

GIS MAPPING OF THE BARENTS AND PECHORA SEAS

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Abstract. Methods of GIS mapping of environmental of the Barents and Pechora Seas under the influence of both natural and anthropogenic factors have been devised. For integrated GIS project of the Russian Arctic Seas several thematic layers have been created. These layers characterize the natural conditions of the Seas, the information on income of pollutants from different sources, possible ways of their transfer and deposition in bottom sediments. The analysis of the maps of geocological situation of the Barents and Pechora Seas allows picking out the next geocological regions: relatively safe, potentially dangerous and of high ecological stress.

PREFACE

Methods of GIS mapping of sea territories for the means of estimating their ecological condition formed under the influence of both natural and anthropogenic factors are being developed. Scientists believe that this situation is due to several reasons: lack of firm evaluation criteria of sea pollution, imperfection of modern technologies and methods of ecological monitoring of the sea water areas. The analysis of the information on sea ecology that has been gathered up to now shows dissimilar data coverage of littoral and open water areas. Most of the information is provided for shelf areas of the water objects. Also there is a great diversity in the observation time and space. Retrieving methods of ecological information provide a diverse character of observations. As a result there is a sure lack of primary data and reliable information that is necessary for forming data banks and bases.

Among the Arctic seas, Barents and Pechora Seas can be set apart due to the factual material accumulated by environmental departments and scientific groups. The Barents Sea is one of the world's largest fishing water areas and its share in the amount and diversity of bio resources remains the largest among European seas of Russia. But the potential danger for biota is the development of oil and gas deposits in the region. About 172 promising oil and gas structures have been revealed in the seas of the Western Arctic (Barents, Pechora and Kara Seas) and about 30 of them are prepared for deep research drilling.

Joint operation of fishing areas, oil and gas retrieving complexes provide new goals for ecological monitoring of the sea water areas. Due to that fact a certain role of GIS mapping in helping to evaluate the ecological condition of the sea areas can be obtained.

SOURCES OF DATA AND METHODS

For the means of producing a series of analytical and complex maps of Barents and Pechora seas with the use of GIS technologies we have analyzed and worked with different data concerning natural and anthropogenic factors that determine ecological condition of the seas. Also we've developed a method of forming data base that includes maps of different scales, topics and numerous statistics [1, 3].

During the production of analytical and complex maps of seas it is important to refer to the geocological approach that attributes to sea as a complete hydrodynamic system, inseparably connected with the adjoining territory of the e catchment Thematic maps of the Atlas of the Oceans can show the natural specifics of Barents and Pechora Seas – interaction of hydrodynamic, hydrometeorological, hydrochemical and hydrobiological processes.

Modern GIS technologies allow for processing of huge amounts of different types of data. Normally data storage is a necessary, but not sufficient part of the research project. Data should be readily accessible on request. Information from different sources must be correlated, compared, analyzed, and visualized in the form of a table, scheme, map, or a chart. Modern GIS technologies provide the framework for such studies and offers diverse possibilities for the acquisition, integration, and analysis of spatial data [2]. ArcGIS family of software products was used for research of the ecology of several seas according to the scope of the project.

Normally GIS is used to provide dynamic connection between two types of information: attribute data containing various characteristics of objects, and the spatial properties of objects connected to the form inherent to them, and a site in space. At the given stage of the project we used both coverages and shapefiles to analyze spatial and attribute data.

In our case base we used GIS ArcInfo to analyze topological thematic layers. Such layers as hydrography, sea shore, populated areas, administrative and political borders, a coastal line, morphological features of a sea bottom, etc. were created. ArcView GIS was used to create an initial database about pollution of the sea environment of the investigated seas, which should be extended and updated the later stages of the project. Information on different sources of water pollution is structured as DBF tables, containing data on the concentration of different pollutants (radioactive substances, petroleum hydrocarbons, pesticides, heavy metals) for different points of the Barents and Pechora seas areas.

Further tasks (visualization, editing, combining and analyzing different layers of information, modeling, creation and editing of legends and attribute tables, charts, layouts) were performed using ArcView GIS.

As a result we have developed several thematic GIS layers that characterize natural conditions of sea water areas and that provide information on income of pollutant from different sources, possible ways of their transfer and precipitation in bottom sediments. First of all is the topography of the sea bottom. The shelf of the Barents Sea is deeper than the ones of other Arctic seas. The biggest depths and the most dissected bottom relief are registered in the western part of the Barents Sea. Overdeepened, dissected with hollows and depression relief of the bottom of Barents and Pechora Seas define the possible paths of transfer and accumulation places of the pollutants. Coastal shallow waters with the depths above 50 meters occupy the most territories only in the south – east and north – west parts of the sea (Medvejinsko – Nadejdinskaya elevation). The layer containing information about geomorphologic specifics of the coast, rugged coastline and geomorphologic characteristics of linear morphostructures and morphologically similar regions, is no less important. The next thematic layer contains data concerning lithological composition of the ground of the Barents and Pechora Seas that actually differ in absorption characteristics. In specialists opinion the regions that are formed with thin dispersion material, such as the middle and border parts of the shelf, are favorable for the absorption of different pollutants. The coastal area that is usually covered with sand and other coarse – grained material is less influenced by the pollutants.

The thematic layer that characterizes the glacial cover of the water surface and archipelagos of islands, demonstrate that the melting of this covers, polluted with the precipitations, will lead to the forming of regions of maximal concentration of pollutants. The edge of the ice is a special border of water – ice – atmosphere. The next thematic layer reflects the hydrological regime of the Barents and Pechora Seas. Bounded with the continent only on south, the basin of these seas becomes an open system for warm waters that come from the Atlantic Ocean. This income of Atlantic waters (its volume 49 – 74 km³/year) comes through the western border of the basin, mostly from the Norway Sea. A significant ecological risk is related to the direction of the systems of the currents. The most powerful and stable flow, that determine hydrological regime of the seas, is formed by the Nordkapsk current, that carry relatively warm and salty Atlantic waters. It enters the sea on the west and while moving to the east splits to several currents. Besides a branched system of warm Nordkapsk current, the Barents Sea has an income of fresh waters of the Arctic Ocean. The income of Atlantic, Kara and White Seas waters and waters of the Arctic Ocean promote the exchange of the pollutants with the Barents and Pechora Seas. Oceanological characteristics – temperature and salinity of water – help to retrace the behavior of the pollutants in the sea environment.

Active hydrodynamic zones (hydrofronts) – the meeting points of masses of water different in origin and oceanological characteristics – determine the distribution of fields of chronic pollution. The thematic layer that depicts the directions of atmospheric streams is vital for the analysis of far – going transfers of pollutants from origins within the territory of Arctic.

The information about the income of pollutants from different sources was used to form the thematic layers that demonstrate the intensity of anthropogenic influence on the ecosystems of sea. They are: 1) carrying of industrial,

agriculture and domestic effluents with the river waters 2) construction and operation of engineering structures on the shelf 3) direct dumping of liquid industrial and domestic wastes and ejection to the atmosphere from the towns situated near the coast 4) operation of all kinds of transport, intensity of shipping, the influence of the shipping tracks, fishing, trade and military vessels 5) nuclear-waste disposal 6) disposal of industrial waste and grounds, produced by high depth operations 7) extraction of minerals resources 8) extraction of oil and gas 9) emergency overflows of oil 10) wreck of nuclear powered vessels and nuclear experiments.

ANALYSIS AND RESULTS

During the research we produced and analyzed a series of analytic maps. The map of content of radionuclide of Cs-137 in the bottom sediments of Barents and Pechora Seas demonstrate a consistent pattern of distribution of Cs-137, related to the origins of income, the forms of the relief of the bottom, types of surface bottom deposits, directions of sea currents and atmospheric transfers. The analysis of the maps shows the local sources of the radioactive pollution of the Barents and Pechora Seas. These are the consequences of nuclear weapons tests, atmospheric ejections of radioactive substances from working Atomic Power Stations and radiochemical factories, the dumping of nuclear wastes. There are a few zones that distinctly have a maximal degree of accumulation of radioactive isotope of Cs-137 in the surface layer of depositions. These are the southern and eastern coast of the Novaya Zemlya archipelago, lip Chernaya, lip Mitushiha – the center of main explosions and Matochkin Shar strait. Uznjo – Novozemelskiy trench has heightened content of radionuclide in the bottom descents, formed by argillaceous allelvrites. A zone of accumulation of Cs-137 in the uliginous bottom deposits is situated near Timano – Pechora coast, with the maximum near the Timansky peninsula, on the south – east of the Pechora Sea and in the region of Pechora lip. It is the result of river drainage influence, global income of the pollutants from the land, developments of oil and gas – condensate deposits. The maximums of concentration of Cs-137 in the allelvrites and argillaceous sediments in the zone of submeridional spread near the Vaygach Island are the consequence of income of radionuclide from the Kara Vorota strait. The coastal zone of Kolsky peninsula and Kolsky bay is the typical example of a fiord polluted with radionuclide, that is used as a base for military and civil vessels with nuclear reactors and that has some income from vessel repair plants. Heightened content of Cs-137 in the deposits of the west coastal zone of Shpizbergen archipelago is related to the waters flowing from the west carrying pollutants from the northern Atlantic, plus the atmospheric transfers from western European radiochemical plants.

The analysis of the analytic maps of the development of oil carbohydrates in the bottom layer of the waters of the Barents Sea helps to distinguish the regions with the maximal values of content of oil carbohydrates. This is the western zone of the Barents Sea – the region of Shpizbergen sandbank and the western coast of Shpizbergen archipelago. Oil carbohydrates are carried here by the Atlantic waters through the western borders of the sea, from the industrially developed regions of Europe and USA and the regions of oil extractions and active shipping. That fact supports a scientific thesis that states that the Barents Sea is an unloading zone for all of the pollutants and specifically for oil carbohydrates. The south – eastern part of the Barents Sea that include the regions of Pechora lip and Pomorskiy strait, is the one mostly influenced by the pollutants, carried with the river drainage of river Pechora, that is receiving waste waters from the oil refinery plants.

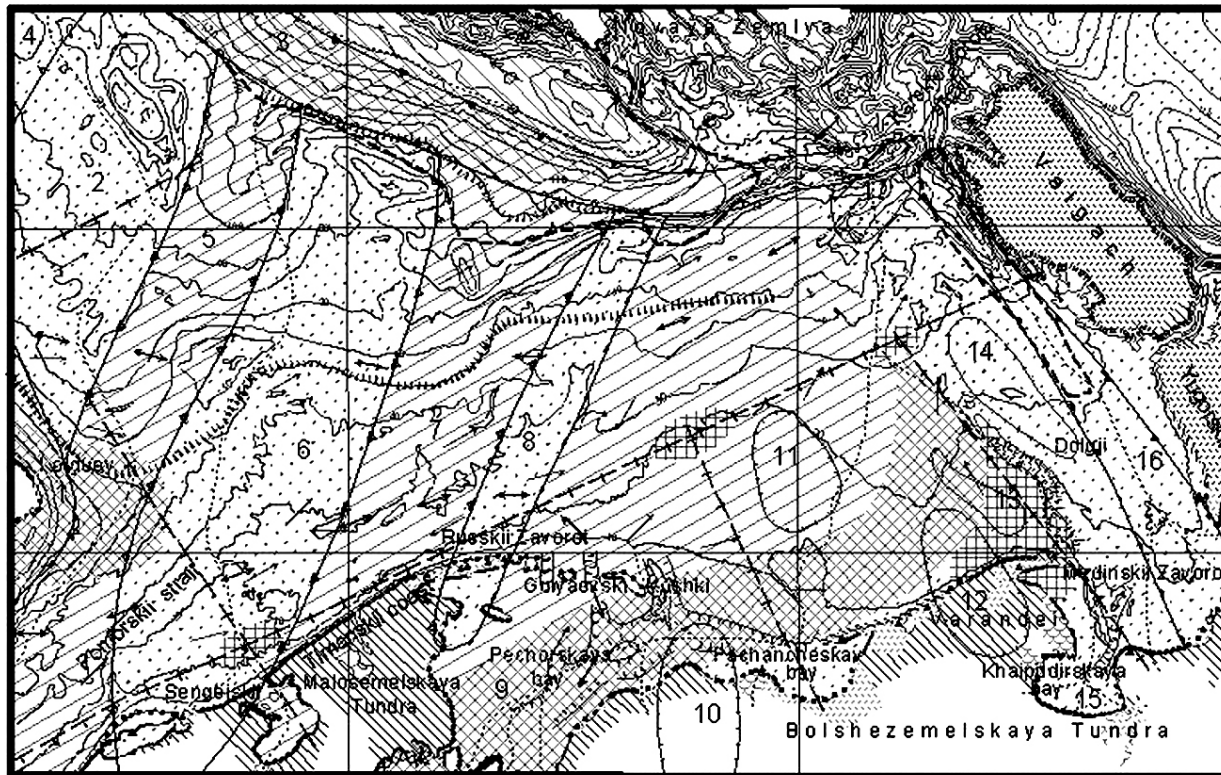
A region situated between the continent and the Vaygach Island in the area of Prirazlomnoe oil deposit and Kara Vorota strait is also highly polluted with oil carbohydrates. A high amount of it is also located in the deep Prinovozemelskiy trench, where in the deep argillaceous deposits goes the accumulation of phenols carried from Novaya Zemlya and the currents of the Barents Sea. According to the map Kolskiy bay stands out, because it is influenced much by the anthropogenic industrial wastes, urban wastes, saturated with oil carbohydrates, and dumping of mineral oils from the numerous vessels of Murmanskiy trade fleet and Severomorskaya naval base located in harbors (Figure 1).

Through the comparison of the maps of development of oil carbohydrates in the surface and bottom layers of water a similarity in the spatial allocation of pollutant fields is registered. The degree of pollution of waters of the Barents Sea with the oil carbohydrates is determined by the atmospheric transfer from the origins situated in the industrial territories nearby, the carrying of river waters from the polluted with industrial and domestic wastes drainage area, emergency overflows of oil and oil products, melting of sea and river ice, polluted with oil carbohydrates, influence of important navigable routes of many thousands of different vessels – fishing, trade, transport, military.

The map of content of polychlorinated biphenyls (PSBs) and pesticides in the bottom deposits of the Barents Sea helps to make a conclusion that the major part of them comes to the Barents Sea with the river and continental runoff, currents of the Atlantic Ocean (Golfstream and its Nordkapsk current) and atmospheric flows. The distribution of the heightened values of PSBs in the western part of Barents Sea collaborates with the scheme of the Atlantic currents. The sources of these pollutants are the industrial and domestic sewage water of the western European countries. The heightened values of PSBs in the bottom deposits are registered in the regions of Shpizbergen archipelago and the Land

of Franz Joseph, as a consequence of melting of ice and snow coverage of these islands, polluted with the atmospheric prolapses. Also a heightened PSBs value zones are registered near the coasts of Novaya Zemlya, Kolskiy peninsula and in the south – western water area of the sea.

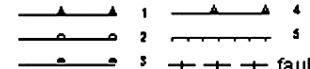
Geoecological situation of Pechora Sea



LEGEND:

Morphostructures of Pechora sea:

Boundaries of morphostructures
1-5 levels:



Structure's elements:

- 1 - Kolguevskoe raising
- 2 - Kolguevskaya step
- 3 - Yuzno-Novosemelskii trench
- 4 - Kurentsovskaya structure terrace
- 5 - Pomorskii depression
- 6 - Sengeiskii raising
- 7 - Sengeiskii depression
- 8 - Malozemelskoe raising
- 9 - Ust'-Pechora depression
- 10 - Dresvenskoe raising
- 11 - Kolvinskoe raising
- 12 - Varandeiskoe raising
- 13 - Medinskoe raising
- 14 - Dolgoostrovskoe raising
- 15 - Khaipudirskaya depression
- 16 - Vaigachskii depression
- 17 - Vostochno-Pechorskoe raising

----- fragments of flooded rivers' valleys

o x o x o x avandeltas

▲ single bedrocks Δ dunes
↔ sea transport ways

Relief of Pechora sea' bottom:

- submarine terraces
- boundaries of Yuzhno-Novosemelskii trench and Korotaichinskaya depression
- bottoms of Yuzhno-Novosemelskii trench and Korotaichinskaya depression
- probable directions of the rivers in Valdai Ice Age
- probable borders of contacts' zone of Yuzhno-Novozemelskii trench and Korotaichinskaya depression

Relief of the coastal land:

- [hatched] flood plains and deltas
- [hatched] eolian-marine (10-12 m) and alluvial-marine (up to 3 m) terraces
- [hatched] lake-alluvial terraces (5-20m)
- [hatched] denudational plains on glacial loose rocks with fragments of high sea terraces
- [hatched] denudational plains on rocks with fragments of socle sea terraces

Scale 1:3 000 000

Geoecological zones of Pechora sea:

- [hatched] zones with stable ecological situation and different litodynamical conditions
- potentially dangerous zones:
- [hatched] with high accumulation of thin fraction on the ways of pollutions
- [hatched] due to radioactive wastes' damping
- [hatched] due to specific tectonical and litodynamical conditions
- [hatched] ecological disaster zones

Types of coasts:

- [hatched] abrasion on rocks with pebble beach
- coasts of thermal abrasion and thermal denudation with sand-pebble beach
- [hatched] abrasion on loose rocks with sand or sand-pebble beach
- accumulative with sand or sand-pebble coast
- delta
- lagoon - bay

Figure 1. Map of geological situation of Pechora Sea

The map of content of heavy metals and pesticides in the bottom depositions of Barents and Pechora Seas demonstrate that the main source of pollution of waters and bottom deposits with heavy metals and pesticides are metallurgical and mining plants situated on the water parting basins of the seas, especially on the territory of the Kolskiy peninsula. A significant influence has urban drains of Murmansk and other coastal cities, the river runoff, precipitations, fishing and trade fleets. Also we should distinguish the Nordkapskoe current that is carrying pollutants from the Atlantic and Northern Europe. The maximal concentration of heavy metals in the bottom deposits are registered in the coastal areas of Kolskiy Peninsula, in the Pechora lip. Minimal concentrations are registered in the open areas of the ocean. The analysis of the map of distribution of pesticides in the bottom deposits of Barents and Pechora Seas helps to locate three zones: the central deep water zone with the minimal values of pesticides; coastal zones of archipelagos of Shpizbergen and Novaya Zemlya and Kolskiy peninsula, all with high values; Kolskiy bay and Varanger fiord with the maximal values.

The information about concentration of different pollutants in the examined water areas has a diverse character of distribution, that's why their interpolation is unavailable. That's why we chose the method of ranged symbols on all of the maps to show the income and distribution of pollutants. These method demonstrates that the zones of highest concentration of pollutants with diverse origins and sources and distributed by diverse ways (atmospheric and sea flows) are located in the same regions of seas.

Analytic and complex maps of geoecological situation of Barents and Pechora Seas produced with the use of GIS technologies demonstrate the interconnection of all of the components of a single geosystem. During the production of these maps we used automatic composition of different thematic layers in ArcGIS for the means of dividing examined water areas due to the degree of their ecological danger. As a result we got these geoecological regions: relatively safe, potentially dangerous and of high ecological stress.

The central water areas of the Barents and Pechora Seas are considered to be relatively safe. Potentially dangerous regions are supposed to be: Novozemelskiy trench with the heightened values of Cs-137 as a result of nuclear experiments and burial of radioactive wastes; routes of intensive shipping from Murmansk; the western coastal part of the Shpizbergen archipelago, south – eastern part of Pechora Sea with the developments of oil and gas condensate deposits. The zones of high ecological stress are the coastal regions of Kolskiy peninsula (Ekaterinskaya lip in the Kolskiy bay), Novaya Zemlya archipelago (Chernaya lip) and the Shpizbergen archipelago. Comparative analysis of produced maps demonstrate that the distribution of the pollutants in the surface layer of water and in bottom deposits of the Barents and Pechora Seas is formed under the influence of interaction of hydrometeorological, hydrochemical and hydrobiological processes as a result of the eternal movement of its water masses. Due to the large-scale circulation of sea waters and global atmospheric flows some regional pollution, caused by the anthropogenic influence, may affect the whole water area in the end.

Analytic and complex maps of sea water surface that characterize interactions of natural processes and anthropogenic activity produced with the use of GIS technologies help to establish general patterns of pollution of the seas and that is very important for the creation of the system of ecological monitoring.

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Education/Degrees:

Graduated Moscow State University, Geographical faculty, 1960
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