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Hydrocarbon Production and Solving Environmental Problems in the Caspian Region

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ABSTRACT

This article examines environmental pollution control during oil and gas production in the Caspian region. Due to intensive offshore oil and gas production, environmental issues and solutions must be a priority for all companies operating on the shelf. The article identifies key challenges for environmentalists and oil and gas industry specialists in five Caspian countries that must be addressed first. It also shows that Azerbaijan, one of the leading gas exporters in the Caspian region, has become an important partner in recent years, playing a significant role in European energy security.

Keywords: Oil pollution; Petroleum products; Drill cuttings; Polyaromatic hydrocarbons; Trans Adriatic Pipeline (TAP); Shah Deniz field; Microelements; Southern Gas Corridor (SGC); Trans Anatolian Pipeline (TANAP)

Introduction

Environmental monitoring of oil pollution in the Caspian Sea, particularly during offshore projects and the operation of oil transportation and storage infrastructure, is crucial. The role of petroleum products and oil waste entering the sea has not yet been fully studied, as oil is a mixture of various substances, 50 to 90% of which (depending on the field) are hydrocarbons, while the remainder are heteroatomic compounds containing C and H, as well as S, N, O and microelements. Polyaromatic hydrocarbons, which accumulate in marine ecosystems and are cyclic hydrocarbons consisting primarily of benzene rings with substituted and unsubstituted hydrogen atoms, have a significant impact on the flora and fauna of the Caspian Sea.

Main Part

Almost all polyaromatic hydrocarbons are carcinogenic substances with mutagenic activity and the most active carcinogenic compound is benzopyrene. Oil-containing formation waters contain high concentrations of hydrocarbon compounds, salts and trace elements. The general characteristics and composition of commercial waters generated during oil and gas production in the Caspian Sea are shown in[1]. Here we will pay attention to the content of microelements, mainly found in the oil-containing waters of the Caspian Sea (in mg/l): Fe (0.1-1100), K (24-4300), Mg (0.9-600), Al (0.4-410), Mn (0.004-175), Pd (0.008-0.88), Ti (0.01-0.70), etc. Drilling waste also contains such toxic reagents as acrylic polymers, caustic soda, soda ash, polyacrylamide, chrome peak, clay, barite, which have been entering the Caspian Sea for years: they accumulate during the construction of countless wells during large-scale drilling in all oil sectors of the Caspian Sea countries[1-3]. The dominant position in the pollution of the marine environment is the presence of heavy metals (Fe, Zn, Cu, etc.), which accumulate

over time in marine flora and fauna and thereby increase the anthropogenic impact on marine natural resources.

The impact of heavy metals on the flora and fauna of the marine ecosystem is complex and is determined primarily by their concentration. While they are highly toxic, many are trace elements essential for fish metabolism. Furthermore, not all metal concentrations exceeding the maximum permissible concentration cause disruption to the marine ecosystem. Thus, the health of the marine ecosystem is primarily determined by the concentration of microelements (heavy metals) and the adaptive capacity of the environment, which depends on the form of heavy metals in the marine environment[4].

It should be noted that, on average, up to 70 tons of oil are released into the aquatic environment from a single well during offshore oil field development. For example, when drilling wells in the Caspian Sea, a clay slurry is used: in this case, finely dispersed clay particles and polymer are discharged from the well into the marine environment. The washing liquid used consists of bentonite clay powder 70 kg per cubic meter, caustic soda and soda ash 1 kg per cubic meter and barite 113 kg per cubic meter.

That is, in addition to sludge, drilling fluid discharged into the sea contains finely dispersed clay, caustic soda, soda ash and barite, which are poisonous to marine flora and fauna[5]. It is also characteristic that drilling fluids are especially toxic when oil and a set of special chemical reagents are used as a preventative anti-stick additive.

It has been established that the specific volume of drilling wastewater, treated drilling fluid and drill cuttings generated during well drilling is 0.24, 0.20 and 0.18 cubic meters per meter of drilling, respectively and 1 cubic meter of waste accounts for up to 68 kg of contaminated organic matter, excluding oil and mineral contaminants[6]. That is, environmental problems associated with the state and pollution of the Caspian Sea require the constant adoption of high-quality environmental measures, since the possibility of restoring the Caspian ecosystem largely depends on the coordinated actions of the five Caspian states (Azerbaijan, Russia, Kazakhstan, Turkmenistan, Iran).

The Caspian's energy significance is primarily determined by its vast hydrocarbon reserves. According to the US Department of Energy (as of 2012), the Caspian Sea's total oil reserves amount to approximately 100-200 billion barrels (more than the entire North American continent combined) and approximately 8 trillion cubic meters of natural gas.

According to the Organization for Economic Cooperation and Development, the Caspian region's proven oil reserves account for approximately 3% of global hydrocarbon reserves and its natural gas reserves account for approximately 5% of global gas volumes. Kazakhstan leads the Caspian Sea region in oil production and proven reserves, followed by Azerbaijan and Turkmenistan. According to the BP Statistical Review, Turkmenistan ranks fourth in the world in terms of natural gas reserves, after Iran, Russia and Qatar (as of September 2015).

All oil and gas companies in the Caspian region must recognize the need to develop and implement comprehensive measures aimed at minimizing risks and environmental impacts during the operation of oil and gas facilities. Against the backdrop of growing production volumes and large-scale oil and gas projects being implemented in the Caspian Sea, industrial ecology and safety must become a priority. Oil and gas production in the Caspian Sea is steadily increasing: for example, in Azerbaijan alone, the leading oil company, the State Oil Company of the Azerbaijan Republic (SOCAR) and partners in the Shah Deniz gas condensate field development project in the Azerbaijani sector of the Caspian Sea signed an agreement in December 2010 to extend the contract for the field's development until 2036 (the previous contract was valid until 2031).

As is well known, Azerbaijani gas supplies via the TAP pipeline to Europe make a significant contribution to the diversification of Europe's energy supplies and its energy security. It should be emphasized that the TAP pipeline, which stretches up to 880 km, was the first project to supply Azerbaijani gas to Europe, providing the European Union (EU) with an additional source of hydrocarbons. On December 31, 2020, a significant event in the global oil and gas industry occurred: commercial supplies of Azerbaijani gas via the TAP pipeline to Europe began (to the gas distribution networks of Italy, Greece, Bulgaria, Croatia, Austria and Germany).

According to SOCAR and bp-Azerbaijan management, the Shahdeniz gas field holds 1.2 trillion cubic meters of gas. According to SOCAR, Azerbaijan's annual gas production is expected to reach 50 billion cubic meters by 2024, while proven gas reserves in the country amount to 2.6 trillion cubic meters. By the end of the first half of 2025, the Shahdeniz field in Azerbaijan produced 14 billion standard cubic meters of gas and approximately 2 million tons (approximately 16 million barrels) of condensate from the Shah Deniz Alpha and Shah Deniz Bravo platforms. Confirmed and newly discovered Azerbaijani gas fields (Shahdeniz, Umid and Absheron, as well as the development of promising structures - Zafar-Mashal, Babek, Shafag, Asiman and Nakhchivan) are accelerating the development of the gas industry in the country. For example, the Babek field, with estimated gas reserves of 400 billion cubic meters and the Umid field, with reserves of at least 200 billion cubic meters.

Significant volumes of gas are planned to be produced from the deep-water portion of the Azeri-Chirag-Guneshli field, as well as from the Absheron gas field, where proven recoverable reserves amount to 350 billion cubic meters. Of this amount, a maximum of 50 billion cubic meters will be used to meet domestic market demand, with the remainder sold internationally. According to SOCAR, the Absheron gas field is one of the largest gas condensate fields.

The primary role of protecting the ecology of the Caspian Sea should also be taken into account in the implementation of the Southern Caucasus Gas Pipeline (SGC), which began shipping 10 billion cubic meters of Azerbaijani gas from the Shah Deniz offshore field to Southern Europe in 2020. It should be emphasized that the SGC is an energy project that has significantly increased the diversification of energy transportation sources, thereby ensuring Europe's energy security.

As a reminder, a strategy for the development of Azerbaijan's oil and gas industry until 2050 was developed and approved back in September 2017. On May 29, 2018, the launch ceremony for the first stage of the South Caucasus Gas Pipeline (SCP) took place in Baku: the first gas from the Shah Deniz field has already passed through the first segment of the SCP - from the Sangachal

terminal, expanded for Shahdeniz-2, through the expanded South Caucasus Gas Pipeline. The next stage was the commissioning of the TANAP gas pipeline, which transports gas to Turkey and onward to Europe.

Azerbaijan is expected to supply approximately 10 billion cubic meters of gas annually to Europe over the next 25 years, with Italy receiving approximately 8 billion and Greece and Bulgaria receiving 2 billion. The total capacity of the South Caucasus Gas Pipeline is 20 billion cubic meters per year. Thus, by directly accessing the European market, the world's largest importer of natural gas, Azerbaijan will diversify its export options.

The success of the SGC is a significant event for Europe, whose energy security has been significantly guaranteed with its launch. Initially, gas produced during the second phase of the Shah Deniz field development was considered the primary source, but later other sources were added to the project. The Baku-Tbilisi-Ceyhan oil pipeline is an example: it currently transports not only Azerbaijani but also oil from Kazakhstan. It is possible that the SGC will also transport gas from the Dostlug field, which will be developed jointly by Azerbaijan and Turkmenistan.

For reference: the Dostlug offshore oil and gas field, which has not yet been developed, was discovered in 1986 by Azerbaijani specialists under the name "Kapaz"; oil reserves are estimated at approximately 50 million tons.

Intensive development is currently underway at various relatively new fields. For example, bp-Azerbaijan is studying the development concept of the Karabakh field, investigating its geological and geographical features and determining the format for further development. This field's geological oil reserves are estimated at over 60 million tons, with recoverable reserves of 21 million tons of oil and 13 billion cubic meters of gas. bp-Azerbaijan holds a 35% stake in the Karabakh field and the Aypara-Dan-Ulduzu-Ashrafi prospective structure development projects in the Azerbaijani sector of the Caspian Sea.

Relatively recently, bp-Azerbaijan and SOCAR signed a corresponding agreement at the Baku Energy Week: The British company will act as the operator of both projects; bp-Azerbaijan plans to begin oil production in Karabakh field in 2029.

Since April 2024, oil production has been underway on the new Azerbaijan Central East (ACE) platform, located between the existing Central Azerbaijan (Central Azeri) and East Azerbaijan (East Azeri) platforms. Once the 48 planned wells are commissioned, the platform is designed to produce up to 100,000 barrels of oil per day. Over its lifespan, the platform is expected to produce up to 300 million barrels (48 million tons). According to bp-Azerbaijan, the ACE platform is one of the most technologically and digitally advanced platforms in the world.

Of note is the presence of American oil and gas giant ExxonMobil in Azerbaijan, which signed a memorandum of understanding with SOCAR on August 7, 2025, in Washington, regarding the exploration and production of onshore tight hydrocarbons. Currently, it is the only American company present in Azerbaijan's production segment.

It should be emphasized that in the near future, the EU will seek to increase oil imports from Kazakhstan, Azerbaijan, the Persian Gulf countries and Nigeria. Kazakhstan, for example, plans to increase production to 105 million tons per year by 2028. This means that the intensive development of the Caspian Sea's hydrocarbon resources continues: the first stage of the Absheron field's development (which began in 2023) produces approximately 600,000 tons of oil per year. Work on the second stage of this field is planned to begin by 2029-2030, with an expected additional production volume of up to 1.17 million tons of condensate. The geostrategic importance of the Caspian Sea is evident, as it serves as a central link between the rapidly growing economies of China, India and the EU. Moreover, even faster oil and gas production is expected in the near future (up to 2050); In this regard, environmental issues and their solutions should be of primary importance for all oil and gas companies operating in the Caspian Sea.

Conclusion

Based on the above, the importance of environmental monitoring (maintaining a monitoring system) of oil pollution in the Caspian Sea is clear. This is necessary for the implementation of new offshore projects, as well as the introduction of cutting-edge technologies aimed at accelerating oil and gas production processes. It is worth noting that environmental impact assessments allow for the consideration of environmental safety requirements and the prevention of potential man-made risks, even at the design stage of production facilities.

When assessing the risks associated with oil and gas production at offshore fields over a given period, all oil companies must conduct a comprehensive assessment of the technical condition of their production facilities, including consideration of specific risk assessment aspects.

In addition to measures to maintain a stable and positive environment in the Caspian Sea and to prevent pollution of the marine environment, it is necessary to develop specific, promising research programs to prevent pollution of the Caspian Sea.

To effectively address environmental issues, joint environmental monitoring by all Caspian states over oil processes in the Caspian Sea is necessary, as well as the use of high-tech equipment to minimize the release of petroleum products into the marine environment[6].

One important measure for preserving the Caspian Sea's ecology is the implementation of temporary restrictions on oil and gas production, taking into account the impact of oil and gas operations on the marine ecosystem.

Energy corridors running through the South Caucasus, particularly those connecting Azerbaijan and Turkey, are of great strategic importance amid changes in global energy markets and the desire of states to find alternatives to traditional supply routes. The South Caucasus has become a vital bridge linking Central Asia and the Caspian Region with European markets.

Discussion

Here are some interesting facts about the intensive development of oil and gas production in the Caspian Sea by Azerbaijan in 2026[7,8]:

On January 8, SOCAR and Total Energies discussed the full-scale development of the Absheron gas condensate field. The

possibility of cooperation in the energy sector both in Azerbaijan and abroad was explored.

bp-Azerbaijan, the world's first, begins servicing subsea wells in the Caspian Sea from the Khankendi vessel. Starting on January 12, the company will begin subsea operations at a number of wells in the Deepwater Gunashli (DWG) block (part of the Azeri-Chirag-Guneshli block) in the Azerbaijani sector of the Caspian Sea.

Since January, Azerbaijani natural gas has been supplied to Austria and Germany for the first time. This means that deliveries via Italy to Austria and Germany expand the geographic reach of Azerbaijani gas in Europe, bringing the number of buyer countries to 16.

On January 22, SOCAR signed an agreement with the Italian company Eni S.p.A. to acquire a 10% stake in the Baleine oil and gas field development project in Côte d'Ivoire. SOCAR is tapping into Africa's vast oil and gas resources; Baleine is Africa's first zero-emission offshore oil and gas project.

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