Harmfulness mapping for the Pechora Sea

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Harmfulness mapping for the Pechora Sea

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Abstract. Pechora Sea is characterized with many species including birds, fishes, benthic fauna and marine mammals. The food chains in the Pechora Sea ecosystems are simple and vulnerable to contamination even in a small concentration of pollutants. If pollutants harm one type of species, the whole food chain will be affected and can result in reducing a population of the specific species. Arctic climate conditions are characterized with low temperatures that have the influence on dilution, biodegradation and evaporation of contaminants. In this paper, conceptual approach for harmfulness mapping is presented. The main pollution sources in the Pechora Sea were identified associated with possible risk and presented in the risk matrix. Distribution maps of the birds, fishes, benthic fauna and marine mammals were used and embedded to risk maps to determine level of harmfulness for every group. Fuzzy approach was used for qualitative assessment of possible risk events for water, air and soil pollution and its influence on marine environment.

1. Introduction

Human activities in the Pechora Sea include shipping, fishing and offshore oil and gas fields development have potential stress on marine environment. Large oil and gas fields are already sufficient explored and ready for development. Compared with Barents Sea, Pechora Sea is semi-enclosed shallow water covered with ice for greatest part of the year. Coastal area is under active erosion due to ice melting and rising of sea level [1].

Bathymetry of the Pechora Sea is represented by flat plains with small sloping to the north. Water depths are around 20-60m reaching around 200m near southwest coast of Novaya Zemlya [2]. The environmental conditions in the Pechora Sea depends on water exchange and ice cover for the greatest part of the year. The Sea is covered with ice from November to April.

Development of the oil and gas fields in the Pechora Sea is associated with activities including offshore drilling, building new infrastructure for production (platforms, subsea modules) and transportation (subsea pipelines) of hydrocarbons. Every group of activities is associated with potential risk of air, water and soil pollution. To reduce possible environmental risks, it is important to evaluate most vulnerable part of the area and increase safety and security levels during field development. Discovered oil and gas fields in the Pechora Sea is shown in the figure 1.

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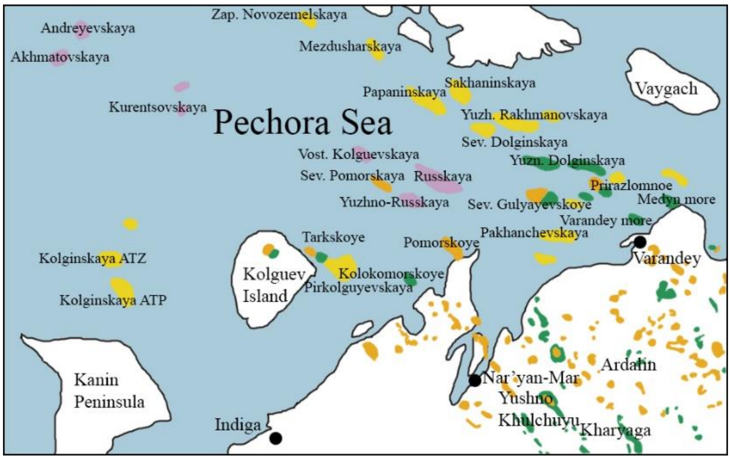

Figure 1. Discovered oil and gas fields in the Pechora Sea.

2. Pechora Sea marine environment

Pechora Sea has reach benthic communities (more 600 species), marine mammals (walruses, beluga whale, seals and polar bears), fish population (cods, salmons, herrings, white fishes, chars, navaga and local species). Pechora Sea is a region with many migration routes of marine animals. Here are the key ornithological territories, several natural reserves and wildlife refuges (see Figure 2).

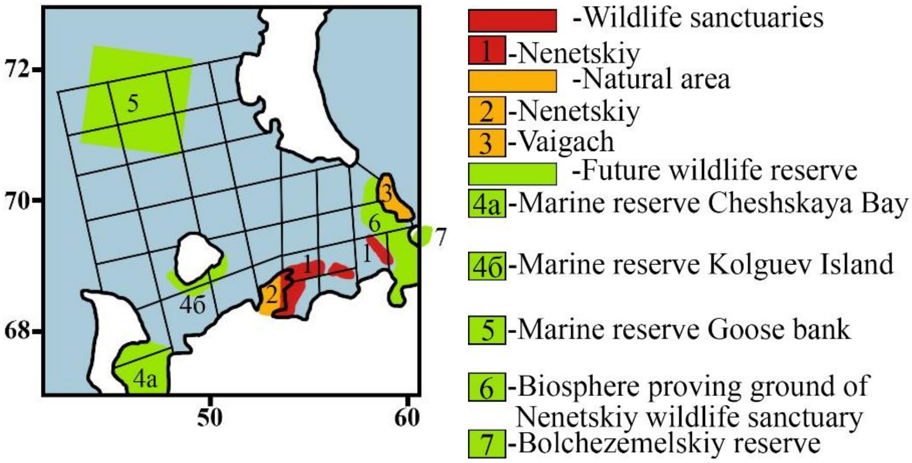

Figure 2. Existing Wildlife sanctuaries and future wildlife reserve.

This water area is inhabited by many animals listed in the Red Books of federal and regional importance: the white- billed loon, the tundra swan, the white gull, the golden eagle, the gyrfalcon, the white-tailed eagle, the Atlantic walrus, the polar bear, the white-faced dolphin, the harbour porpoise and others. these species are currently minimal, they need protection from negative anthropogenic influences [3].

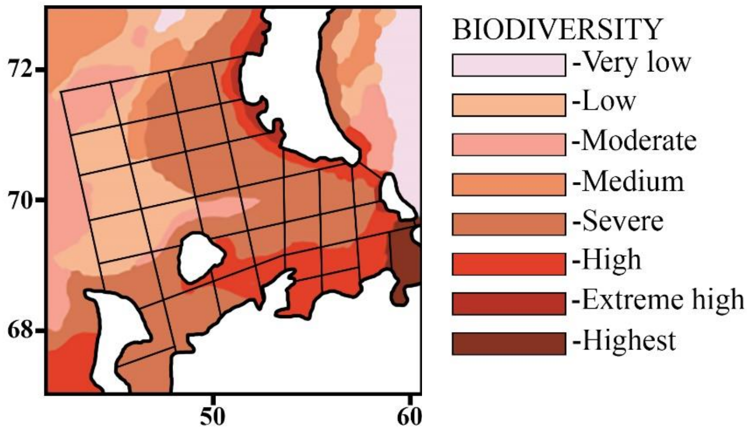

Figure 3. Biodiversity of Pechora Sea (based on [4]).

It is an important place for nesting, breeding and moulting of many bird species and stop area for migration. Around 130 different species were identified. Dominant species are Anseriformes (duck, swans and geese) and Charadriiformes (gulls and waders) [5]. Areas with large concentration of seabirds are shallow waters [6].

Bird colonies in the Barents and Pechora Sea are shown in the figure 4.

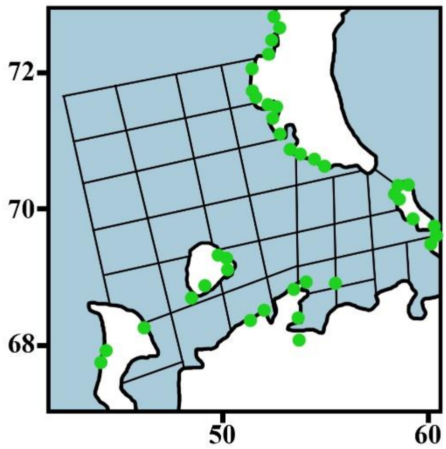

Figure 4 Bird colonies in the Pechora Sea (based on [7]).

3. Possible pollutants from the offshore operation in the Pechora Sea

Discharges from offshore platforms present a continuous source of contaminants for marine ecosystems. Possible pollutants during offshore oil and gas field development can be divided into three groups:

- Drilling waste (drilling fluids and cuttings)
- Oil spills
- Produced water

Drilling waste is consisted from drilling fluids and cuttings and it is largest waste during drilling operations [8]. Drilling waste is complex mixture of fluids and solids including:

- liquid fluids (water, oil, synthetic fluids)

- clays (barite)
- viscosifiers
- pH controlling agents
- shale controlling agents
- emulsifiers (alkyl acrylate sulphonate, polyethylene oxide)
- rock particles

Toxicity of drilling waste depends on type of mud (oil or water-based mud) and used additives. Discharge of drilling fluids and cuttings from platforms into the sea must fulfil oil-in-cuttings contents and disposal standards. During discharge lighter fluids will stay in the water column while the heavier components tend to sink on the bottom. Accumulated drilling cuttings piles have very slow biodegradation (50 cm) and deeper parts of the piles in most cases are still unchanged. Every disturbance of accumulated piles can cause erosion and uncover deep layers which can lead to leakage of possible contaminants. Safe method of drilling waste disposal is conversion to slurry and disposal into appropriate underground formation [8] [9].

Oil spills are defined as uncontrolled release of hydrocarbons into the environment caused by human activities. Major oil spills as the Deepwater Horizon arise consciousness around the world and triggered development of new advanced technologies for spill prevention, response and cleanup. However, in Arctic environmental conditions it is more difficult to fight with oil spills then in warm waters [9]. Main types of contaminants in the oil spills are:

- Crude oil
- Refined oils (diesel, gasoline…)

Oil spills present the most dangerous types of pollution with global consequences in every phase of field development including:

- Transportation (tanker collision, tanker damage, shipwrecks…)
- Subsea pipeline damage (icebergs, ruptures, damage from falling objects)
- Platform spills (wellhead damage, riser damage, offloading damage, storage tank damage)

Many toxic compounds in crude and refined oil have negative impact on environment. Volatile oil compounds can kill many aquatic organisms (planktons), floating oil can contaminate birds, mammals and coastal vegetation, heavier oil compounds tend to sink to the bottom and contaminate fish, mammals and benthic fauna. Oil compounds can be accumulated in marine organisms through water, sediments and food and cause negative effects on growth and reproduction.

Produced water management has become a major challenge in the oil and gas industry. Produced water is a mixture of formation water and injection water that is produced with oil and gas and it is largest byproduct generated during the oil and gas production. Water is present in every stage of oilfield life and can consist more than 95% of the produced fluid [11-13]. Produces water is consisted from:

- Dissolved compounds (oil, gas, formation minerals, radioactive minerals)
- Dispersed compounds (oil, chemicals, solids)
- Suspended solids (rock particles, scales, corrosion products).

Produced water is an integral part of the production system and requires proper management to satisfy environmental regulation, which requires more water reinjection into underground layers and aquifers [14].

4. Methodology

The methodology of risk mapping was based on the fuzzy logic theory. Pechora Sea was divided into several zones. Those areas were studied and assessed by using multi-criterion approach (air, water and soil pollution risks, benthic communities, fish, birds and mammal's population). Potential pollution risk mapping was made here for the case of the Prirazlomnoye oil field development and the routes of oil transportation from this field. Other discovered oil and gas fields in the Pechora Sea were not considered in this study. A whole range of impact was divided into eight different classes, where the 1st class has the lowest and the 8th – the highest risk factor [15].

Each group is described by well-defined numerical values from the interval [0, 1], which is divided into 8 subintervals of 0.125 widths each.

To aggregate these characteristics in order to build a technical accessibility map, the authors from the existing approaches to fuzzy systematization of data chose the Weighted Geometric Mean method (WGM). This method is based on the method of aggregation of a multicriteria estimate into a single criterion using the following rule:

$$\mu_{A_0} = \mu_1^{\omega_1} \cdot \mu_2^{\omega_2} \cdots \mu_n^{\omega_n}. \quad (1)$$

Here μ_i is an estimate by the i-th criterion, ω_i is the coefficient of significance of the i-th criterion [3]

Risk maps for air, soil and water pollution is shown in the figure 5.

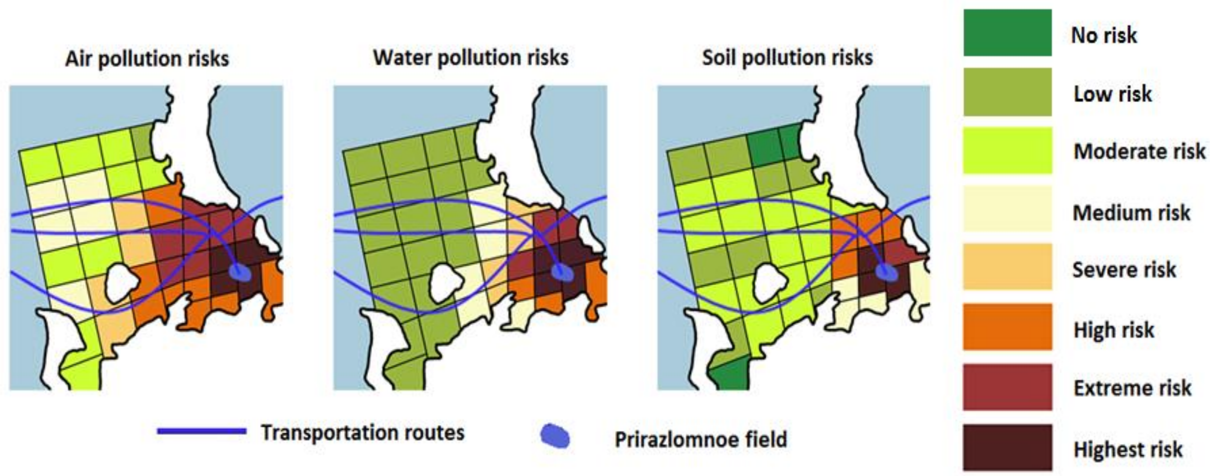

Figure 5. Risk maps for air, soil and water pollution [15].

As follows from the figure, the highest risk factor is determined by the Prirazlomnoye oil field and the transportation routes. It is important to note here that this map illustrates only risk associated with air, water and oil pollution and does not account for the weather and ice conditions [15].

By combining air, water and soil types of pollution risks using fuzzy logic it is possible to build one aggregate pollution risk map shown in Fig. 6.

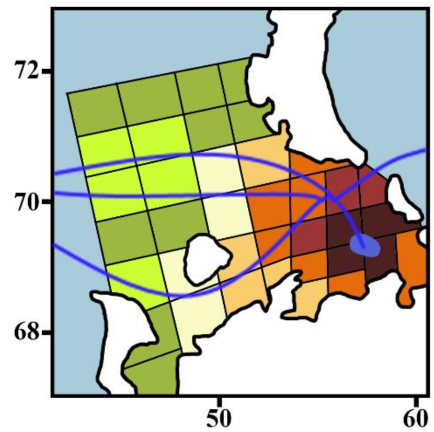

Figure 6. A combined map of pollution risk caused by oil production from the Prirazlomnoye oil field and the oil transportation routes [15].

Analysis of the previously mentioned and some other open sources allowed us to construct maps of the quantitative and qualitative diversity of the animal world (see Figure 7).

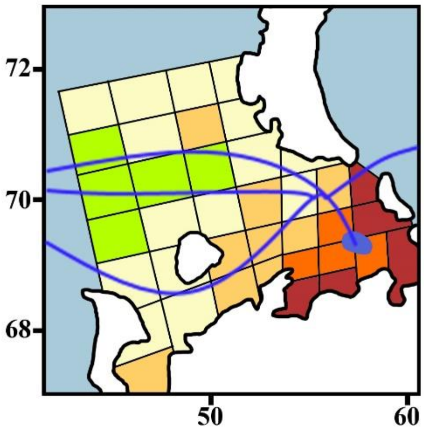

Figure 7. Biodiversity and quantitative assessment of the animal world (benthic communities, fish, birds and mammals).

It is easy to see that this map is vaguely resembles Figure 3. This means that the chosen method, based on fuzzy logic, enables to adequately display the available data and is suitable for constructing such maps. In its turn, the difference between these maps is explained by the displayed data: Figure 3 takes into account only the species diversity of the animal world, while Figure 7 also shows their quantitative assessment.

Combination of Figures 6 and 7 enables mapping of critical for vulnerability areas of the Pechora Sea associated with the development of the Prirazlomnoye field, and transportation of hydrocarbons from it.

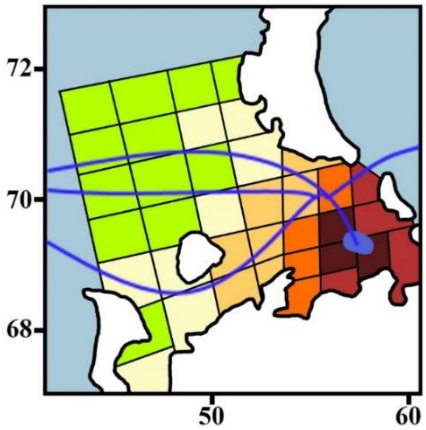

Figure 8. Harmfulness of the Pechora Sea.

As can be seen from Figure 8 the most vulnerable animals are those living in the vicinity of the field itself, as well as on the shores adjacent to these zones. Considering Figure 2 and the existing and prospective protected areas delineated there, it can be concluded that it is necessary to strengthen environmental control around the Nenets national reserve and wildlife refuge, as well as at the Vaigach reserve (zones 1, 2 and 3 in Figure 2). For projected reserves, it is worth noting the extreme vulnerability of the territory of the Biosphere polygon of the Nenets Reserve and the Bolshezemelsky Reserve (zones 6 and 7, respectively, in Figure 2). To preserve animal populations in this area, strict environmental monitoring should be carried out. At the same time, the areas of the projected wildlife

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refuges, the Goose Beam and the Czech Guba, are less prone to the risks of being affected by extremal situations that might be caused by the Prirazlomnoye field development.

5. Conclusion

Pechora Sea is a region known for its environmental sensitivity and it is important to minimize negative anthropogenic impacts. Expansion of oil and gas activities in the Pechora Sea can create additional stress and serious threats, such as oil spills and difficulties in oil spill response in ice-infested waters can affect vulnerable Arctic ecosystems. Minimization of the environmental impact can be achieved by reducing emissions to atmosphere as well as discharges to water and waste into the sea. With an increased level of safety and security, it is possible to avoid those negative impacts and minimize risk of undesirable events.

Identification of vulnerable areas is very important and present first priority for taking all necessary steps for protection. The most vulnerable areas of the Pechora Sea are coastal and islands. High population of seabirds and marine mammals are located in those areas.

Given the complexity of the Arctic region, it is important to emphasize that only close international cooperation in the field of environmental monitoring and emergency response in emergency situations is able to preserve and protect the ecosystem of the Pechora Sea and the entire Arctic as a whole.

References

[1] Nikiforov S, Dunaev N, Politova N 2005 *Past, modern, and future state of the Pechora Sea*, Pechora Sea Environments: Past, Present, and Future. Ber. Polarforsch. Meeresforsch p 501

[2] Matishov G 1997 *Bathymetric Map of the Barents and West Kara seas* (Russian Academy of Sciences, Murmansk Marine Biological Institute) Mercator projection. Scale 1 :2.313.000 at latitude 72^{O}N.

[3] Pivovarov K, Zolotukhin A 2018 *Use of multicriteria approach and methods of fuzzy mathematics for estimating development conditions of arctic seas in terms of the southeastern part of the Barents Sea* Arctic: ecology and economy 3 (31) p 100-111 DOI: 10.25283/2223-4594-2018-3-100-111.

[4] Larsen T, Nagoda D, Andersen J 2003 *A biodiversity assessment of the Barents Sea Ecoregion*. (Oslo) WWF's Barents Sea Ecoregion Programme 160p

[5] Boere G, Galbraith C, Stroud D 2006 *Waterbirds around the world* (Edinburgh, UK: the stationery office) Scottish Natural Heritage. available at: http://jncc.defra.gov.uk/PDF/pub07_waterbirds_part5.5.2.pdf

[6] Isaksen K, Strøm H, Gavrilo M, Krasnov Y 2000 *Distribution of seabirds and wildfowl in the Pechora Sea, with emphasis on post-breeding marine ducks* (Norwegian Ornithological Society) Seabird and wildfowl surveys in the Pechora Sea during August 1998. https://data.npolar.no/publication/204d2c97-17b0-487a-9873-c4878d6db4ba

[7] Vaschenko P, Moiseev D, Dukhno G, Shavykin A, Kalinka O, Karnatov A 2018 *GIS "Ecological State of the Barents Sea"* (Murmansk marine biological institute)

[8] Bakke T, Klungsøyr J, Sanni S 2013 *Environmental impacts of produced water and drilling waste discharges from the Norwegian offshore petroleum industry* Marine Environmental Research 92 p 154-169. DOI:10.1016/j.marenvres.2013.09.012

[9] Norsk olje&gass 2016 *Guidance document for characterization of offshore drill cuttings piles* available at: https://www.norskoljeoggass.no/contentassets/d7c4e49a4a1443d89def8dec143c4c43/norog-guidance-for-drill-cuttings-pile-sampling-2-1-2017-final.pdf

[10] Chen B, Ye X, Zhang B, Jing L, Lee K 2019 *Marine Oil Spills—Preparedness and Countermeasures* World Seas: An Environmental Evaluation p 407-426. DOI:10.1016/b978-0-12-805052-1.00025-5

[11] Utvik T 1999 *Chemical characterization of produced water from four offshore oil production platforms in the North Sea* Chemosphere 39(15) p 2593-2606 DOI:10.1016/s0045-

6535(99)00171-x
[12] Fakhru'L-Razi A, Pendashteh A, Abdullah L, Biak D, Madaeni S, Abidin Z 2009 *Review of technologies for oil and gas produced water treatment* Journal of Hazardous Materials 170 (2-3) p 530-551 DOI:10.1016/j.jhazmat.2009.05.044
[13] Veil J, Clark C 2011 *Produced Water Volume Estimates and Management Practices* SPE Production & Operations 26(03) p 234-239 DOI:10.2118/125999-pa
[14] Nesic S, Streletskaya V 2018 *An integrated approach for produced water treatment and injection.* Georesources, 20(1), pp. 25-31. DOI: https://doi.org/10.18599/grs.2018.1.25-31
[15] Nesic S, Pivovarov K, Streletskaya V, Zolotukhin A 2017 *Mapping the main risks for offshore operations in the Pechora Sea* International Conference on Safety and Security Engineering, SAFE 2017, Rome, Italy