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Ecological Consequences of Reservoir Water and Drill Cuttings Discharging in the Sea Continental Shelf

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***Abstract* — The article studies the impact of drilling waste and industrial water on the fauna of the aquatic environment. The analysis of the impact of emissions on the continental shelf is presented. The study revealed that in the ecological system of the marine continental shelf, the source of pollution is drilling waste and industrial water. The latest studies of the impact of drill cuttings and industrial water on the fauna of the continental shelf were analyzed, their specific impact on inhabitants of the aquatic fauna were examined, the role of alkyl phenols and polyaromatic hydrocarbons was studied. This article also analyzes detrimental effects of formation water on the fauna of the marine world. Alkylphenols (AF) and polyaromatic hydrocarbons (PAHs), which are part of industrial water, accumulate and settle in the mitochondria of cells of living organisms. They are rapidly metabolized in the body. It was also revealed that alkyl phenols, naphthenic acids and polyaromatic hydrocarbons can disrupt reproductive functions and affect chemical, biochemical and genetic biomarkers. Water-based drill cuttings can affect the biomarkers in the filter which is manifested in the increased oxygen consumption by living organisms, which destriys the marine fauna.**

Key words* — *marine fauna, process (reservoir) water, drill cuttings, petroleum hydrocarbons, fish, alkylphenols (AF), environmental impact, risk evaluation

I. INTRODUCTION

The continental shelf provides a unique pantry of resources, high fixation of which causes the formation of various collisions during their development. One of the more colorful collisions is pollution. More details about the areas of oil production and the platforms installed in this area on Figures 1, 2.

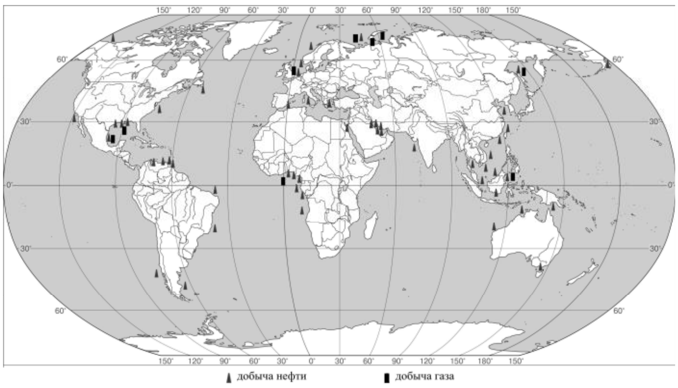

Fig. 1. Areas of oil and gas marine production.

In the last twenty or thirty years, there has been intensive development of the resources of the marine continental shelf in the Barents Sea. In 1996, intensive development of oil and gas fields on the Arctic shelf began.

At present, in the Russian Arctic, there is only one offshore ice-resistant platform Prirazlomnaya; in 2012, 226 million barrels of oil were produced by this platform. Research centers are exploring the environmental consequences of the drilling process and further development of the well on the continental shelf, for example: in the USA, this task is studied by the Institute for Environmental Studies (IES), North American University of Petroleum (NAUP), in Europe - the World Institute of Environmental Studies (WIES), in the Russian Federation Institute of Oceanology of the Russian Academy of Sciences, Murmansk Marine Biological Institute (MMBI), and the Russian Natural Science Establishment of Marine Ecology (RNSEME) and others. Nevertheless, ignoring the achievements in the environmental safety of the inhabitants of water resources, there are shortcomings in the concept of eliminating and preventing pollution in the North Sea region. Ignoring the ongoing studies, the present situation demonstrates that the issues of ensuring the environmental protection of the area, selecting highly informative, rapid methods of hydrocarbon pollution of water areas and coastal zones rating, proving the coastal protection strategy in the Northern Shelf area remain important and are calling for later unifying study.

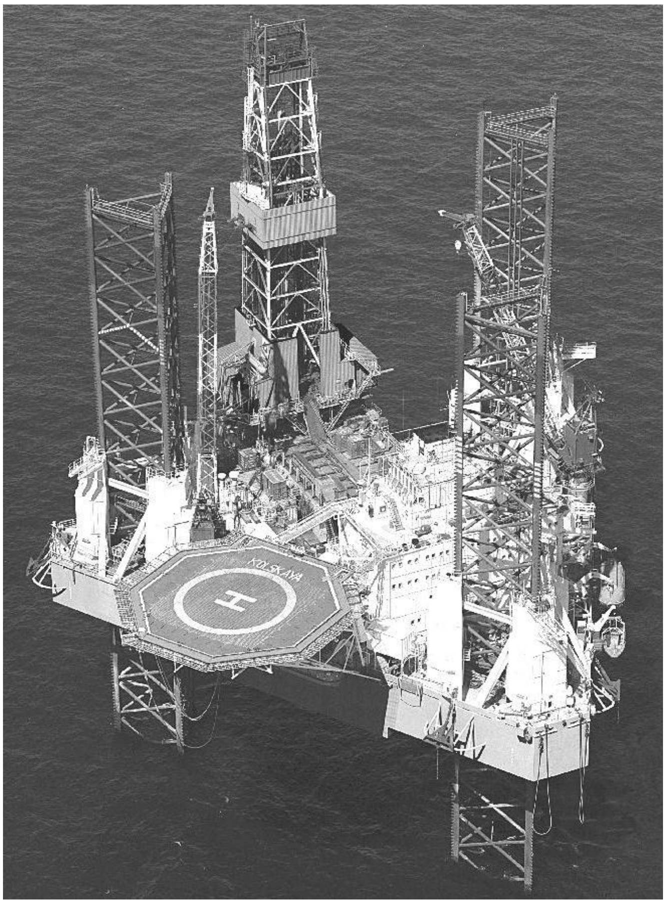

Fig. 2. A typical drilling platform in the North Sea

In the last twenty to thirty years, the resources of the Research purpose

The main purpose of this work is to study and describe the detrimental effect of heavy metals associated with drilling waste (slush), as well as the exposure to polyaromatic hydrocarbons including Alkyl phenols for fauna in the aquatic environment, and assess the associated environmental risks. To conduct a quantitative analysis and comparison of the heavy metals content near the offshore platform [1]. Assessing the environmental risks posed by potentially hazardous substances requires a balance between excessive and insufficient protection, i.e. between the social benefits associated with the use of specific substances and their potential risks. The processes of drilling, development and exploitation of oil and gas condensate fields on the Arctic and offshore continental shelves cause a damage to the marine fauna. A striking example is industrial water obtained in the process of oil production. In countries having an access to the sea or ocean, or producing oil on a shelf, there are strict limits on the amount of discharge of drill cuttings and other pollutants. To eliminate the damage caused to the water fauna during the drilling process, drill cuttings are pumped into injection or mothballed wells.

As practice shows, the application of the above method significantly reduces the concentration of formation fluid and the amount of drill cuttings. It is impossible to completely avoid sea accidents or accidental spills. Leakages of oil, industrial water and drilling fluids were caused by cracks in the wellbore. At the beginning of the 21st century, the reservoir pressure support using injection of esters and produced water was the main method for increasing the oil production rate on the continental shelf. One of the pressing environmental issues is legislative regulations.

During the monitoring and further research conducted in "Environmental Monitoring, Assessment and Control", the legislation on emissions into the sea became stricter. A striking example is the identification of special sea zones where individuals sensitive to substances of drill cuttings live [2]. There were tests in order to identify the number of permissible emission values. One of the major Norwegian research programs which deals with the research and environmental monitoring and takes into account the impact of drilling and production discharges on the continental shelf. The direction of the program is very important for technical (formation) water, since its potential environmental consequences are less known than ones of drilling fluids.

II. Results

Water produced along with oil or gas is technical. This is a mixture of injection and condensation water. The content of certain substances depends on the geological characteristics of each well. The composition of reservoir water is complex and may contain several thousand compounds, which vary in concentration over the entire life cycle of the well, table 1. Particularly concerning are dispersed oil, aromatic hydrocarbons and alkyl phenols (AF), heavy metals, and natural radioactive material (PFP). Process water may also contain a large amount of organic material, particles of inorganic salts and low molecular weight organic acids, such as acetic acid and propionic acid, and may have high levels of sulfur and sulfides. Moreover, water injected into the reservoir contains chemicals such as biocides, corrosion inhibitors, scale inhibitors, emulsions, coagulants, flocculants and oxygen scavengers. Also in the composition of technical water contains sulfate-reducing bacteria. An excessively large amount of discharge of technical (formation) water, as well as the content of hazardous complex chemicals and a lack of knowledge about the long-term environmental impact, made the best researchers carry out their research in this area

TABLE I. CONTENT OF AQUEOUS AND BUFFER EXTRACTS OF DRILLING CUTTINGS

Element	Content, µg/ml	
	In aqueous extract	*In buffer extract*
Aluminum	10.0	1398
Barium	2.1	2474
Boron	-	0.46
Vanadium	<0.02	<3
Iron	15.0	8388
Cadmium	< 0.002	1.9
Manganese	0.3	2006
Copper	0.3	41.6
Tin	<0.1	<0.1
Mercury	<0.001	1.3
Lead	5.2	3905
Strontium	0.18	2265
Chromium	0.9	435
Zinc	0.4	1925

Monocyclic aromatic hydrocarbons (MAH benzene, toluene, ethylbenzene, xylenes), polycyclic aromatic hydrocarbons (PAHs) and related heterocyclic aromatic compounds are considered to be the main toxicants, that is, poisons in the process water. Data compilation from field emission reports for 2012 shows that the average MAH concentrations in process water on the Norwegian continental shelf ranged from 2 to 58 mg / m3. For two or three ring aromatic hydrocarbons (naphthalene, phenanthrene, dibenzothiophene and their C1-C3-alkylated homologs), the concentrations ranged from 0.5 to 8.1 mg / m3, for 4-6 ring aromatic hydrocarbons, the concentrations ranged from 0.4-12 mg / m3 of Polyaromatic hydrocarbons (PAHs)) (anthracene, benzopyrene, benzofluorantene, benzoperylene, chrysone, dibenzene anthracene, fluorantene, pyrene, etc.).

UIA is less environmentally harmful, quickly evaporates from sea water [4]. The effects of alkyl phenol cannot be excluded. Phenol and AF are dangerous and toxic, cause a number of adverse biological effects [5]. In 2012, the total amount of phenol and C1-C9 AF on the SCS was 206 and 316 tons, respectively. Processed water includes such metals as arsenic, cadmium, copper, chromium, lead, mercury, nickel and zinc. Barium and iron also exceed minor concentrations in seawater. In 2013, the barium concentration was 2.1 per 1100 mg and 0.3 for copper. The highest values are above the solubility of these elements in sea water. The dissolubility of pollutants and the chemical processes caused by these pollutants quickly reduce the concentration of inorganic elements entering the sea. Barium and iron are redox-sensitive substances that can accelerate after being released into the sea and cause adverse effects on living organisms.

The range of biogeomechanical processes that affect inorganic elements was analyzed in other studies. In the course of the study and the calculations carried out using linear differential equations [6], it has been found out that the level of metal content near the facilities increased compared with the figure of the 2000s. Higher levels of trace metals in sediments collected near installations. This is mainly due to the discharge of drill cuttings. There is no indication that the level of trace metals in fish and mollusks collected near offshore installations is significantly higher than the natural background concentrations, table 2, figure 3.

TABLE II. FRACTIONAL STRUCTURE OF DRILLING SLUSH AND ITS DEPOSITION RATE IN WATER MEDIUM WHEN DRILLING WELLS ON THE SEA CONTINENTAL SHELF

Particle size, microns	Content, % by weight	Deposition rate cm / s
<42	37.5	0.06
42-60	4.5	0.22
60-86	3.6	0.37
86-123	4.5	0.75
123-147	1.8	1.4
147-175	2.2	1.9
175-248	4.0	3.0
248-418	8.0	4.9
418-830	15.5	8.5
>830	19.2	10.5

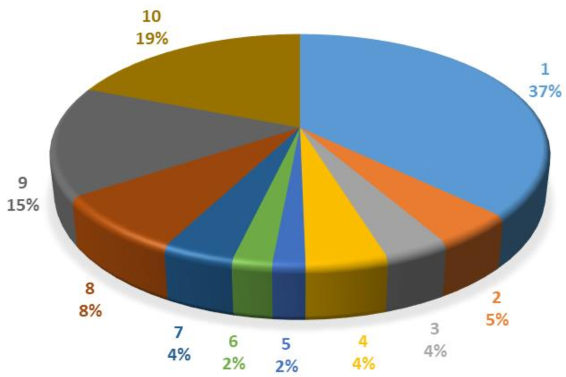

Fig. 3. Fractional structure of drilling slush and its deposition rate in water medium when drilling wells on the sea continental shelf

The most common elements of SCS in process water are radium-226 and radium-228. Reservoir water in different areas of SCS contains different levels of these elements. The research and monitoring of the aquatic environment shows that the concentration of radium-226 varies within the range acceptable for the life of organisms.

The chemical composition of process water in the continental shelf has been studied by many researchers. Analyzing the studies on the chemical composition of this water, we can conclude that its concentration is different in different areas. The researchers revealed a lack of correlation between the process water and the content of aromatic hydrocarbons. Consequently, the impact of process water discharges cannot be excluded from the legislation [7]. The biological effects of the process water make generalizations difficult.

Identification of concentrations of industrial water in the sea is complicated due to the fact that when it gets into sea, it quickly dissolves. In order to facilitate the process of detecting the concentration of substances in sea water, concentrator devices were developed. The widespread use of concentrometers has led to the emergence of reference data on concentrations of substances in the sea.

Analyzing the obtained values, we concluded that the concentration of alkyl phenols in the muscles and tissues of organs of certain sea species is low. The low content of alkyl phenols is due to the fact that getting into the body, these substances are quickly absorbed. Therefore, the analysis of the concentrations of the starting compound in tissues is of limited value in assessing the effects of industrial water pollutants on fish around drilling platforms. Since the early 1980s, the analysis of polyaromatic hydrocarbon metabolites in fish bile has been used to assess the effects of polyaromatic hydrocarbons using radioactive alkyl phenols and to show that the concentration of alkyl phenols in the liver was low, while metabolites of alkyl phenols are found mainly in bile. Recently, reviews of methods for the determination of impurity metabolites in fish bile have been published. The quantitative analysis of metabolites of polyaromatic hydrocarbons and alkyl phenols in bile is used in integrated monitoring systems [8], since it indicates the chemical contamination and a biological response. In many laboratory experiments with Atlantic cod, the relationship between the effect of industrial water or oil on the metabolites of polyaromatic hydrocarbons and alkyl phenols in bile was lyophilized at the level of bile metabolites. It was found that for some polyaromatic and alkyl phenols in Atlantic cod, the content of artificial industrial water in the water mixture is from 2 to 8 months. Most compounds were found as monatomic metabolites. It was found that the bioconcentration of four radioactively labeled alkyl phenols was ten times higher after the exposure to water than after the absorption by the intestinal wall after the exposure to food. It was found that metabolites of polyaromatic hydrocarbons in various fish species exposed to dispersed crude oil correlate both with the parameters and polyaromatic effects (DNA adducts).

Young Atlantic cod is able to metabolize and secrete short-term AF. It was found that heptylphenol rapidly accumulates in most tissues of young Atlantic cod. Precipitation lasts 13 hours. This corresponds to the observed half-lives [9] for alkyl phenols in cod tissues and previous studies with other fish species. Thus, elevated levels of AF metabolites in marine cellular fish indicate an impact on the sea fauna.

Drilling waste consists of crushed stone and residual drilling fluid. The task of the drilling fluid is to lubricate and cool the rock and rock cutting tools, stabilize the wellbore, control the pressure and transfer the drill cuttings to the platform. The composition of drill cuttings includes previously used drilling fluid with lost technical properties. The main components of drilling fluids are fluids (water, oil and other organic fluids [10, 11]) and barium sulfate. To improve the physicochemical composition of the drilling fluid [12], various additives are used: thickeners (e.g., polyacrylates, other organic polymers), emulsifiers (e.g., alkyl sulfonate acrylate and polyethylene oxide) and deflocculants. The main modifications of the drilling fluid depend on base fluid, aqueous solutions containing sea water as the base fluid, oil-based drilling fluids (BRD) containing diesel oil or a low content of aromatic mineral. Oil-based drilling fluids and synthetic drilling fluids are used to preserve and stabilize lubrication in the horizontal wellbore. Chemicals that make up the drilling fluid are classified according to the nature of the impact on the introduced medium.

III. Conclusion

Offshore emissions are a continuous discharge of pollutants into the sea from many sources. It is difficult to study the effect of discharges on fish and marine ecosystems. We carried out studies of the effect of process water on the fauna of the marine environment. The data on the concentration of harmful substances say that the harmful effects are observed within 1000-2000 m from the platform. It is necessary to conduct research on the effect of drilling water on the fauna of the aquatic environment. Therefore, there minor, cumulative effects of operational discharges which we cannot be measured and ignored. There is no assessment of the potentially significant impact of water discharges. We offered to

- develop methods that can be used for the large-scale medical examination of organisms;
- conduct research on natural interaction of species at the ecosystem level.

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