Information and analytical system for environmental monitoring of water bodies

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Abstract. An integral part of maintaining a favorable environmental situation on our planet is the observation of its individual objects, including special attention is paid to water bodies. This is due not only to the natural human need for its consumption, but also to other aspects of the anthropogenic factor, which includes unintentional pollution of the environment with industrial and other waste. The task of increasing the effectiveness of measures aimed at the effective performance of work on the collection of water and soil samples from individual reservoirs, as well as the collection, accumulation and processing of data on reservoirs through the introduction of a system of environmental monitoring of water bodies is being solved. Such a system will speed up the work of environmental organizations, and also contributes to the formation of a brief set of recommendations for restoration measures and will give an overall assessment of the ecological state of the reservoir. The purpose of this work is to automate the process of accounting and processing information about the results of laboratory studies of various types of samples and tests on the basis of the performed cycle of calculations to form estimates and recommendations on the ecological state of the reservoir and to make final reports.

1. Introduction

While maintaining a favorable environmental situation, an integral part is the monitoring of fresh water reservoirs. This is due to anthropogenic factors, which include unintentional pollution of the environment with industrial and other waste.

The immediate proximity of a water body to human activity can affect its ecological state, such processes can worsen the condition of the reservoir over a long period of time. It is important to detect the threat in time and take measures to neutralize it.

To monitor the condition of water bodies and take water samples, quality control points of reservoirs and watercourses are organized. The samples taken are subjected to laboratory examination to assess the water quality. Processing of information takes some time, and on a large scale the number of reservoirs, different in size and length, it is difficult.

There is a need to organize and systematize the data in the considered information system (IS) and provide easy accessibility for a quick and objective assessment of the state of the reservoir. The IS should store in its database the results of laboratory studies of water and soil samples from a separate reservoir and use them to calculate indices and coefficients of the ecological state of reservoirs.

At the moment, there are a number of similar environmental information systems for monitoring water bodies that solve this task.
For example, the analytical information system «Ecology of fresh waters of Russia». It is intended for the import, storage, and management of information of samples of fresh water bodies of the country.

This system includes a set of databases, a data management system, user instructions, cartographic materials for hydrographic regions of Russia with an indication of sampling lines, information on sampling methods and methods for obtaining fresh water quality assessments, information on chemical, toxicological, hydrological and biological monitoring programs in Russian river basins, about the individual abilities of hydrobionts.

However, this system has many disadvantages:

- outdated technologies;
- a limited number of water bodies under study;
- lack of automated means of monitoring priority pollutants in the reservoir;
- untimely receipt of information by nature users and regulatory organizations about changes in the quality of a water body;
- lack of methods for identifying pollution sources.

The main purpose of this work is to automate the process of accounting and processing information about the results of laboratory studies of various samples and bottom sediments on the basis of the calculations made to form estimates and recommendations on the ecological state of the reservoir and make final reports.

Thus, this will allow us to quickly identify the causes of water pollution, perform an analysis and forecast of environmental situations, and use this information to develop a number of measures to improve the condition of water bodies.

2. Methods

Information Management System (IMS) is a system designed to accumulate knowledge and provide data for decision-making based on a comprehensive analysis of information [1].

Monitoring of the state and pollution of the environment is a long-term observation of the state of the environment, its pollution and natural phenomena occurring in it, as well as an assessment and forecast of the state of the environment [2].

It should be noted that the IMS is not the only comprehensive integrated system to meet all information needs. Since there may be a desire to get a system of this nature, it is necessary to specify this aspect, that due to the great difficulties in real organizations, the probability of creating it is small. The IMS of an organization rather consists of a number of information systems, each of which serves to make decisions in some specific area.

The input information to the IMS is information about the laboratory studies of the samples taken.

The source of intermediate information is information about the selected water object contained in the program database, as well as a list of constants set by the subject area and necessary for the formation of forecasts and results.

The output information includes the results of data processing, in this case, the results of calculations of the program, as well as the forecasts and recommendations formed by it. Figure 1 shows the general structure of the unified information space [3].
As the applied method, according to which the program will work, the calculation algorithm will be used according to the formulas for calculating the level of pollution of the reservoir.

In the developed information system, the assessment of the degree of water pollution of the environmental monitoring object will be carried out by calculating a number of parameters:

2.1. Hydrochemical index of water pollution (IWP)

The calculation of IWP for surface waters is carried out only for a strictly limited number of ingredients. The results of the analyses for each of the indicators are averaged. The number of analyses to determine the arithmetic mean must be at least 4 [4].

The calculation of the IWP for the surface waters of the land is carried out according to the formula:

\[
IWP = \frac{\sum_{i=1}^{n} c_i}{6}
\]

where \( n \) – a strictly limited number of indicators taken for calculation that have the greatest value, regardless of whether they exceed MPC or not, including the dissolved oxygen indicator БПК,

For surface waters of the land \( n = 6 \); \( c_i \) = concentration \( i \)-th a contaminant in the water; \( MPC_i \) = maximum permissible concentration \( i \)-th of the polluting substance.

2.2. Bottom accumulation coefficient (BAC) and the accumulation coefficient in hydrobionts (Kn)

To characterize the processes occurring in water bodies, coefficients are also given that take into account the ability of pollutants to accumulate in bottom sediments (BAC) and hydrobionts (Kn).

BAC it is defined as the ratio of the concentration of substances in the bottom sediments \( C_{\text{before}} \) to the concentration of the same substances in water \( C_{\text{water}} \).

Accumulation coefficient in hydrobionts \( (K_a) \) it is defined as the ratio of the concentration of substances in hydrobionts \( C_{\text{hydrobiont}} \) to the concentration of the same substances in the water of the Vault.

Calculation BAC in this information system, it will be produced for a number of heavy metals (copper, nickel, manganese, iron, mercury, zinc).

2.3. Biotic index (water quality class, according to Mayer)

The convenience of this technique is to identify indicator organisms in the reservoir, the presence of which indicates the degree of its contamination. It is applied to any reservoirs and uses the association of various groups of aquatic invertebrates with reservoirs with a certain level of pollution [5].
2.4. Biological indicator of pollution (Horasawa Index)

The Horasawa index is the ratio of the number of single-celled organisms that do not contain chlorophyll (B) to the total number of organisms, including those containing chlorophyll (A), expressed as a percentage [6]:

\[ \text{BIP} = 100\% \times \frac{B}{A+B} \]  

(2)

2.5. Index of the trophic state of the reservoir (TSI)

When monitoring the ecological state of surface waters, it is customary to assess the degree of trophic activity based on a set of qualitative and quantitative signs. There are practically no integral quantitative trophic criteria suitable for environmental monitoring, mathematical models and engineering calculations [7].

Meanwhile, the assessment of the trophic level of a particular reservoir is a serious problem, the relevance of which is determined by the fact that a quantitative description of the ecological state of the ecosystem is important when developing a strategy and measures for the protection of reservoirs.

Trophic capacity – the ability of reservoirs to create organic matter in the process of photosynthesis, later called primary production.

Primary production is the first link in the production process, i.e., the amount of solar energy accumulated in the organic matter photosynthesized by autotrophic plant organisms.

\[ \text{TSI} = 40 + 20\log \text{Chl}_a \]  

(3)

where \( \text{Chl}_a \) – the concentration of chlorophyll in water, mg/l.

If TSI < 40, then the reservoir is oligotrophic; TSI > 60 – eutrophic reservoir; TSI from 40 before 60 – mesotrophic reservoir.

An oligotrophic reservoir is a type of reservoir with poor trophic conditions and insignificant production of organic matter. It occupies the opposite position relative to eutrophic reservoirs. It is characterized by high water transparency, color from blue to green and a gradual drop in oxygen content to the bottom.

Eutrophic reservoir – a reservoir with a high content of organic matter.

The color of the water changes from green to brown, the oxygen content drops sharply to the bottom, in winter there are sometimes zamora. The bottom is peaty or covered with organic silt. In summer, water «blooms» due to the strong development of phytoplankton.

Favorable conditions for the development of vegetation and animals are created in the eutrophic reservoir. The natural evolution of a small-sized eutrophic reservoir in a cold and temperate climate leads to the formation of swamps.

After obtaining the values of the above parameters, we can talk about the degree of contamination of the water body and take measures to improve these indicators.

3. Results

Created on the basis of the developed UML diagram of use cases (figure 2) [8], ER-the database diagram is capable of storing the entire amount of data IMS [9]. It includes the following tables (figure 3).
Figure 2. UML-use case diagram.

Figure 3. Diagram of the database being developed by the IAS.

On the interactive map (figure 4), the user can view the sampling locations. Thus, you can plan the collection of the following samples. When analyzing places, it is possible to determine the factors that affect pollution.
Figure 4. Users with different roles in the system.

The use case diagram demonstrates the basic functionality of the system, which only authorized users have access to. The process of calculating the results of these water and soil samples is energy-intensive, but at the same time fully automatic and convenient for the end user.

The use case diagram demonstrates the basic functionality of the system, which only authorized users have access to. The process of calculating the results of these water and soil samples is energy-intensive, but at the same time fully automatic and convenient for the end user:

- place of sampling of water and soil;
- location of the laboratory examination.

After the selection is made, the user will be able to enter the results for the selected sampling location. Next, the user will be able to enter data into the database and calculate the level of pollution of the water body, and then, on demand, generate a report on the work done.

On the basis of the designed database and the diagram of variants, a system was developed for the automated process of accounting and processing information about the results of laboratory studies of various samples and bottom sediments, and their analysis.

When logging in, the main page is presented, on which the name and a small description of the system are located. In the upper part there is a navigation menu, in the right part of which there is a login button. After authorization, the following navigation menu items are available to the user:

- list of samples taken;
- sample results;
- exporting results;
- viewing the map of samples taken;
- adding a sample page.

Figure 5. Main menu of the system.
In the section «Samples» the user can view a list of all samples taken, a table with information for sample identification is shown on the page, by clicking on the «View» button, you can see the detailed parameters of the sample. The sample can be changed and a new result with calculated coefficients for the new sample parameters can be added in the «Results» section.

In the «Results» section, a table of analyzed samples is presented with the possibility of switching to the sample itself.

The user can view an interactive map of the reservoir, on which the places of sampling are marked.

On the «Add sample» page, the user can enter information about the sample taken and specify the sampling location on the map.

4. Conclusion
In the course of the work performed, an information and analytical system for monitoring water bodies was designed, which will allow automating the process of collecting information on the results of laboratory studies of various types of samples and tests, as well as forming assessments and recommendations on the ecological state of the reservoir and making final reports.

This system will make it much easier to analyze the situation, make maps and passports of objects, make decisions about water bodies. Also, the layout of the interface of the information and analytical system was developed and the database was designed.

In the future, it is planned to create a wider functionality and allow users to customize the system for themselves: add the markers they need on maps, filter data, as well as a moderator panel that would allow more extensive and convenient work with data.

It is also possible to develop algorithms for other objects under study – for example, assessment of the level of atmospheric air pollution.

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