The Influence of Anthropogenic Factors on the Ecology of the Arctic Zone during the Construction of Oil Production Facilities

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Abstract. The purpose of this study was to determine the level of influence of production factors of construction work during the construction of oil production facilities in the Arctic zone. The study included such factors as: air pollution, vibrations and sound waves produced by the equipment, as well as losses of oil produced during exploration. The influence of these factors on the Arctic biosphere is considered. The proposed measures to protect the Arctic zone from the harmful effects of construction equipment.

1. Introduction

Our century is a century of active development of the Arctic infrastructure, mainly associated with oil and gas production. If at the beginning of the 20th century it was the “white desert” that was least affected by man-made factors, today the Arctic shelf is one of the most promising areas of oil and gas production due to the huge reserves concentrated in its depths. The mining industry is one of the most polluting of the environment. Consider the environmental effects caused by polluting factors.

2. Geological consequences

In the mechanized method of extraction (pumping) of petroleum products, a process harmful to nature proceeds. Water injected into the subsoil instead of oil violates the established geological structure. The violation manifests itself in a change in the established density of the soil due to the difference in density of liquids (the density of average oil is 845 kg/m³, and that of water is 1000 kg/m³).

One of the results of this violation is soil subsidence. The subsidence of the base of the structures, as a rule, causes various subsidence of the supports, taking the structures out of normal operation and causing technogenic accidents (for example, due to subsidence of the seabed, the Ekofisk oil platform broke down, causing an oil spill and gas release for 8 days) [1].

The second consequence is the occurrence of anthropogenic earthquakes in violation of the isostatic equilibrium over the crust. These earthquakes are not the strongest, but if they coincide with the natural seismic regime, it can provoke an earthquake that people can feel, the scale and consequences of which are difficult to predict. Under the conditions of the Arctic, the probability of occurrence of such earthquakes increases due to the presence of many tectonically active zones and a network of synokineal rupture faults.

In addition to deep-seated, surface transformations also affect the environment [2]. Changes in the relief of built-up areas, construction of foundations, redirection of underground flow, disturbance of
surface runoff and evaporation of moisture, laying of engineering networks lead to a sharp rise in the level of groundwater. Waterlogging affects the seismicity of the flooded areas, and also affects the hydrological regime.

3. Air pollution
The construction process is conducted in three stages: preparatory, main and final. All the variety of construction and production processes at any stage of construction of special-purpose facilities is reduced to the operation of vehicles, construction equipment and work equipment. And on remote construction sites, electricity is provided from portable power stations (gasoline and diesel) [3].

Table 1 identifies the main pollutants emitted into the atmosphere, depending on the type of construction work.

Table 1. Emissions of pollutants in the implementation of various types of construction works.

| Type of work                        | Pollutants                                                                 |
|------------------------------------|----------------------------------------------------------------------------|
| Welding, cutting                   | Iron (II, II) oxides                                                       |
|                                    | Manganese and its compounds                                                |
|                                    | Chromium hexavalent                                                        |
|                                    | Inorganic dust containing silicon dioxide (SiO2) above 70%                 |
|                                    | Nitrogen (IV) oxide (nitrogen dioxide)                                     |
|                                    | Fluorides inorganic soluble                                                |
|                                    | Inorganic fluoride poorly soluble                                          |
|                                    | Carbon oxide                                                               |
| Work of motor transport (on gasoline and diesel) | Nitrogen (IV) oxide (nitrogen dioxide)                                     |
|                                    | Nitrogen (II) oxide (nitrogen oxide)                                       |
|                                    | Carbon (soot)                                                              |
|                                    | Sulfur dioxide (sulfurous anhydride)                                      |
|                                    | Carbon oxide                                                               |
|                                    | Gasoline (petroleum, low-sulfur)                                          |
|                                    | Kerosene                                                                   |
| Work road equipment (diesel fuel)  | Nitrogen (IV) oxide (nitrogen dioxide)                                     |
|                                    | Nitrogen (II) oxide (nitrogen oxide)                                       |
|                                    | Carbon (soot)                                                              |
|                                    | Sulfur dioxide (sulfurous anhydride)                                      |
|                                    | Carbon oxide                                                               |

An important fact is that huge damage to nature is caused by abandoned wells without proper conservation or stubbing them. As a result, from the bowels of the earth into the atmosphere evaporated harmful gases contained in the depth of the field.

4. Noise pollution of the world’s oceans
The physical nature of the underwater environment, as well as its turbidity is the reason that the range of sound propagation in the sea is much higher than that of light. The consequence is that most marine animals have adapted to use sound as the main means of communication, navigation and perception of
the environment as a whole. Anthropogenic activity is the source of so-called “extra” noise for these species. These noises can disorient sea creatures, knock them off course, and in critical cases cause damage to the hearing organs or even death.

Of particular interest is the impact of anthropogenic noise on the biosphere during the construction of the structures of the Arctic shelf, which is now beginning to actively develop. Thus, during the construction of oil-producing structures, serious acoustic noise may be caused by the following work: cleaning of the water area from potentially dangerous objects, underwater earthworks, piling, construction itself. Also, structures are sources of acoustic noise in operation.

Consider the influence of anthropogenic noise on the vital activity of mammals in the Arctic zone during the construction of oil-producing facilities. The study is conducted with regards to the following types: the beluga whale, the narwhal and the ringed seal. For these three types, frequency auditory ranges are given [4,5,6]. Figure 1 shows a comparison of these parameters with frequencies, the sources of which are man-made factors in the construction of oil-producing facilities [4].

![Figure 1. Range of hearing of arctic mammals.](image)

As can be seen from the diagram, human activity is a source of “extra” noise perceived by individuals of all three species. These noises lie in the areas of low and medium frequencies and therefore have a greater propagation length. Obviously, this overlap will have a negative impact on all creatures in the area of dispersion. For example, “extra” noises can scare off or knock off the course toward a food source. Reproductive ability of some species may also be threatened. If one or more whales stop singing near the breeding site, then perhaps a new one will not be found. Also, “extra” noises are one of the probable causes of the mass stranding of cetaceans.

Due to the above circumstances, the design of structures on the Arctic shelf should take into account possible frequencies and ranges of effective propagation of harmful noise and choose the location of the structure in such a way as to eliminate the impact on the ocean's biosphere: away from reproduction sites, food and other active life activities of ocean inhabitants. This applies primarily to endangered and rare species. To reduce the level of general noise by using sound barriers, as well as the introduction of less noisy technologies in the extraction and transportation of petroleum products. Also, during the construction and operation of mining companies, it is necessary to periodically conduct acoustic monitoring as part of industrial environmental monitoring.

5. Impact of oil and gas production on marine life
In general, oil production from the sea bottom makes a significant contribution to the pollution of the water area. Its share is 7.5% of the total oil pollution [7], and the losses resulting from production
correspond to 1% of the oil produced [8]. When a ton of oil is spilled, a continuous film with an area of 2.6 km² is formed [9]. Getting into the aquatic environment, the oil very quickly ceases to exist as the original substrate. On average, only about 1-3% (sometimes up to 15%) of crude oil is dissolved in water, while from 10 to 40% evaporates. There are several states of oil in water: surface films (slicks); dissolved forms; emulsions ("oil in water" and "water in oil"); suspended forms (oil-oil units floating on the surface and in the water column, oil fractions adsorbed on suspensions), solid and liquid components deposited at the bottom [10]. The duration of the existence of oil spills on the water surface depends on the following factors: the amount of spilled oil; its chemical composition; weather and climatic conditions; water temperature; the nature of the circulation, etc. This time is from several hours to several months. It is possible to move oil spills over a considerable distance. There is a case when within 50 days the spot covered a distance of more than 200 miles [11]. The rate of movement of oil spills is 3% of the wind speed. With a high density of oil its immersion to the bottom. Thus, 20 thousand tons of oil disappeared off the north-west coast of Germany, and 6.4 thousand tons of heavy diesel fuel spilled in the Arctic Ocean after sinking to the bottom with the onset of summer again surfaced. The data on the transformation of oil spilled in the accident of the tanker Amoco Cadiz are given by R. J. Seymour and R. A. Geyer [12]: 30 thousand tons dissolved in water; 18 - sank by penetrating bottom sediments; 62 - cleaned and destroyed in the intertidal zone; 67 - evaporated; 10 - microbiologically degraded; the fate of the remaining 36 thousand tons is unknown. Marine oil production has a significant negative impact on the animal world. which manifests itself mainly through pollution of the water area. Seabirds are extremely affected, oil sticks together feathers, and the insulation is broken. The body temperature is maintained by speeding up the metabolism, which leads to the rapid depletion of fat reserves and the death of birds from exhaustion. Trying to cleanse themselves with their beak, they only bring the oil inside the feather cover. Oil then enters the digestive tract. With an "average" oil spill kills about 5 thousand birds, the crash of the tanker "Exxon Valdez" off the coast of Alaska killed about half a million birds [13].

References
[1] Zarhidze V S 1985 The newest stage of development of the Arctic shelf In the book: Geology and geomorphology of shelves and continental slopes (M.: Nauka) pp 58-65
[2] Avetisov G P 1979 On the tectonic nature of the Arctic seismic belt In: Arctic Tectonics: Fractures of the continental shoals and the ocean (M.: NIIGA) pp 59-80
[3] Nechaev L A 2013 Estimation of pollutant emissions for the period of construction of non-production objects Ecologist's Handbook 7 (Moscow) pp 125–128
[4] Sills J, Southall B, Reichmuth C 2015 Amphibious hearing in ringed seals (Pusa hispida): underwater audiograms, aerial audiograms and critical ratio measurements Journal of Experimental Biology 218 (GB: The Company of Biologists) pp 2250-2259
[5] Racicot R, Darroch S and Kohno N 2018 Neuroanatomy and inner ear labyrinths of the narwhal Monodon monoceros, and beluga Delphinapterus leucas (Cetacea: Monodontidae) Journal of Anatomy 233 (GB: Anatomical Society) pp 421-439
[6] Wright A 2014 Reducing Impacts of Noise from Human Activities on Cetaceans: Knowledge Gap Analysis and Recommendations (Switzerland: Gland, WWF international)
[7] Govorushko S M 2009 Geocological Design and Examination: A manual for university students (Vladivostok: FENU) 388 p
[8] Dolotov Yu S 1996 Problems of rational use and protection of coastal areas of the oceans (M.: Scientific world) 304 p
[9] Zuev O S 1999 Environmental problems of the development of oil fields of the Krasnoyarsk Territory (Environmental Assessment) 3 pp 50–53
[10] Korobov V B 2004 The Impact of Oil Extraction and Transportation on the Arctic Environment Problems of Regional Ecology 2 pp 55-62
[11] Botvinkov V M, Degtyarev V V, Sedykh V A 2002 Hydroecology on inland waterways (Novosibirsk: Siberian Agreement) 356 p
[12] Seymour R J, Geyer R A 1992 Fates and effects of oil spills II *Annu. Rev. Energy Environ* 17 pp 261-283
[13] Belikov A I 2003 By-effect *Ecology. Culture Society* 4 p 14