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SYSTEM APPROACH TO THE ASSESSMENT OF ANTHROPOGENIC IMPACT ON MARINE ECOSYSTEMS DURING OIL PRODUCTION ACTIVITIES

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Abstract. The system of quality categories, integrated and single indicators was created for the marine ecosystem under the impact of oil production. On the basis of the integral differential approach, a significant and moderate degree of influence has been substantiated for the stages of drilling the well and extracting oil, as well as an insignificant impact for seismic exploration and decommissioning.

Key words: shelf fields, marine biota, biodegradation, bioaccumulation, oil pollution, quality indicators.

1. Introduction

The process of oil deposits developing and operating on the land and on the continental shelf differ significantly, not only in engineering and technological aspects, but also in the nature and strength of the impact on the natural environment. Aqua ecosystems are functionally and structurally different from terra ecosystems, which substantiates the need for the development and implementation of a differentiated approach to the estimation of the technogenic load on the corresponding natural complexes.

Oil production in the sea and in the ocean has high potential, but due to geographical geological, climatic, geophysical and other conditions, continental shelf deposits of such countries as Saudi Arabia, the USA, Brazil, Angola, Russia, Norway, the United Kingdom and Kazakhstan are actively developing. Oil production is carried out in the Mexican and Persian Gulf, the Baltic, Caspian, Barents, Northern, Pechora seas, the Arctic shelf. 46 deep water (> 200–2942 m) gas, condensate and oil fields are discovered, explored and developed on the continental slopes of mainland Asia, in particular in the Caspian Sea, the Mediterranean Sea and the South China Sea, the Bengal Bay and the Lake Baikal, in the waters of Azerbaijan, Israel, China, India and Russia [1].

Quite often, the problem of normative and legal regulation and management of the environmental safety of a particular sea is amplified by the division of the marine environment between several states, which creates uncertainty in the legal status of the sea. The border between the countries is often difficult to establish, for example, the Norwegian and English drilling rigs operate in the Barents and the North Seas, while the Caspian Sea is divided among Russia, Kazakhstan, Azerbaijan, Turkmenistan and Iran [2].

Taking into account the growing volumes of oil production at sea, which according to various data of the researchers today make up 29–31 % of the total world production, and the potential reserves available for the development, the level of environmental hazard will only increase. The polluting effect of offshore oil production both for biota and air basin, subsoil, water and land resources is complicated by the risk of emergency spills during drilling and industrial operations, oil storage and transshipment operations, pipeline transfers and tanker transportation.

According to [3], the probability of accidents on pipelines is estimated to be from $6.3 \cdot 10^{-4}$ to 10^{-3} leakages / km / year, and accidents in case of tanker oil transportation – from $9 \cdot 10^{-4}$ to $1.5 \cdot 10^{-2}$ spills per year. Significant environmental hazards and the greatest environmental damage are caused by the fires that result from an open fountain of oil and can be enhanced by the release of hydrogen sulfide, which is typical of shallow water zones and is confined to carbon deposits, lower perm, triasses [4]. The consequences of the explosion of the Deepwater Horizon oil platform in the Gulf of Mexico (2010) were the formation of an ecological disaster area with a radius of 400 km, in which most species of mammals and birds died [5]. The fire at No. 37 Tengiz field (Northern Caspian, Kazakhstan) caused three times increase in the incidence rate among the population within a radius of 350 km^3 and resulted in the death of 200 thousand birds [6].

The analysis of the research on the effects of marine pollution on crude oil indicates their narrow orientation and applied nature for a particular case, which determined the purpose of the work and the subject of the study. The purpose of the article is to develop a systematic approach to a comprehensive assessment of the oil production load on all components of the marine ecosystem.

The main tasks of the paper are:

1) to determine the basic eco-destructive factors in the development and operation of offshore deposits, which create a danger zone for marine biota;

2) to analyze significant approaches to assessing the impact on marine ecosystems;

3) to assess the impact on ecosystems using the integral-differential approach.

2. Theoretical part

2.1. Characteristics of the impact on the abiotic component of the ecosystem

The technological load on the marine ecosystem is present at all stages of oil production – during exploration, drilling, oil and gas production, preparation and storage, transportation and processing. An adequate assessment of the impact of the investigated process involves the allocation of four main stages of the development of oil and gas fields (Fig. 1). Such approach is associated with the presence of various environmental degradation factors that cause parametric and ingredient contamination.

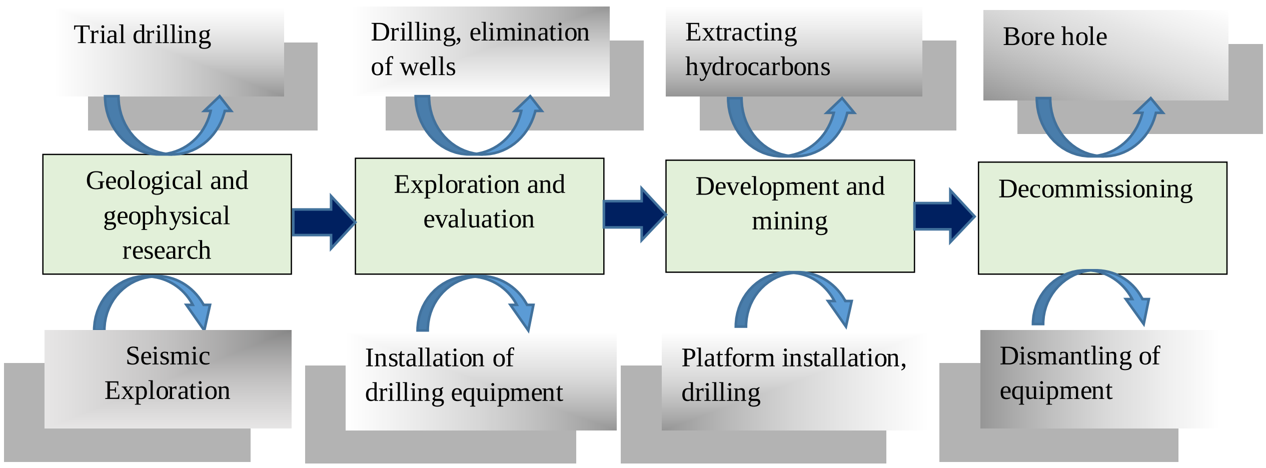

Fig. 1. Structural-stage scheme of the oil field development process

Effect on the air. Atmospheric air is negatively affected, mainly at the stage of the well development and oil production, due to the formation of a large number of pollutants caused by the combustion of associated gas and excessive amounts of hydrocarbons. The main pollutants of the atmosphere are: greenhouse gases CO_2 and CH_4, nitrogen oxides NOx and volatile organic non-methane hydrocarbons.

Impact on water resources. The main factors determining the impact on the aquatic environment during the work at all stages of oil production are: the physical presence of water craft in the water area; seawater intake for own / production needs; discharge of normative-clean drains; discharge of normative purified oil-contaminated and domestic sewage; insignificant interfusion of bottom sediments during stabilization of the vessel at the drilling point; insignificant interfusion of bottom sediments during the installation of a water separating column; discharge of comminuted food waste.

As a washing liquid, sea water is used with the addition of bentonite powder. To drill one well 100 m deep, about 30 m^3 of sea water is required. Under the conditions of a closed circulation system of the washing liquid, the filling of the circulating system is assumed to be 10 % per well. During the operation of the vessel, such types of wastewater are formed: process wastewater; drilling wastewater; domestic wastewater; drainage wastewater; normative-clean water.

Influence on the subsoil. At the stages of construction and operation of facilities for offshore field development, the following types of impacts on the subsoil are carried out: geomechanical; hydrodynamic; geochemical; geothermal.

2.2. Predicting the effect for aquatic organisms due to contamination of the aquatic environment

The greatest risk to marine hydrobionts is chemical contamination of the aquatic environment, the source of which in the process of oil production on the shelf is mainly oil and to a small extent –drilling fluids reagents and metals. Over time, petroleum hydrocarbons undergo active transformations under the influence of the combination of physical, chemical and biochemical processes: photooxidation, photodegradation, biodegradation, etc. (Fig. 2), and migrate to all components of the ecosystem in different ways.

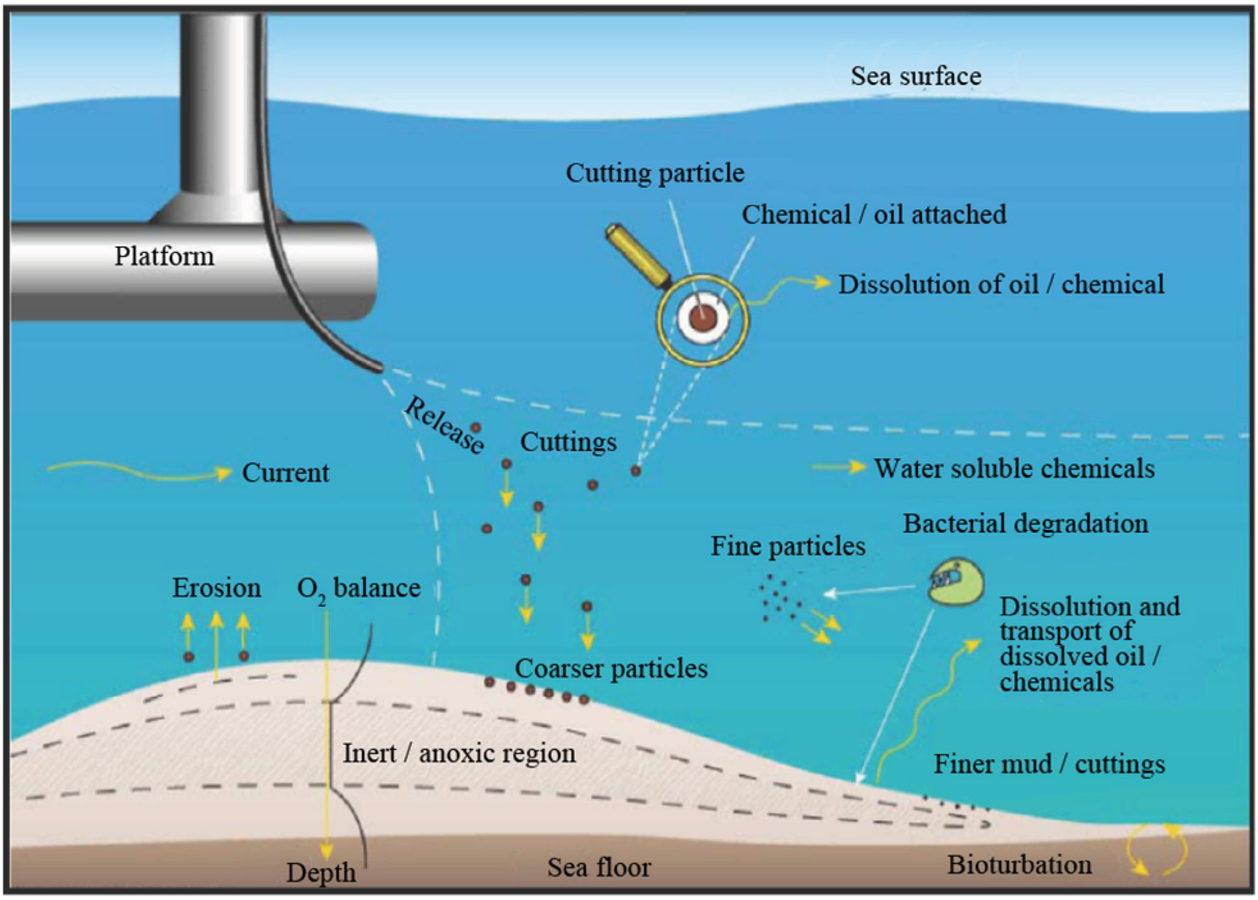

Fig. 2. Systematization of the impact of well drilling and oil production on marine hydrobionts [7]

In paper [8], the content of pollutants in seawater, sediments, marine flora and fauna entering the marine environment as a result of accidental spills in the example of the Gulf of Mexico was analyzed. The choice of such abiotic and biotic components of the ecosystem is primarily due to the chemical nature of the oil itself, which is not the only substance, but contains about 1700 different substances from the classes of aliphatic, aromatic and cyclic hydrocarbons. In this regard, there is a significant difference in the physical and chemical properties of each compound, which determines the patterns of their distribution in the aquatic environment: volatile substances can be absorbed by plankton organisms and / or diffuse into the atmosphere. Paraffins, high-molecular hydrocarbons are in the water only for a short time and are deposited in the sediments. Petroleum hydrocarbons with composition in the range of C10–C34, polycyclic aromatic hydrocarbons have bioavailability [9] and undergo biotransformation and biodegradation involving fungi Trichoderma harzianum, Aspergillus fumigatus – with respect to naphthalene [10], Aspergillus spp. – crude oil [11], Cunninghamella elegans – phenanthrene, anthracene, Aspergillus niger, Penicillium sp – n-hexadecane [12], Cunninghamella elegans, Aspergillus ochraceus – benz(a)pyrene [13].

High efficiency of the application of consortia of different types of bacteria, for example, Alcanivorax sp., Pseudomonas sp., and Rhodococcus sp. [14], or Alcanivorax, Acinetobacter, Marinobacter, and Pseudomonas [15] has been theoretically substantiated and experimentally confirmed. The complexity of predicting the influence of hydrocarbons on the biota and the processes of their biodegradation consists in the need to take into account the whole range of factors, among which are: temperature, oxygen regime, salinity, nutrient content, hydrogen index pH, water activity, bioavailability, microbial consortium, toxicity of products [16] At the same time, under the influence of abiotic factors within the marine environment a group of specific bacteria has been formed, for which the conditions of high mineralization of water, the presence of petroleum hydrocarbons with predominant carbon content as the main source of energy and moderate temperature are optimal for productive life.

The development of organisms such as Oceanobacter [17], Alcanivorax borkumensis, Marinobacter hydrocarbonoclasticus, Oceanicaulis alexandrii, Oleispira hydrobionts [18] in marine ecosystems is quite favorable for other hydrobionts due to the weakening of the toxic, mutagenic and carcinogenic effects of pollutants in the case of low concentrations. In high salinity conditions (up to 30 %) for aliphatic hydrocarbons, polycyclic aromatic hydrocarbons, aromatic hydrocarbons such as benzene, toluene, ethylbenzene, xylene, high efficacy of biodegradation from 100 % to 70 % is confirmed, with the participation of bacterial consortia with dominant species of Halomonas Alcanivorax, Marinobacter, Haloferax, Haloarcula and Halobacterium [19].

In the Arctic seas and oceans with cold climate, the most effective consortia of thermotolerant oil-deficient bacteria of species Oceanospirillales, Alteromonadales, Pseudomonadales, Legionellales, Rhodobacterales, Rhizobiales, Sphingomonadales, Rhodopirillales, Myxococcales, Methylophilales, Flavobacteriales, Sphingobacteriales, Acidimicrobiales, Actinomycetales, and Bacillales are formed [20].

It is advisable to analyze separately the effect on hydrobionts during and after emergencies as the spectrum and strength of determining destructive factors change, in particular, the direct and indirect effects of the physical and thermal factors of the fire, the formation of areas of highly concentrated contamination with crude oil, which often leads to the instantaneous death of higher-level organization organisms, mainly sea birds and mammals.

The most significant catastrophe in the history of the oil industry, due to the explosion on the Deepwater Horizon oil platform in the Gulf of Mexico in 2010, caused the need for an impact assessment, the development of a system of measures for prevention and rapid response, modeling and forecasting of possible scenarios for the development of such situations in order to minimize the load on the environment and prevent the negative impact on the local biota. The study of long-term effects is particularly important, since over time, according to various data, from 14 % [21] to 47 % [22] of oil entering the aquatic environment is the subject to gradual sedimentation and accumulation in marine bottom sediments and bodies of benthic organisms.

2.3. Approaches to assessing the impact on marine ecosystems

In assessing the impact, special attention should be paid to such criteria as the level, duration and geographical extent of the proposed interaction in spatial and temporal frames. This approach involves the use of four categories of significance:

I Significant influence: the degree of the effect on the entire population is sufficient to cause the reduction in the number and (or) a change in distribution, beyond which the natural replenishment does not return the population to its previous level for several generations of the species disturbed by the influence;

II Moderate influence: influence on a part of the population and can cause a change in the number and (or) distribution within one or several generations of the disturbed species, but do not threaten the integrity of this population.

III Insignificant influence: influence on a specific group within the genetic population for a short period of time (no more than one generation of the individuals affected by the influence), but do not affect other trophic levels or population;

IV Negligible impact or lack of influence: no significant predictable environmental impact; the impact is so insignificant that it does not need further consideration when conducting the impact assessment.

Technogenic load on marine ecosystems from oil production can be estimated using indicators and target quality indexes. In the framework of the study of the Barents Sea, the authors of the paper [23] suggest the allocation of indicators within the individual categories, integrated into the system from three interrelated groups of signal parameters:

- indicator of the state characterizing the ecosystem quality under natural conditions – S (state);
- indicator of the influence, which identifies the nature and strength of the impact of the technological process on the ecosystem – I (influence);
- indicator of the consequences, pointing out specific qualitative and quantitative changes in the ecosystem – C (consequences).

The disadvantage of this approach is the lack of unification, as categories and relevant indicators were selected from the list of the most significant for the studied ecosystem.

The authors of the paper [24] recommend using the system of key parameters during complex environmental monitoring (Table 1).

Table 1

The system of environmental parameters used for environmental monitoring of oil exploration works

Type	Category	Parameter
Physical	Meteorological	Temperature and humidity of air, atmospheric pressure, direction and wind speed, cloudiness
	Oceanographic	Temperature and salinity of water, speed and direction of currents, transparency, excitement, ice
Geochemical	Descriptive sedimentology	Visual description of the surface of sediments; granulometric composition; scent; color; total organic carbon (TOC); water content; oxidation-reduction potential (Eh)
	Hydrocarbons	Total hydrocarbon content (THC); naphthalene, phenanthrene / anthracene, dibenzothiophene and their C3 alkyl homologs (NPD); bicyclic aliphatic hydrocarbons such as decolines; 2–6 cyclic aromatic hydrocarbons
	Metals	Necessarily: Barium Ba, Cadmium Cd, Copper Cu, Lead Pb, Zinc Zn, Mercury Hg, Ferrum Fe; Desirable: Cobalt Co, Nickel Ni, Vanadium V, Chromium Cr, Strontium Sr, Aluminum Al
Biological	Zoobenthos	Number of species per unit area or per unit volume of sediment; quantity and biomass of individuals of each species
	Ichthyofauna	THC, NPD, bicyclic carbohydrates in muscle and liver; age and size of each individual subject; dimensional sample and statistical analysis

3. Results and discussion

3.1. The results of the application of the system approach

A system approach to assessing the load of complex oil production on the biotic component of the marine ecosystem involves taking into account all the factors of influence at each stage of the process under study. From the standpoint of environmental safety, it is advisable to decompose destructive factors: by the direction of the impact – into direct (directly on the organism) and indirect (through changing parameters and environmental conditions); by the nature of the action – physical, chemical and mechanical; by the duration of the action – constantly acting and suddenly arising; due to occurrence – regular and emergency situations.

To predict the strength and significance of the negative impact of the above stages of the oil extraction process on marine hydrobionts, it is necessary to take into account both external factors and the structure of internal relationships that arise between different ecological groups of organisms. In ecological systems trophic connections are the key ones, as they determine the place of each trophic level in the food chain and most fully and adequately testify the interdependence of producers, consumers and decomposers. Within the biocenoses of the aquatic environment, under the influence of abiotic ecological factors, the following enlarged categories of hydrobionts are formed: phytoplankton, zooplankton, zoobenthos, periphyton, which form a rather complex system.

Seismic exploration works are negative, even lethal, for zooplankton, in particular, ichthyoplankton within a radius of 2–3 to 5–7.5 m, a maximum of 10 m [25]. Single pneumatic springs (PDs) form the areas of ecological danger, within which the pressure reaches 0.3 MPa and more, and as a result, mortality among planktonic organisms is 80–100 %. The boundary radius of the influence depends not only on the parameters of the source, but also on the individual properties of the recipients, first of all, the size of the organisms, the structure of the body, taxonomic units which values vary greatly for the representatives of the ecosystems of the northern seas and subtropics.

The technological process of drilling wells, regardless of land or sea, involves the use of drilling mud, which includes a range of chemicals combined in the groups for functional purposes: corrosion inhibitors, lubricants, emulsifiers, dispersants, surfactants, thickeners, foam agents, etc. There is high probability of pollutants of the 2nd-4th grade of danger entering the water environment due to the application of the spent drilling mud and drilling sewage. The toxic components of waste, such as heavy metal ions, petroleum hydrocarbons and radioactive elements, have a toxic effect in relation mainly to marine invertebrates, fish and mammals. The use of environmentally safe technologies for handling drill wastes, in particular, their solidification and stabilization in construction materials such as gypsum concrete, facilitate the immobilization of heavy metals in the crystal lattice of a composite that prevents their leaching into the environment and transforms into a non-bioavailable form [26].

In the case of non-compliance, the most harmful organisms are exposed to higher trophic levels due to the principles of biomagnification. Therefore, various scenarios for the development of ecosystems are possible under the influence of chemical pollution, the dominant among which is oil. According to expert estimates, about 500 thousand tons of raw product come from ocean water every year due to unusual situations and transportation of oil. An additional source is biogenic formation, since for some bacteria the final metabolite product is aliphatic and cyclic hydrocarbons.

The greatest danger is caused by thin oil films on the surface of the water which, on the basis of hydrophobicity and nonpolarity of the molecules, violate the mechanism of gas exchange at the interface between the phases of the liquid (sea water) – gas (atmospheric air). As a result, hypoxia occurs in fish and mammals; less susceptible are benthic species which include the most common species such as Nereis worms, Dreissena molluscs, Didacna, crustacean Corophiidae, Cumacea, Gammaridae. Due to the specific sensitivity and response of the daphnia, artemia, to the action of oil and components of the drill mud they are recommended to be used as test objects during biotesting and experimental determination of the hazard class of waste (Fig. 3).

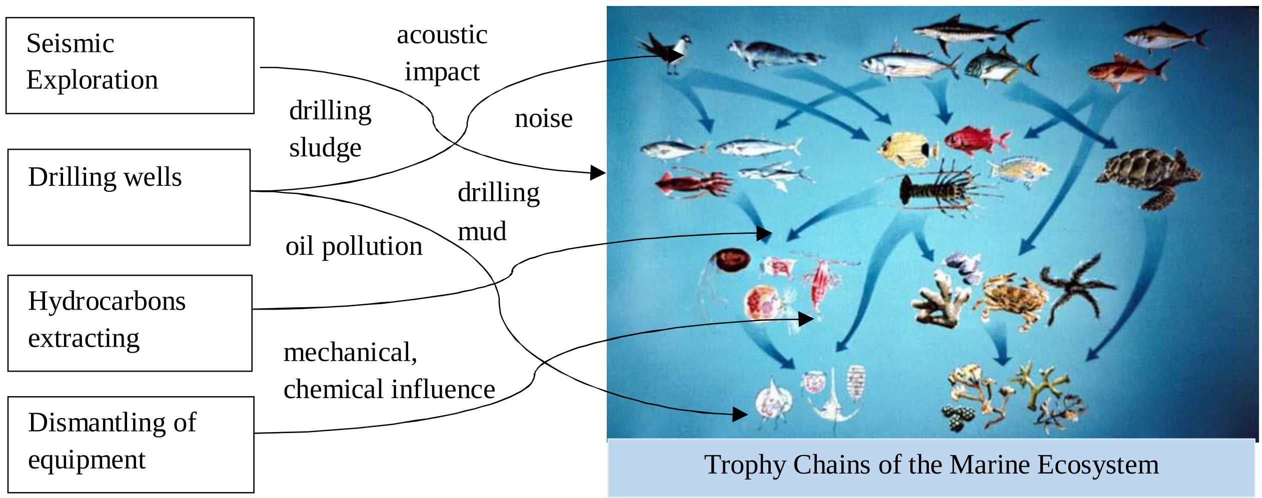

Fig. 3. Schematic representation of the influence of destabilizing factors on hydrobionts during each stage of oil production

Isotopes of radioactive elements enter the aquatic environment mainly during the development of the deposit and oil production due to the discharge of reservoir waters and drill waste water contaminated by 238U, 232Th and decay products – 226Ra, 228Ra, 210Pb, and 210Po due to their contact with the rocks. At the stage of decommissioning, the main source of radioactive contamination is deposits on industrial drilling equipment. Considering the chemical properties of isotopes of radium before the formation of insoluble salts such as sulfates and carbonates, the abiotic component of the biogeochemical cycle is associated with their deposition in bottom sediments which, together with seawater, serve as a source of radioactive elements for hydrobionts.

Under these conditions, both external and internal irradiation with α and β-rays occurs, and the migration of isotopes along the trophic chain from phytoplanktonic producers to marine mammals, including bioaccumulation and biomagnification processes. The diversity and branching of trophic bonds within the studied ecosystem cause uncertainty in the radiation dose estimation at each level of the ecological pyramid of the biomass, which complicates the prediction of the expected effect by the methods of mathematical modeling.

Ionizing radiation, having extremely short wavelengths and high energy, initiates the decomposition of many organic components, degradation of proteins and amino acids, damage to the tissue and bone marrow. Toxic effects can be observed only in the short-term exposures of low doses, due to changes in enzymatic systems and violation of the mechanism of metabolic processes. Long-term effect is manifested in carcinogenesis and mutagenesis caused by mutations in DNA and cellular nuclei.

The strength and nature of the effect of certain doses of radioactive radiation on individual organisms depend on a number of factors that can be grouped into three categories related to: 1) the source of influence; 2) environment parameters; 3) characteristics of the recipient. To the first category we will consider: the type of radiation (α, β, γ-radiation); kind (external or internal); isotopes of radioactive elements with different physical and chemical properties, which determines the degree of bioavailability, the location of localization and accumulation in the body. The second includes temperature, mineralization, pH, Eh medium. The third is the taxonomic affiliation and individual features of the organism.

3.2. Assessment of the impact on ecosystems by the integral-differential approach

After analyzing the specificity of the influence on hydrobionts at each stage of oil production, it became possible to identify the dominant factors of the influence and their contribution to the complex man-caused load. It has been established that taking into account the principles of bioaccumulation and biomagnification, the higher concentration of pollutant per unit body weight is characteristic for higher trophic levels. Therefore, on the basis of the described categories of significance, the degree of the influence on marine mammals, birds and fish as a result of technological operations accompanied by chemical and parametric contamination of the water and air environment is estimated (Table 2).

Table 2

Assessment of the impact of oil production on marine ecosystems by categories of significance

Impact / Recipient	Noise and research vessels	Discharge of sewage	Emissions from combustion	Removal of solid and hazardous waste	Random spills and leakage
Quito and pinnipeds	II	IV	IV	IV	III
Sea fish	IV	IV	IV	IV	III
Sea Invertebrates	III	IV	IV	IV	III
Seabirds	IV	IV	IV	IV	III
Water quality	IV	IV	IV	IV	III
Air quality	IV	IV	IV	IV	III

The data in Table 2 indicate the greatest damage of acoustic effect to cetaceans and pinnipeds during seismic surveys. Random spills and leaks, characterized by variability in composition and quantity, constitute danger to all components of the marine ecosystem. Other technological operations in case of observance of the established requirements have a negligible small effect.

In order to assess the load on marine ecosystems from oil production, it is advisable to use an integral-differential approach, the essence of which is in the following aspects:

1) development of a single extended system of categories of signal indicators of quality, taking into account climatic, geological, geographic, geophysical, geochemical, hydrobiological and other parameters of the environment of oil production and, consequently, its impact on local biota;

2) allocation of aggregated indicators within each category, which would most fully characterize the state of the ecosystem of the open ocean and the continental sea, the Arctic shelf and the Gulf of Mexico;

3) the application of the system of refined indicators within the corresponding aggregated units for each individual object under study.

An adequate assessment of the impact of the development of marine deposits and oil production on the quality of the environment can be made based on the developed system of integral categories of indicators. We have selected and substantiated seven categories of indicators: water parameters; phytoplankton; zooplankton; sea fish; sea birds; marine mammals; benthos. Any ecosystem, including marine, is a collection of organisms of different taxonomic groups and levels of organization, interconnected by trophic, topical, foric and factory relations, that is, it consists of an abiotic and biotic components.

For marine hydrobionts, the determinants of the abiotic environmental factors are the parameters of the aquatic environment itself, although the substance turnover and energy exchange occur both with atmospheric air and with the subsoil. The biocenoses of marine ecosystems are quite diverse, which again depends primarily on geographical and climatic conditions. So, for example, the environmental pyramids of the Elton numbers for the northern seas indicate a small number of trophic levels (up to 4–5), while for the equatorial or tropical latitudes, the trophic chains are well developed in both quantitative and qualitative terms. In this regard, all ecological trophic groups of hydrobionts will be affected by the negative impact of oil pollution on the marine environment.

The structural and organizational chart of individual indicators within each category is presented in Table 3.

Table 3

Systematization of indicators and signal indicators of man-caused load on marine ecosystems

Quality Categories	Integrated Indicators	Refined Indicators
Water parameters	Hydrological	Speed and direction of flow, water level, system lock, ice.
	Physical	Temperature, salinity, transparency, color
	Chemical: unspecific specific	Anionic and cationic composition (Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, NO_3^-, SO_4^{2-}), N, P, БСК, ХСК, dissolved oxygen; oil, synthetic surfactants (SS), phenols, organochlorine compounds, heavy metals, hydrogen sulfide. Risk factor within the limits of one limiting sign of harm (LSH): $K = \sum_{i=1}^{n} \frac{c_1}{ГДК_1}$; condition of safety $K \leq 1$.
Phytoplankton	Species composition Amount Biomass and production Bioactivity Trophy index Saprobity index	% green algae of the total number % blue-green algae of the total number % diatoms algae of the total number Photosynthesis speed By the method of Milius: $Ib = 44.87 + 23.22 \cdot logB$, where B – total biomass of algae in the sample; The method of Pantle and Bucc in the modification of Sladechek $S = \frac{\sum_{i=1}^{N}(s_i \cdot h_1)}{\sum_{i=1}^{N} h_1}$, where N – number of selected types of indicators; h_i – relative number of i-th type; s_i – individual index of saprobity of the i-th type.
Zooplankton	Species composition Number Biomass Secondary production	Species diversity index of Shannon Species richness index of Margalef Indices of dominance Biotests on daphnia (fecundity, vitality)
Sea fishes	Biomass Fishing Spawning stock	Index of growth Extraction rate from the ecosystem Coefficient of reproduction
Sea birds	Population development Population dynamics Population size	Number of species
Sea mammals	Population dynamics Population size Xenobiotics content	Number of species Areas sizes Bioaccumulation factor $BAF = \frac{C_i}{C_c}$, where C_i – the concentration of the i-th contaminant in the body, 10^{-6} kg/kg; C_c – the concentration of the i-th contaminant in the environment, 10^{-6} kg/kg.
Benthos	Biomass Biotic potential Species ratio	The content of radioactive elements The content of hydrocarbons The content of heavy metals

Conclusion

The load on ecosystems as a result of oil extraction on offshore fields is not limited to the consequences of oil pollution of the aquatic environment. The atmospheric air, water and biological resources, as well as subsoil undergo a negative influence of various degrees. Due to the combustion of the associated gas, mostly greenhouse gases CO_2 and CH_4, nitrogen oxides NOx and volatile organic non-methane hydrocarbons enter the atmosphere. Effect on the subsoil is associated with geomechanics, hydrodynamic, geochemical and geothermal changes present at all stages of oil production.

It has been established that in an aqueous environment, petroleum hydrocarbons undergo transformations caused by physical, chemical and biochemical processes, the leading role among which belongs to biodegradation with the participation of bacterial consortia of the Alcanivorax, Acinetobacter, Marinobacter and Pseudomonas composition and some fungi of the Trichoderma, Aspergillus Cunninghamella, Penicillium genera.

A systematic approach to the solution of this problem involves the study of oil production as a whole system, therefore decomposition of the process into interrelated components was performed in order to identify the key factors of the influence at all stages. It was determined that at the stage of seismic research the main eco-destabilizing factor is noise, in relation to which cetaceans and pinnipeds act as the most sensitive recipients. Drilling and oil extraction are accompanied by contamination of the habitat of marine hydrobionts with oil, drill mud, drill wastewater, heavy metals and radioactive elements.

To predict the level of load, a system of indicators and signal quality indexes has been developed, which takes into account both physical and chemical properties of the abiotic component of the ecosystem and the parameters of the ecological and trophic groups of the biota.

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