuttings coming out of the borehole.

3.1 Produced water

PW is the water from the co-produced formation when oil or gas is extracted. So, it is a by-product of the drilling process. This by-product is undesirable and must be removed. In some cases, it may also contain injection water and condensate. There are naturally occurring chemicals in PW. The composition and properties of these materials are closely related to the geological features of the drilled reservoir. Therefore, it differs according to the field of study. From this point of view, it is very important to examine the previous studies in the Black Sea.

The composition of PW is complex and may contain several thousand compounds that vary in concentration between wells and over the life of a well. These compounds, which are highly environmentally hazardous, are shattered oil, heavy metal, aromatic hydrocarbon and alkylphenols (AP), and naturally occurring radioactive material (NORM) [13].

PW may also contain large amounts of organic material, particulates, inorganic salts, and low molecular weight organic acids such as acetic acid and propionic acid and may contain high levels of sulfide [14]. In addition, water injected following PW may reveal traces of extra chemicals such as biocides, corrosion inhibitors, limescale inhibitors, emulsion breakers, coagulants/flocculants, and oxygen scavengers [14, 15]. The emergence of these traces can cause unexpected problems as well as expected problems. Finally, sulfate-reducing bacteria can also be found in PW [16]. Large overall discharge volumes, complex content of partly hazardous chemicals and lack of information about possible long-term ecological impact are the main handicaps of PW. For these reasons, PW discharges have become the most prominent target for concern and research in recent years [17].

3.2 Drilling fluids and chemicals

Drilling waste is made up of drilling fluids and the cuttings generated during drilling. Drilling fluids (drilling muds) are used to remove cuttings from the hole, prevent blowouts by controlling back pressure, maintain the integrity of the hole to permit the installation of a casing, and cool and lubricate the drill bit [18]. There are other functions of the drilling fluid as listed: (1) Supplying hydraulic power to the drill bit; (2) Seal permeable formations of the borehole; (3) Suspend cuttings when circulation is interrupted such as when adding a new piece of drill pipe; (4) Support part of the weight of the drill string through buoyancy; (5) Ensure the securing of important information about the formation being drilled to permit its successful evaluation [19].

In terms of basic components, the main types of drilling fluids are three [20]: (1) Water-based in cases where the liquid phase is water; (2) Oil-based in cases where the liquid phase is oil; (3) Synthetic base where the liquid phase is a synthetic base compound such as an ester. Water-based drilling fluids are the most common type and often contain various chemicals formulated as needed from a limited list of additives. Observing US waters, more than 90% of the total content of most water-based drilling fluids used offshore has been found to consist of the four materials. These substances are barite, bentonite, lignite, and lignosulfonate [18, 19]. While more than 1000 products are available for formulating drilling fluids, the total number of components in most drilling fluids is in the number range of 8–12 [17]. This indicates that we encounter a limited number of unwanted substances most of the time. Other substances are rarely encountered.

Offshore drilling activities in Italy provide a good example for drilling chemicals. Seven types of drilling mud account for about 89% of Italy's offshore activities. These muds contain nine basic products. These are listed below by Terzaghi et al. [21]. Terzaghi's list is very popular and has been cited many times in literature outside of Italy.

- Lignosulfonate, a by-product of the separation of pulp from wood using the sulfide process, is used as a dispersant in water-based drilling fluids when added with iron and chromium.
- Modified starch made from bacterially stabilized potato starch used to provide low viscosity filtration control.
- Soltex is an asphalt produced as a residue in oil refining and sulfonated to make it water-soluble and primarily used for shale control.
- XC-polymer is a high molecular weight polysaccharide used as a viscosity enhancer in fresh and saltwater liquids.
- Mor-rex, a chemically modified enzyme hydrolyzed corn starch is used as an effective dispersant in calcified sludges.
- Carboxymethylcellulose (CMC) LV, a cellulose derivative used as a fluid loss reducer and shale inhibitor.
- Polyanionic cellulose (PAC) LV, another polymer used as a fluid loss reducer and shale preventer, but with greater tolerance to salts.
- Wetting agent/detergent, a specially formulated blend of surfactants (including barite, calcite, and hematite) used to minimize lice build-up and improve lice removal in water-based drilling fluids.
- A high molecular weight alcohol blended with fatty acid derivatives is used as a defoamer and antifoaming agent.

3.3 Cutting wastes

The environmental impacts of drilling cutting (DC) waste are partly related to the drilling fluids and chemicals used. Because the biggest disadvantage of cutting waste is that it contains chemicals used for drilling. However, we need to address this issue in a separate topic. This is because these cutting wastes create unnatural heaps, especially on the seafloor. The characteristics that make up the chemical composition of the post-drilling cut piles are numbered as (1) Appropriate size, (2) content of drilling material and muds used, (3) environmental conditions and mineralogy of the strata above the drilled target reservoir. Therefore, shear piles contain various mixtures of components affected by human activities and natural processes [22]. Heavy metals found in piles of drill cuts include barite, bentonite, speciality chemicals, hydrocarbons, organic pollutants, and radioisotopes [22, 23]. These substances were previously mentioned in the drilling fluids and chemicals section. Information on drilling interruptions focuses on three chemical groups: Hydrocarbons, heavy metals, and less radioactive nuclei [23].

A study was conducted in the Norwegian sector of the Barents Sea on drilling cutting waste. The main aim of that study was to determine the environmental impact of drillings released around three wells in the Barents Sea. These wells were drilled in 1992 (Well E-1992), 2000 (Well G-2000) and 2012 (Well S-2012). Sediment cores (20 cm long) were investigated along the downstream (> 5-250 m distance) from the wellheads. Due to the use of barite ($BaSO_4$) as the weighing agent during the drilling process, high Ba concentrations (approximately > 200 mg/kg) of sediment layers affected by drilling were encountered. Each of the wells, with thicknesses ranging from between 1 cm and 20 cm, contains layers of drill-affected sediment throughout the entire section [24]. The findings obtained in the examinations are listed as: Foraminiferal assemblages were studied in the core samples taken along the sections < 250 m from the wells; E-1992 shows no effect of DC on the foraminifera, indicating that low amounts of released DC limit environmental impact; impact in wells G-2000 and S-2012 is limited to < 30 m and can be attributed to suffocation of fauna resulting in low foraminiferal density [24]. Therefore, the researchers argue that previous monitoring studies focusing primarily on samples collected >250 m from wellheads cannot capture the full effect of DC. Moreover, in well G-2000, a recovery layer shows partial recovery 15 years after DC applications; no recovery was observed in well S 2012, after 3 years of release; and released DC did not result in fauna composition [24].

In addition, as stated in the study of Dijkstra et.al., the regulations during the drilling activity of the healing well are quite strict, proving that the treatment process of the ecosystem will be successful when the necessary legal measures are taken [24]. The time factor is quite important, and thus after such cutting activities, remediation should not be expected in a short time. Finally, the environmental impact of cutting waste, which is released in low amounts, is very limited, and environmental destruction can be prevented by applying the right regulations.

4. Discussion

Firstly, according to the I. Morosanu [10], Romania is the most important country that has been actively engaged in offshore drilling in the Black Sea since the 1970s. In this respect, the findings of the study regarding the offshore of Romania are very valuable. On the other hand, the drilling activity field to be noticed by the Turkish Republic, which is the initial idea of this article, is very close to the Romanian offshore. This should also be considered for the necessary assessments. The findings in Romania show that offshore drilling activities are changing the concentrations in the seawater dramatically. In addition, hard-to-predict variations were detected in the water. In the simulation study for benthic creatures off the coast of Russia, it was concluded that hereditary risks may occur, especially for the creatures close to the drilling zones.

The biggest environmental impact of PW is that the resulting water is directly discharged into the sea, which eventually causes pollution. Unwanted secondary substances cause outputs such as infertility, negative mutations (changes that will negatively affect the life of the living thing) and narrow the living space of aquatic organisms [13]. Especially preferring oil and synthetic based PW is negative for nature. Water-based PW should be preferred instead. The most important adverse effect of the chemicals used to protect the borehole is to induce ecotoxicological reactions in the marine environment. These reactions destroy the habitats of aquatic organisms. These chemicals can be of thousands of varieties. But the chemicals used as the oil are quite limited. This makes it easier to take preventive measures. It also causes more predictable problems such as respiratory diseases, cancer, declining of the population [13, 16, 17]. The chemicals in the cutting waste are like those in the borehole protection fluids. On the other hand, these wastes from heaps contain harmful chemicals lying on the seafloor, and this is very dangerous for benthic habitats and small fish [12, 25]. On the other hand, the upper links of the food chain (large fish) are not affected much by normal discharge amounts. However, it has also been observed that large fish are affected in unexpected accidents [26].

Finally, it should be noted that the Black Sea is very polluted. There are many social, economic, and political reasons for this fact. In addition, due to its natural structure, it is easily exposed to pollution. This article mentions the results of the previous and current offshore drilling activities in the Black Sea region. In addition, the general results of the drilling activities in the world's oceans are mentioned. In the light of all these, it is a necessity to show serious sensitivity when a step is taken regarding the Black Sea.

5. Conclusion

Current developments show that Turkey and Black Sea littoral countries will continue their offshore drilling activities. Although technological developments have reduced the dependence on fossil fuels, it is an undeniable fact these resources will be needed in the future. Considering the current account deficit, Turkey can’t give up such a natural resource. In this case, what the authorities should do is to look out for possible environmental impacts. In this way, the process can be carried out with the least damage. The main purpose of this study is to address possible environmental problems and to encourage the authorized bodies to protect our seas and nature by taking preventive measures, to ensure that our country and nature are minimally affected by the adverse environmental effects of offshore drilling activities.

6. Acknowledgement

First, I would like to thank my lecturer, Dr Sevil Deniz YAKAN DÜNDAR, who led me to this study and never spared her support and comments. In addition, I would like to thank the Istanbul Technical University Faculty of Naval Architecture and Ocean Engineering and ITU GIDB Journal for giving me this opportunity. This study was carried out within the scope of the ADM505E Environmental Aspects of Offshore Activities graduate course. Therefore, no interest groups were worked with during the study and no funds were used.

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