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CONTENT

The method of space monitoring of oil pollution on the sea surface on the example of the Caspian Sea

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The article presents the experience of developing the method for space monitoring of oil pollution on the sea surface using the example of the Caspian Sea within the Atyrau region (hereinafter the method). Today, the level of development of technologies for remote sensing of the Earth (hereinafter - ERS) and data processing technologies in geographic information systems (hereinafter - GIS) allows one to create accurate digital models as well as scientific and applied methods for analyzing effects of oil pollution on the sea surface and coastal ecosystems.

The paper describes the main approaches and methods of modern satellite monitoring of oil pollution of the sea surface and the development of a digital map of "oil pollution facts in the KSCS aquatorium within the Atyrau region."

A wide amount of data allowed us to analyze existing methods for detecting oil pollution and to choose the optimal solutions to the problem of detecting and predicting oil and oil product spills. Considerable attention is paid to the practical use of remote sensing and GIS data for monitoring oil pollution. Based on the analysis of the successfully applied detection methods, the most exemplary and diverse solutions of space monitoring of oil and oil products extraction and transportation areas were identified. The developed Methodology is intended for a wide range of users and can be considered as an information system that contributes to the accumulation of scientific knowledge, its display, analysis, and updating. The methodological foundations of the Method can be used to conduct similar studies at other water bodies of Kazakhstan.

Keywords: Earth remote sensing, Geoinformation systems, Kazakhstan sector of the Caspian Sea, Oil / oil-containing products, Monitoring of oil pollution processes

1. INTRODUCTION

The UN member states at the UN summit of September 25, 2015 adopted the Agenda for Sustainable Development for the period 2015-2030 consisting of 17 global sustainable development goals aimed at conserving natural resources and solving problems associated with climate change.

The adoption of the historic Convention on the legal status of the Caspian Sea at the last Summit of the Heads of State of the five Caspian countries (Aktau city, August 12, 2018) laid a solid foundation for the beginning of a qualitatively new stage of multilateral international cooperation, which will contribute to the sustainable development of the Caspian region.

We believe that sustainable development in the Caspian is synonymous with safe development, which is based on the ability to anticipate and prevent threats and dangers such as pollution of the coastal zone and sea water, environmental degradation, desertification and degradation of coastal landscapes, destruction of coastal infrastructure, decrease in stocks of biological resources, threat to biodiversity as a whole.[1]

The Caspian Sea is an inland continental drainage reservoir with high sensitivity and vulnerability to anthropogenic impact. Currently, in the water area of the Kazakhstan sector of the Caspian Sea (hereinafter - KSCS) active development of oil and gas fields continues. Significant natural, technical and labor resources are involved in the development of KSCS. Intensification of work on the development of oil and gas fields of the Caspian shelf increases the risk of technological disasters. This justifies the need for monitoring oil pollution in the KSCS aquatorium using remote sensing devices installed on artificial Earth satellites (hereinafter - AES).

As part of the study, the authors developed a new method based on a comprehensive analysis of satellite information on oil pollution of the sea surface by distinguishing features, taking into account the influence of dynamic and circulating processes on their distribution, as well as created a digital map of “oil pollution facts in the KSCS aquatorium” and created an automated workstation (hereinafter - AWP).

The aim of this work is to develop a technique for space monitoring of oil pollution on the sea surface using the example of the Caspian Sea within the Atyrau region, as well as to create an information-analytical system with the possibility of independent monitoring of oil pollution processes in the KSCS aquatorium within the Atyrau region for the Municipal Public Institution “Situation Center” of the Atyrau region’s Akim administration.

The objectives of the study are:

1) Analysis of modern methods of space monitoring of oil pollution processes in the sea water and inland waters;
2) Study of the influence of dynamic and circulating processes on their distribution;
3) Determination of oil pollution process indicators using remote sensing;
4) Creation of a digital map of "oil pollution facts in the KSCS aquatorium within the Atyrau region.”

Relevance and subject of research. The main pollutants of the sea are oil and oil products. In the open sea, they cause significant, sometimes, irreversible changes in its properties. Oil pollution covers huge sections of the water surface, disrupting oxygen, carbon dioxide and other types of gas exchange.

These changes cause deterioration in the state and bioproductivity of marine flora and fauna. Also, seasonal sea level fluctuations and surging phenomena caused by the shallow North Caspian shelf and the lowland of its adjacent coast increase the impact of the effects of oil pollution on coastal ecosystems, on social, economic and industrial facilities.

When solving issues related to the environmental safety of the entire region, the priority is to prevent and timely detect environmental pollution as a result of unauthorized discharges or accidental oil spills.

The problem of oil pollution as a result of human activities associated with the use of oil and oil products is undoubtedly one of the most significant environmental problems not only in Kazakhstan, but across the globe. Oil pollution of water and bottom sediments is mainly caused by routine maintenance during oil transportation, emergency spills during transportation and oil production offshore, the discharge of industrial and domestic wastewater, and garbage.

In this regard, one of the most important tasks of scientific and applied research is the development of effective methods for the detection and timely identification of oil pollution.[2]

According to statistics, shipping accounts for 45% of the oil pollution of the ocean in the global waters, while oil on the shelf accounts for only 2%, so shipping, including oil transportation and transshipment at terminals, has the main negative impact on the marine environment and the coastal zone. The main sources of pollution from ships are oil-containing flushing and ballast water from the premises of cargo pumps.

It is believed that due to the expansion of oil production on the shelf and the growth in the volume of shipping, the oil pollution of the World Ocean will increase both due to accidents at drilling rigs and as a result of disasters with supertankers and the discharge of untreated from oil products wastewater. According to some reports, every year millions of tons of oil and oil products enter the World Ocean.[3]

According to UNESCO forecasts, increase in the number of accidents involving the release of oil and oil products is expected in the foreseeable future. This is due to the physical deterioration of the global transport fleet and oil production platforms. Unfortunately, the forecasts of scientists for today come true, and the fight against pollution of the oceans has become one of the most important environmental problems.[4]

The lack of rapid detection and timely response to oil and oil products emissions as well as the inaccessibility of regular monitoring of the aquatic environment state have been the key reasons for the mass death of marine flora and, in particular, phytoplankton. Phytoplankton is the main consumer of carbon dioxide and a supplier of about 50% of oxygen to the atmosphere, and it also forms the basis of marine organisms’ food supply. Such limiting factors did not allow one the widespread practical use of various methods for eliminating oil spills in the marine environment.[5]

Currently, oil spills are detected using remote sensing data, which allows one to quickly respond to leaks of oil and oil-containing elements onto the water surface.

WORLD EXPERIENCE IN APPLYING MODERN SATELLITE MONITORING OF OIL POLLUTION OF THE SEA SURFACE.

At the present stage, monitoring the environmental safety of not only the Caspian Sea, but also of the entire oceans, takes as its basis the acquisition and interpretation of Earth remote sensing data for the detection of oil pollution. Recently, a large number of satellites with scientific equipment on board operating in different ranges of the electromagnetic spectrum have been launched all over the world. A huge amount of information received from satellites is used not only for scientific purposes, but also for solving many economic and environmental problems. Oil pollution of world waters is constantly increasing. This is due, first of all, to an increase in the volume of shipments by sea, in particular, the transportation of exported oil by water, the commissioning of new oil terminals and offshore rigs, and the discharge of polluted waters by rivers.[6]

As part of the development of space monitoring of oil pollution of KSCS within the Atyrau region, previously published problems of monitoring and timely response were examined using examples of the areas of the Mexican, Kola and Persian Gulfs, as well as the Caspian Sea.

Gulf of Mexico. April 20, 2010 was the black day of the calendar for British Petroleum. A floating drilling platform in the Gulf of Mexico, 80 km off the coast of Louisiana, completed drilling at Macondo when it was hit by a massive explosion. The explosion led to the destruction of the drilling platform, its flooding and the formation of a gigantic oil slick of thousands of square kilometers on the sea surface in the northeastern part of the bay. Immediately after the accident, filming of the scene of the accident from space began with optical and radar satellites. Continuous daily surveys made it possible to precisely determine the size and configuration of the spot, the direction of its drift, and a number of other characteristics.

Indeed, in the elimination of the disaster, remote sensing data played one of the main roles - both in monitoring the spill itself and in assessing its impact on the environment. As a result, more than 650 satellite images were obtained and analyzed. For the first time, the advantages of a multi-sensor approach for monitoring the catastrophic oil spill were fully professionally implemented, including the ability of various remote sensing sensors to receive quasi-synchronous images from space in different spectral ranges, with different visibility and resolution. In addition, based on remote sensing and GIS data, special interactive tools were created that visualized images from space, the spill itself, as well as its various parameters and characteristics, including environmental sustainability indices (ESI indices) for the coasts of Louisiana, Mississippi, Alabama and Florida. In particular, a number of online services have been created based on remote sensing data and providing visual information about the spill in real time. US research institutes that simulated the Gulf of Mexico water circulation to determine the most probable oil slick drift trajectories (6 different models were used) also compared the results with remote sensing data.

This environmental catastrophe took the world community by surprise and revealed the urgent need for scientific and applied solutions in the field of remote sensing and GIS technology to collect and consolidate information in a spatial context, providing tracking of consequences and timely response. The Gulf of Mexico has become a kind of a test site, which used the technologies of all leading space agencies, which created an erratic data stream and a number of unstructured methods for identifying and verifying oil pollution. But in a crisis situation, empirically, and an analysis of the materials obtained, the foundation was laid for the formation of modern techniques for space monitoring of oil pollution processes in world waters.[7]

Kola Bay. Satellite monitoring of oil spills of the Kola Bay began in June 2011. Space data, previously analyzed on-line by the SCANEX specialists, were sent to the monitoring center of the State Educational Establishment for Civil Defense and Public Safety of the Murmansk Region. They were actively used in the work of the monitoring and forecasting center of the Murmansk State Civil Emergency Situations for monitoring oil spills in the water area and in the coastal zone of the bay in 2011–2014. Monitoring of the bay lasted four years. Satellite images and products, obtained during monitoring, were uploaded to the geoportal with access via the Internet. To detect and identify film pollution of the sea in the Kola Bay, data from space-based radar imaging of the Radarsat-1 and Radarsat-2 satellites were used, which had been taken on-line at the SCANEX UniScan-24 and Uniskan-36 ground receiving stations. These satellites were equipped with side-scan SARs, which make it possible to obtain radar images of the sea surface regardless of the light and weather conditions, which was an important advantage in the specific physical and geographical conditions of the Murmansk region.

As a result, according to the results of four-year satellite radar monitoring using GIS for the Kola Bay, maps of the actual distribution of film pollution were first created, their spatial and temporal distribution was analyzed, and the main sources of oil pollution were identified. It is shown that extensive film formations of oil and oil products were periodically observed in the bay. The main sources of pollution were enterprises of the Ministry of Defense, maritime transport and housing and communal services, as well as coastal oil storage facilities and tank farms. A significant contribution to total pollution was made by the systematic discharges of various pollutants from ships passing through the water area of the bay. According to the monitoring results, the Kola Bay can be considered one of the "hot spots" of the Russian Arctic according to the degree of oil and oil products contamination.[8]

Persian Gulf. Based on the analysis of integrated pollution maps, experts concluded that the Persian Gulf was subject to serious oil pollution, mainly as a result of intensive oil production, oil transportation, and active shipping. The current situation threatens the ecological state of the bay, even with the formal observance of global standards and environmental requirements. A systematic radar survey of the water area can help the environmental authorities of the Persian Gulf countries to conduct daily monitoring of the Gulf, and can also be used as evidence.

Currently, satellite radar monitoring continues to be an effective tool for monitoring oil pollution, including the Persian Gulf. An analysis of the radar data collected during monitoring made it possible to visualize the extent of pollution of one of the most unique water bodies in the World Ocean and provided new information for understanding the essence of the problem.[9]

Caspian Sea. The Republic of Kazakhstan also supports the global trend to combat pollution of water by oil and oil products. In 2011, the Mekensak Research and Production Center, together with Sovzond specialists, performed space-based radar monitoring of oil spills in the water area of the Aktau port according to the satellite constellation COSMO-SkyMed (Italy). Space monitoring of oil spills in the waters of a major port like Aktau seems to be necessary to maintain environmental safety in the region.

In the Caspian Sea, many oil and gas fields are being developed. Proven oil resources in the Caspian Sea are about 10 billion tons, total oil and gas condensate resources are estimated at 18–20 billion tons. The Aktau city, located on the eastern coast of the Caspian Sea, is the largest cargo and the only port in Kazakhstan intended for international crude transportation oil and oil products.

The image dated September 22, 2011, revealed six oil spills on the surface of the water, including two oil spills directly in the vicinity of the Aktau port. All six discovered oil spills were delivered to the customer in the form of a vector polygonal shapefile (vector format for storing the geometric location and attribute information of geographical objects). In the attributes of each oil spill, the spill area is recorded in sq. km, date and time of detection.[10]

An analysis of world-wide space monitoring techniques for detecting oil pollution in four different water areas accumulated a massive amount of data from long-term satellite observations of the Caspian Sea, the Mexican, Kola and Persian Gulfs. These data were highly important in the analysis and timely response, both in monitoring local spills and in assessing their environmental impact.

RESULTS.

Determination of satellite technical characteristics and identification of sea surface oil pollution indicators.

In order to effectively monitor oil pollution, the Method is based on specific technical solutions that take into account natural indicators of oil pollution processes. When identifying oil spills, parameters such as shape, size, geographical location, surface wind speed, as well as the direction of the surface current, wave height, and other indicators are considered.

Choosing the optimal satellite.

An important component of the Method is the choice of satellite constellation, in particular, such technical characteristics as a sensor, date of recording, spatial resolution, spectral properties, processing level. The right choice of the listed characteristics will allow one to get the most reliable data, and will also serve as a trustworthy source of information for further analysis and interpretation of oil pollution.

Decryption and entry into the database.

The stage of processing, analysis and decoding of the obtained satellite images is fundamental to the Method. A well-formed data processing strategy allows one to empirically derive the most effective algorithms for the analysis and verification of oil pollution facts.

The technique of space monitoring of oil pollution on the sea surface on the example of the Caspian Sea.

The development of scientific foundations and a methodology for the quantitative assessment of the ecological state of marine water areas and the determination of pollution parameters and the dynamic characteristics of the KSCS aquatic environment within the Atyrau region based on a comprehensive analysis of satellite information is an urgent task today. In this regard, the authors of the study conducted a step-by-step cycle of actions for obtaining and processing satellite images with the possibility of detecting and identifying oil pollution processes in the KSCS water area within the Atyrau region. The results of the study were introduced at the "Situational Center" of the Atyrau Region Akim's administration for continuous and systematic monitoring of the environment, operational detection of oil spills in the areas of offshore oil platforms, loading and unloading tankers, as well as on their sea routes.

Satellite image processing.

Processing of satellite images includes two stages – the preliminary and the main stages. At the first stage, preliminary processing of remote sensing data takes place, which includes geometric correction of satellite images, radiometric calibration of images, restoration of missing pixels, contrasting, etc. At the main stage, visual and automatic methods are used to decode the images.[11]

Decryption is performed using top-down approach. The objects in pictures are distinguished by direct and indirect decryption signs. Direct signs include shape, size, color, tone and shadow, as well as a complex unifying feature - the image $Fig.1$. Indirect signs are the location of the object, its geographical proximity to potential sources of oil pollution, traces of interaction with the environment.[12]

FIGURE 1. An example of the oil pollution detection in an optical image.

Joint analysis of satellite radar and optical data.

In radar images, the vast dark areas of attenuation of the backscattered signal, corresponding to the areas of weak near-surface wind, stand out as dark areas.[13]

The identification of slicks of oily films in this image is extremely difficult. The ambiguities in the interpretation of such radar data and the detection of oil pollution of the sea surface are solved on the basis of the combined use of satellite radar data and data obtained in the visible and near infrared regions of the electromagnetic spectrum. The data of the optical range sensors contain additional information about processes and phenomena occurring on the sea surface, including the areas of local wind attenuation, i.e., in those areas to which dark areas of reduced intensity of the backscattered signal correspond to in the radar image.[14]

When speaking about the problem of identifying biogenic films, it is worth noting that in the data of the optical range, oil-containing slicks and slicks caused by biogenic films appear in different ways. In a color-synthesized image, oil-containing slicks have increased brightness and appear as homogeneous structures, while slicks of biogenic origin films are not detected [15](Fig. 2). When analyzing optical and radar images, observed contrasts are caused not only by attenuation of surface waves, but also by differences in the optical characteristics of pure water and oil-containing films, which contributes to their identification.

Expert analysis

Expert analysis allows one to solve problems that cannot be solved using usual analytical way, including:

- Choosing the best solution among available;
- Forecasting the development of the process;
- Search for possible solutions to complex problems.

a)Satellite radar image b)Optical satellite image

FIGURE 2. Elimination of nutrient spots using optical satellite images.

Expert analysis is the most effective method for detecting oil spills since this approach involves the identification of film-based oil contaminants through photo-interpretation.[16] Photointerpretation distinguishes oil spills from other natural emissions or stains. The distinction seems difficult in the presence of natural oil spots or areas with low wind speeds. In these situations, a more detailed analysis is needed where several factors need to be considered. The most important of which are the state of the wind, period of the year, shape analysis, spot size and general morphology of the observed area.

Factors Affecting Oil Pollution Identification

Rain. The difficulty is caused by the attenuation of short surface waves (Bragg waves) - turbulence created in the upper water layer by falling raindrops (Fig. 3). However, it cannot be completely ruled out that some dark spots in the rain cyclone are the result of mineral oil films. Since this may be an accumulation of oil due to local winds associated with the rain cyclone and the current.

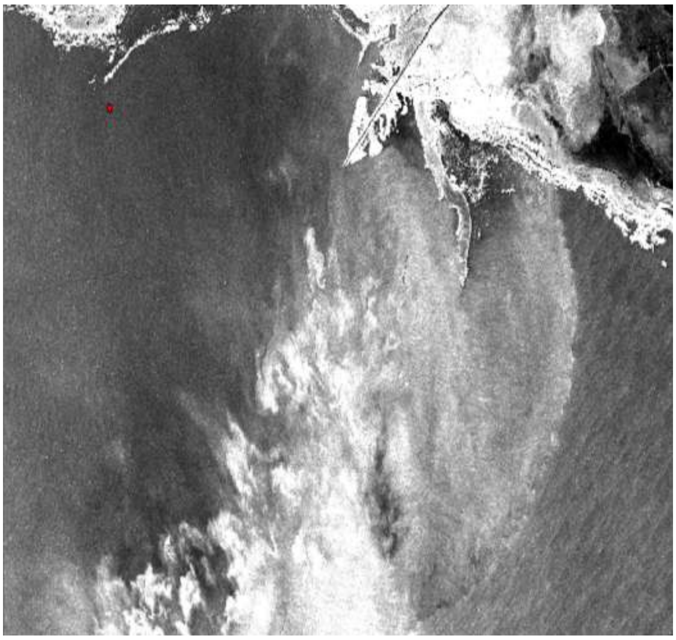


FIGURE 3. Turbulence of water in the upper layer of the sea surface.

Wind and current. A strong wind (more than 7 m/s) breaks a slick into fragments. The wind drives a thick layer to the leeward side, the current gives direction, that is, the waves extinguish the wind signal. On the other hand, at high wind speeds, usually above 7–8 m/s, biogenic surface films disappear from the sea surface, since they are "washed off" by waves (Fig. 4).

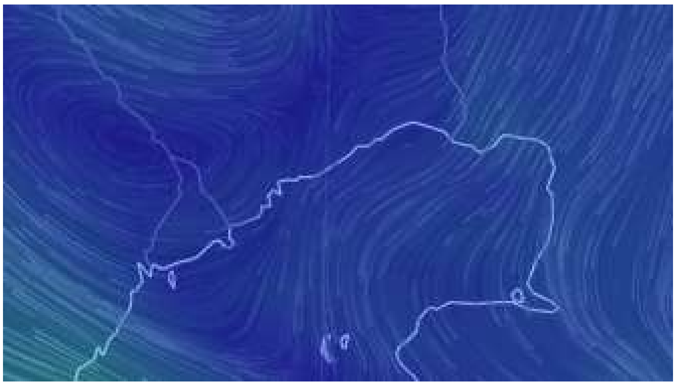


FIGURE 4. Map of the wind direction of the Northern part of the Caspian Sea.

Position/Form. The feather shape shown in Fig. 5 is a consequence of the fact that the wind captures the heavier components of the oil film more strongly and these components are moved faster by the wind than the lighter ones. In the image, the heavy components of the oily products on the leeward side of the mineral oil films have clear boundaries. Oil from natural leaks or from oil platforms can be detected using time series radar images.

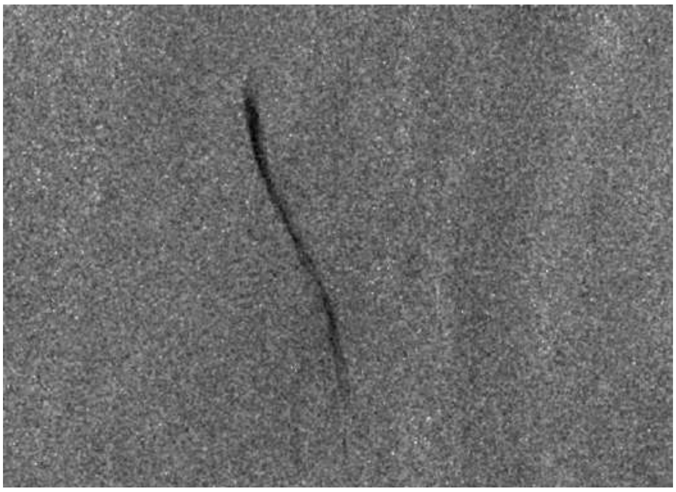


FIGURE 5. A form with feathers of an oil slick.

Radar reflection. The satellite's radar image works by reflecting radio waves from the Earth's surface and receiving the signal back. Radio waves are measured on a scale of dividing frequencies by decibels (Fig. 6), which determines the degree of signal absorption in the image. The signal frequency value determines the origin of a spot/discharge/leak:[17]

• oil (mineral oil) and oil-containing products have a difference of 3dB less than the total background (average) in the image;

• upwelling - the rise of deep waters to the surface. The difference is 7dB more or less than the total background (average) in the image;

• turbulent water from ships or internal currents is 11/12dB (average) in the image, and sand banks on the coast vary in the region of 10dB.

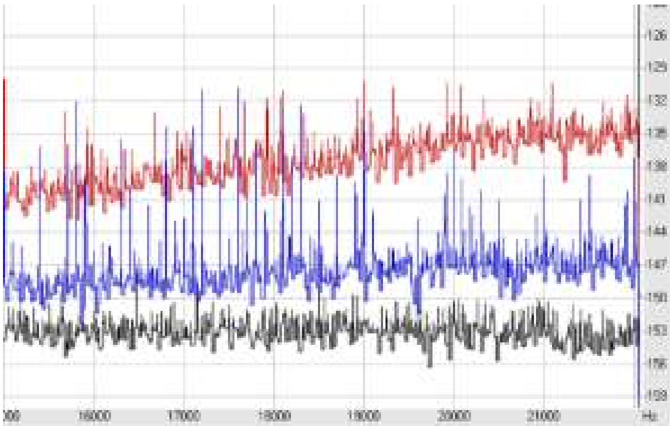


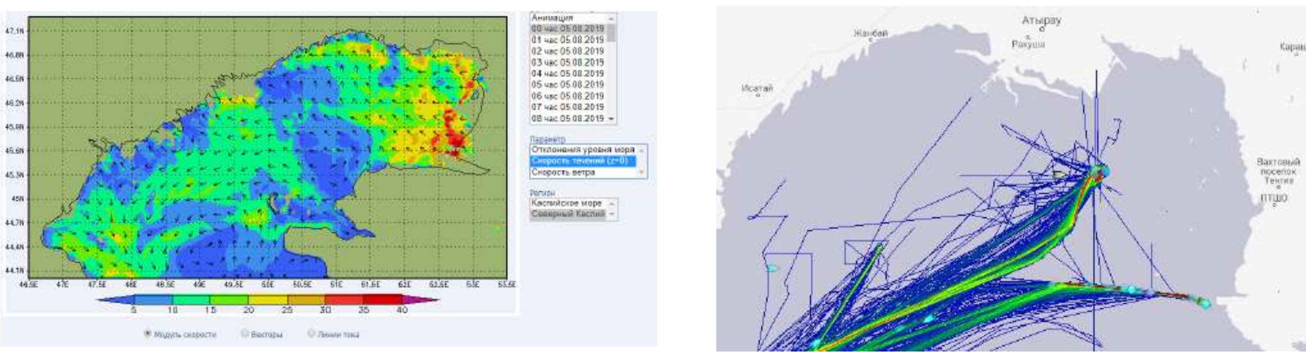
FIGURE 6. Scale for dividing frequencies by decibels.

Additional resources for expert analysis. When identifying oil pollution, the following factors are considered:
• location of oil platforms, terminals;
• sea surface relief;
• wind field of the sea surface;
• surface current direction;
• ship routes;
• weather conditions, etc.

It is necessary to pay attention to the direction of currents, temperature, as well as the strength and direction of the wind. There are open data sources that provide access to such information.[18]

The "Operational module "Yoshimo" (Fig. 7a) provides access to the service, which indicates the hourly forecast of wind and currents, as well as sea temperature.[19]

The "Marine traffic" resource (Fig. 7b) makes it possible to track and analyze the movement of vessels in real time, which allows one to compare the time and coordinates of pollution, and the direction of movement of the suspected vessel to determine the oil spill source. Analysis and identification of the most active routes of sea vessels on the territory of the Atyrau region, enable identification of anthropogenic pollution along these routes.[20]



a)"Operational module "Yoshimo"

b)Resource "Marine traffic"

FIGURE 7. Auxiliary sources of additional information.

VALIDATION OF THE DEVELOPED METHOD AND CREATION OF A DIGITAL MAP.

Testing the Method.

Over the period of satellite observations on the territory of the KSCM within the Atyrau region, more than 120 satellite images were analyzed, with a total area of more than 5.5 million km2, which at different frequencies (due to the peculiarities of each satellite) captured partially or completely the area of interest. It has been experimentally established that it takes up to four hours to process one optical image, processing of radar images takes up to six hours. As a result of the application of the Method, more than 25 facts of oil pollution were revealed and the following conclusions were drawn: 1. An analysis of the oil spills shapes showed that the main source of the sea surface pollution is moving vessels, which leave narrow spots of an extended shape. The vast majority of anthropogenic pollution of the sea surface detected on satellite images of the KSCM within the Atyrau region are oil-containing films caused by discharges of water containing oil products from ships. The main components of pollution from ships are oil-containing flushing, ballast, and bilge water from the premises of cargo pumps. 2. It was established that in the northern part of the Caspian Sea there are no locations with a constant concentration of oil spills on a regular basis. 3. The average area of one oil slick was determined, which ranged from 80000 m2 to 100000 m2, the total area being more than 1.9 million m2. 4. The seasonal variability of the number of oil spots and their total area, which is associated with the seasonal variability of the winds in the study area, is determined. In the autumn-winter period, there are certain difficulties in detecting oil spills on radar and optical images due to storm conditions.

Collection and transportation of water samples from identified oil pollution areas for subsequent laboratory analysis.

The research plan for 2019 included at least two trips. Departure to oil pollution sites was carried out no later than 48 hours from the receipt of the request. Departure coordinates were given at the time of requests. The task at the study sites is sampling from the oil pollution area of the Caspian Sea:

- sampling from the surface and the "average" water column (3 samples within a radius of 50 meters from the coordinate) for subsequent laboratory determination of the presence of oil and oil products.
- sampling from the surface and the "average" water column at 2 points (within a radius of one kilometer from the coordinate) in order to confirm the content of oil and oil products near the coordinate.

Sampling of the sea water in the identified oil pollution areas was carried out on August 20 and 31, 2019 (Figure 8).

The average concentration of oil products in the surface water horizon in the identified areas of oily water exceeded the maximum permissible concentration of oily substances for water bodies from 224.3 to 897.4 times accordant with the class of water use.[21]

The observed differences in the concentration of petroleum products (August 20 and 31, 2019) in the selected samples can be explained both by the sampling time frame (from detection of the slick to the arrival of the research vessel) and environmental conditions (excitement, temperature, etc.). According to the results of geospatial analysis in 2011, the majority of film pollution in the Russian and Kazakh sectors of the Caspian Sea were grouped along shipping routes leading to the Astrakhan and Caspian canals, on approaches to the ports of Aktau, Atyrau and Makhachkala, where a large concentration of ships was observed.[22]

The high content of naphthalene, acenaphthene, phenanthrene, fluorene in the first slick area suggests the natural origin of sea water pollution caused by the flow of oil hydrocarbons from the seabed in the form of a gas-oil mixture (periodic discharges through cracks in the Earth's crust), or the transfer of a spot by currents from nearby oil fields (for example, during exploratory drilling).

Low hydrocarbon concentrations in the region of the second slick in samples from a depth of up to 2 meters are probably caused by mixing of the surface water layer by vortex flows of ship propellers. It can be assumed that hydrocarbons could get into ballast or household water, which could be discharged during the ballasting of the vessel, before the forthcoming call to the port.

FIGURE 8. Sampling for laboratory analysis.

Creation of a digital map of "oil pollution facts in the KSCS water area within the Atyrau region."

In information-analytical control systems, digital maps must provide a real-time assessment of the situation, solve problems and organize interaction, study the geographical features of the monitoring object, and also perform the necessary calculations when assessing the situation, modeling actions, predicting changes, determining the coordinates of objects on the ground.[23]

Creating a map based on radar and optical images allows one to specifically visualize the magnitude of the consequences and make an unbiassed decision in the events of oil and oil products spilling.

Thus, in the study "Analysis of oil pollution of the Kazakhstan sector of the Caspian Sea within the Atyrau region based on the use of Earth remote sensing data and geographic information systems", a Map was created on the basis of QGIS software (Fig. 9). The map acts as:

• systems for providing operational information on the facts of the leak of oil and oil products on the territory of KSCS within the Atyrau region;

• archival database for analysis of identified contaminants;

• archive of satellite images of the Earth from satellites with radar and/or optical apertures.

The map not only provides quick access to the analysis data on the ecological state of the KSCS water area within the Atyrau region, but also provides the opportunity to receive information data to specialists outside the field of remote sensing and GIS.

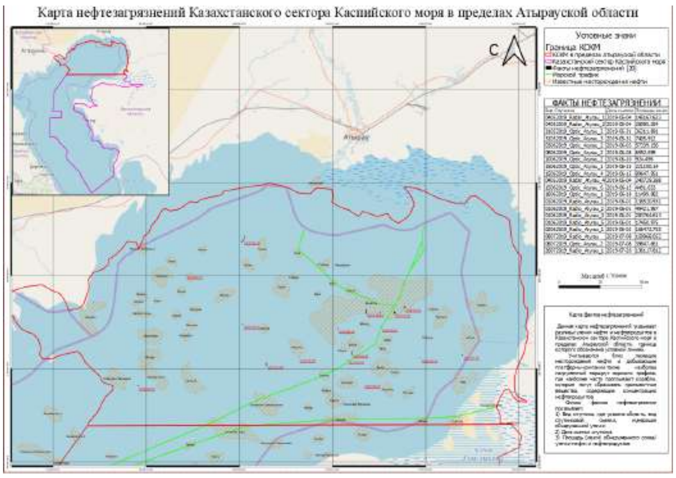


FIGURE 9. Map of the facts of oil pollution of the KSCS within the Atyrau region.

CONCLUSIONS

1) Modern methods of space monitoring of oil pollution of the seas and inland waters was analysed. Information on oil pollution of the KSCS water area within the Atyrau region was collected.

2) The new Method for space monitoring of oil pollution on the sea surface using the example of the Caspian Sea within the Atyrau region has been developed and tested. A stepwise cycle of actions has been designed to obtain and process satellite images, which allows one to detect and identify oil pollution in the Caspian Sea.

3) "The map of KSCS oil pollution facts within the Atyrau region" has been created. Field studies of oil pollution sites identified during the testing of the Method were carried out. According to the results of laboratory analyses, oil-containing substances have been found in the water samples.

4) As a final stage of the project material and technical support was provided in the form of computers with specialized software for monitoring of oil pollution. In addition, the training course was conducted for the representatives of the "Situational Center" of Atyrau region. The main economic and social effects of the study are as follows:

• the data obtained allow one timely and effectively coordinate actions aimed at eliminating the effects of oil pollution, environmental protection, as well as the rational use of natural resources.

• timely collection of information and analysis of the situation allows one to warn in advance of dangerous natural and man-made phenomena, which prevents casualties and reduces damage.

• continuous and unbiased monitoring of oil pollution at KSCS encourages subsoil users to comply with the standards for oil production and transportation of oil products.

• the method will allow one to get reliable identification and analysis of oil pollution, which will significantly save time and labor when making decisions and developing measures.

DIRECTIONS FOR FUTURE RESEARCH.

The systems for monitoring the state of the environment and its resources that exist today in the Caspian region require improvement. Most state and non-state organizations and companies in the region systematically or occasionally monitor various environmental parameters. This information is collected in the information resources of organizations and companies and are not interconnected. These observations are scattered both in time and in space and do not have a single methodological basis.

Accordingly, in the region there is no regional interdepartmental structure for the collection, assessment and analysis of environmental monitoring results, which does not allow one to see the general picture of the state of the natural environment in the KSCS water area and the coast within the Atyrau and Mangistau regions.

For this purpose, on July 29, 2018, the LLP "The Caspian Regional Center for Monitoring of the Environment and Emergencies" was created, the founders are the Caspian Research Institute of the International Scientific Complex Astana, JSC Kazakhstan NC "Garysh Sapary", and the LLP "Kazakhstan Agency of Applied Ecology".

Also, on September 19, 2018, a Consortium was created with the participation of the LLP "The Caspian Regional Center for Monitoring of the Environment and Emergencies", the Caspian Research Institute of the International Scientific Complex Astana, JSC NK Kazakhstan Garysh Sapary, the LLP "Kazakhstan Agency for Applied Ecology" and RSE "Kazhydromet". The purpose of the Consortium is to create a unified system for monitoring the environment and emergencies in the Caspian region of Kazakhstan throughout the KSCS water area and the territory of Atyrau and Mangistau regions.

The consortium may become an interdepartmental structure to create a unified system for monitoring the environment and emergencies in the Caspian region of Kazakhstan. The scientific potential of the Consortium and the Caspian Regional Center for Monitoring of the Environment and Emergencies would enable to conduct large-scale research work on the creation and operation of a regional integrated monitoring system, including space monitoring of the condition, identification of anthropogenic impact of oil and other pollution in the KSCM using GIS and remote sensing, modern research methods and information processing.

The developed Method has shown its effectiveness in detecting and predicting the spread of oil pollution, taking into account the features of the Northern Caspian, such as shallow water, temperature and water circulation. In the future, we plan to conduct a similar study within the Mangistau region and to develop a methodology, which will take into account the morphometric features of this region, the regularity of shipping routes and the number of offshore platforms for the extraction of natural resources. The experience gained on the basis of the Atyrau and Mangistau sectors of the Caspian Sea will serve as the basis for the detection and timely response to oil and oil products spills in the water area of the Kazakhstan sector of the Caspian Sea.

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