Information Support in Environmental Monitoring Systems

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Annotation. The current issue of environmental safety in general, and the world ocean in particular, is discussed. The main sources of pollution of the world's oceans are listed, which, when combined, lead to progressive eutrophication of coastal marine zones and microbiological water pollution. It is shown that in order to detect pollution sources in a timely manner, predict their spread, and monitor the progress of mitigation and mitigation measures, it is necessary to organize monitoring at the protection facility. The structure of environmental monitoring is considered with a description of the functions of the system that implements the process of monitoring the object of protection. A matrix approach is proposed to determine the structure and parameters of the monitoring system, where types of pollution are deposited horizontally, and types of fields – electromagnetic, optical, infrared, acoustic, hydroacoustic, and seismic-acoustic–are deposited vertically. The matrix is formed for the territory where the monitoring system will be located and allows you to identify the most dangerous sources and determine the composition of monitoring tools.

1. Introduction
The sustainable development strategy of our society and humanity as a whole implies, first of all, the greening of all areas of activity while ensuring the relative safety of society from various kinds of harmful factors. Environmental safety is associated with the concept of general safety, which is understood as the state of protection of a person, society and the environment from the harmful effects of anthropogenic, natural and other factors. One of the definitions of environmental safety is the totality of certain environmental properties and the conditions created by purposeful human activity, under which a harmonious structure, interconnections and self-regulation of natural processes are maintained. At the same time, the anthropogenic impact on the environment and the negative changes occurring in it are kept at the lowest possible level, the ecological balance in ecosystems, human health are maintained, and the long-term consequences of harmful effects for present and future generations are eliminated [1].

Today, the issue of pollution of the world's oceans is acute. The main sources of pollution of the oceans and seas are:
– discharge of industrial and household water directly into the sea or with river runoff;
– receipt from land of various substances used in agriculture and forestry;
– deliberate dumping of pollutants in the sea;
– leakage of various substances in the process of ship operations;
– accidental releases from ships or underwater pipelines;
– development of minerals on the seabed;
– transport of pollutants through the atmosphere.

The most common toxic components of large-scale pollution in the oceans are radionuclides, organochlorine toxic DDT and its metabolites, metals, oil and petroleum products, detergents. In addition, numerous organic compounds, factory waste with a high content of harmful substances, and suspended particles enter the ocean in various ways. All of them differ in the degree of toxicity and scale of distribution - from coastal inversions (local) to global ones.

New pollutants are constantly discovered in the world's oceans. The most dangerous organochlorine compounds, polyaromatic hydrocarbons, and some others are gaining global distribution. They have a high bioaccumulative capacity, a sharp toxic and carcinogenic effect [2-3].

2. Methods and Materials
The increase in the total impact of many pollution sources leads to progressive eutrophication of coastal marine zones and microbiological water pollution, which significantly complicates the use of water for various needs, so it is necessary to detect sources of pollution in a timely manner, predict their spread and monitor the progress of mitigation and elimination measures [4].

From the point of view of the information concept, environmental monitoring can be defined as a system for collecting, processing, interpreting and distributing data. Monitoring at all stages should be accompanied by an analysis of information support. It should be assumed that only a small part of the potentially necessary information can be obtained directly from the observation data [5].

The organization of environmental monitoring involves a complex and extensive set of interactions, in which there are always sources of information, operators and consumers. These blocks should be separated at considering any observation system and any information. The General structure of environmental monitoring is discussed in figure 1.

Figure 1. Structure of environmental monitoring.
The main information components of such environmental monitoring are observation, assessment and forecast.

Traditionally, when studying the ecological situation in marine ecosystems, two basic modes of observation are used: in-situ (i.e. in the process of conducting field studies directly in the marine environment itself) and in-vitro (i.e. in laboratory conditions). The most effective way to conduct environmental control is to use both modes in combination.

The forecasting process begins with an analysis of the results of monitoring the environmental condition of the controlled object and evaluating the current environmental situation. Next, a physical and mathematical model of the observed phenomenon is created. This model can be changed and refined many times in the future. A mandatory stage of forecasting is to assess the reliability of the received forecast.

Assessment of the environmental situation and forecast of its dynamic in water areas, that is subjected to intense anthropogenic impact is carried out by solving direct (based on a priori knowledge of the state of pollution sources) and reverse (based on a posteriori information about the factors of natural and anthropogenic impact) environmental monitoring tasks [6].

The problem of the formation of systems for remote monitoring of the environment is multidimensional. The structure and composition of the system is determined by a large number of factors:

- parameters of monitoring objects and conditions of functioning of monitoring systems;
- customer requirements for the system;
- pairing the monitoring system with other systems, etc.

Therefore, in order to unify the procedure for designing monitoring systems, it is necessary to have algorithms for formalizing the above factors. One of the most convenient approaches to determining the structure and parameters of a monitoring system is the matrix approach, which involves consistently solving the following main tasks:

- forming a matrix describing the main objects and monitoring systems;
- creating a vector of parameters of the monitoring object that displays these parameters in the parameter space of physical fields;
- forming a combined vector of the most informative parameters.

Using the matrix method, the most dangerous sources can be identified and the composition of monitoring tools can be determined. The composition of monitoring tools and particularly dangerous sources are identified on the basis of an information and situation matrix. In this matrix, types of pollution are deposited horizontally (for example, oil spills, emissions into the atmosphere, industrial waste pollution, radiation pollution, fires), and types of fields are deposited vertically (electromagnetic, optical, infrared, acoustic, hydroacoustic, seismic). A similar matrix is formed for the territory where the monitoring system will be located. Table 1 presents an information and situation matrix for certain types of pollution, which determines the relationship between the type of pollution and the physical field that carries information about this type of pollution. Then probability matrix is generated for the types of pollution, taking into account the probability of such an emergency (emergency). This matrix can be formed after analyzing all possible sources of contamination [7].

| Field type       | Type of emergency | Oil spill | Emissions to air | Industrial waste pollution | Radioactive contamination | Fires | Destructive vibrations |
|------------------|------------------|----------|------------------|---------------------------|--------------------------|-------|------------------------|
| Electromagnetic  | +                | +        | +                | +                         |                          | +     | +                      |
| Optical          | +                | +        | +                | +                         |                          |       | +                      |
| Infrared         | +                |          | +                | +                         |                          | +     |
| Acoustic         |                  |          |                  |                           |                          | +     |

Table 1. A table with headings spanning two columns and containing notes.
After analyzing these matrices and taking into account the available resources, a final matrix of a multi-sensor environmental monitoring system can be formed, in which the names of the subsystems used should be presented in the rows, and the types of pollution controlled by each subsystem in the columns.

3. Results and Discussion
The main tasks, that a multi-sensor monitoring system should solve, determine its composition. On the basis of the considered principles, the structure of the integrated environmental monitoring system is formed, as shown in figure 2.

Consider the following subsystems for remote monitoring of the water surface, water column, and bottom sediments in order to detect oil and oil products spills [8]:

− radar stations in the millimeter and centimeter bands (detection of an oil slick on the surface, tracking its movement, and determining geometric dimensions);
− television subsystems for organizing television monitoring of the process of filling a tanker with oil in order to visually detect an emergency situation;
− infrared subsystems for detecting oil spills on the water surface in the terminal area;
− lidar subsystems for detecting oil spills on the water surface and measuring the film thickness in the terminal area;
− hydroacoustic subsystems for detecting oil in water and measuring its concentration in water;
seismoacoustic subsystems for sounding bottom sediments to detect heavy fractions on the bottom for emergency recovery operations.

The systems listed above have specific characteristics and have different sensitivity to climatic, hydrological, and hydrodynamic conditions. Therefore, the choice of a specific subsystem depends on the requirements for a multi-sensory environmental monitoring system. Monitoring of the water area across the entire area of responsibility of the multi-sensor environmental monitoring system: the radar subsystem of the millimeter and centimeter bands, the lidar subsystem for detecting an oil slick, measuring its geometric dimensions and tracking its dynamics. The radar subsystem is designed for all-weather remote monitoring of the water surface. Estimates of flow velocity and flow size, wave strength, height, length, and wave velocity vector, and detection and evaluation of motion parameters for ice floes and oil slicks are based on differences in reflection intensities (amplitude contrast) and on differences in Doppler spectra of reflected signals. The feasibility of using a centimeter band of electromagnetic waves (wavelength 1-10 cm) to measure the parameters of ripples in the gravitational-capillary region of the sea wave spectrum has been established. Parameters of large waves affect the patterns of diffuse and resonant reflections of small waves, determining the nature of the amplitude-frequency modulation of echo signals. It is also known that the specific effective scattering area of the agitated sea surface when used for sounding radio waves in the millimeter band is an order of magnitude or higher than in the centimeter band. In the absence of intense precipitation, a millimeter-band radar is preferable, however, the requirement for all-weather operation of the radar subsystem necessitates the use of two-band radars.

Monitoring of oil content in water and bottom sediments: hydroacoustic and seismoacoustic subsystems [9].

Collecting, processing information from subsystems and predicting the development of an emergency: information subsystem.

Each of the subsystems must work in a complex, and the information subsystem must contain algorithms for joint processing of information from each of the subsystems in order to ensure the specified characteristics of monitoring in General and do not depend on the conditions of its operation [10]. A review of the literature and the practice of operating subsystems shows that a separate subsystem cannot perform tasks with the required characteristics under existing operating conditions. The most effective systems are complex multi-position environmental monitoring systems that implement remote and contact methods.

The essence of the method of forming the structure of a complex system of environmental monitoring of the water area is the information interface of complementary subsystems that register the state of the input surface, the driving layer of the troposphere, the water column and the bottom. Information interfacing is based on the joint analysis of comparable data obtained from various proprietary subsystems and external information sources, as well as in the management of subsystems by means of information feedback and in the creation of targeted requests for external information sources.

Own information subsystems, that make up a complex system of environmental monitoring are remote systems: radar and lidar, seismoacoustic, hydroacoustic, optical and infrared, as well as, contact subsystem of physical and chemical analysis. Each subsystem has its own local processor that manages the subsystem and processes the data received from it. The operation of local processors is controlled by the Central processor, which performs joint data processing of various subsystems and analyzes:

- radar signals and images received from different angles on the area of the water surface;
- optical images from a network of TV cameras;
- thermal portraits of the water area from a network of infrared cameras;
- portraits of the water area obtained by laser locators;
- results of surface-time-frequency processing of seismic acoustic signals;
- results of volume-frequency-time processing of hydroacoustic signals;
- results of physical and chemical water samples;
− meteorological conditions.

4. Summary
Detection and control of pollution is performed using both automatic tools and with the help of an operator who analyzes radar images of areas observed on monitors. The necessity to attract a person (DM – decision maker) along with the use of highly effective technical means is due to the importance of the task and high responsibility for the decisions made.

Based on the results of a joint analysis of these data, a conclusion is formed about the presence or absence of pollution in the controlled area of the water area, the quantity and quality of pollutants. Conclusions are transmitted to pollution prevention and elimination services, as well as transmitted back to the primary information subsystems of environmental monitoring.

Further development of the problem of building multisensory distributed water area monitoring systems should follow the path of solving the following problems:
− Development of a standard structure for collecting and processing information in a multi-sensor monitoring system for the port's water area;
− Analysis of received information from sensors of different physical nature;
− Development of a mathematical apparatus for processing information in local processors under various external conditions;
− Development of mathematical apparatus for joint information processing in the Central processor;
− Development of methods for displaying and transmitting information to the consumer.

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