Software solution for social monitoring of water bodies

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Abstract. The network of state water monitoring stations established in Russia is stationary, which creates certain problems for timely detection of problems related to negative impact on the respective ecosystems. One of the main problems is the unauthorized discharge of wastewater into centralized sewage systems or natural water bodies, which in the first case increases the critical load of the networks and in the second case threatens the environmental well-being. Involving the local population in the processes of monitoring and control of the state of water bodies is able to detect the problem location in time. The purpose of the work was to create the functionality of an intelligent system that provides interaction of the population with public authorities, specialized agencies and organizations on the identification of problems related to the state of water resources. Formalization of the subject area allowed us to develop the functional capabilities of such an intelligent system and determine their availability in accordance with the role of the user in the system.

1 Introduction

Russia's water resources are among the largest in the world. Despite the development of techniques and technologies, the quality of water resources is currently negatively affected by the discharge of wastewater into them. The nature of wastewater can be diverse: it can be the result of domestic, industrial or agricultural human activity. This determines the need to monitor the state of water resources and to carry out an extensive set of works to ensure the required water quality depending on its purpose [1, 2]. For this purpose, the constant state monitoring of all water resources is carried out, regulated by the Water Code of the Russian Federation and the Decree of the Government of the Russian Federation [3, 4]. In particular, they define the peculiarities of interaction of all entities whose activities are related to water resources.

Any organization that discharges wastewater into a nearby water body is obliged to carry out a set of measures related to its treatment [5]. For this purpose, specialized equipment is installed, providing mechanical, chemical or biological treatment, filtration and disinfection. The technological process of purification of such waters depends on the type of activity carried out by the corresponding organization. For example, the wastewater of greenhouse complexes contains pesticides, dissolved mineral and organic fertilizers [6], food processing

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enterprise - proteins and fats prone to rapid rotting [7]. Domestic wastewater is approximately the same in its composition, regardless of the region, climate, time of year, living conditions or cultural characteristics of the inhabitants.

Water resources are monitored through a fixed network of monitoring points for certain indicators and a temporary expeditionary network of points (e.g., during emergencies). Stationary observation points are placed on water bodies depending on their category, which determines the nature of monitoring tasks [2].

According to statistics, the number of registered cases of extreme high pollution of freshwater water bodies in Russia for 2023 increased by 62% [8]. It is noted that among the traditional sources of pollution (metallurgical, mining and pulp and paper industries) a large number of cases of unauthorized discharge of polluted wastewater and accidents associated with inefficient operation of municipal treatment facilities have been recorded [8].

At present, it is possible to report a problem related to the pollution of water bodies or changes in their condition using the Internet resources of the local administration or the body supervising compliance with the requirements of legislation in the field of water resources. This method has an objective disadvantage related to the regulations of processing of received appeals. The solution to such a problem is the creation of a software tool that ensures the fixation of the problem that occurred at a water body, the determination of its danger in automatic mode and the formation of a set of measures aimed at its elimination, as well as the corresponding consequences.

Thus, the purpose of the study is to model the process of public monitoring of the state of water resources using digital systems. To do this, it is necessary to perform the tasks of determining the key objects and processes of the subject area; to establish the rules of interaction between them; to develop the main functional capabilities of the digital system; to establish the categories of users of such a system.

The theoretical significance of the study lies in the systematization of data obtained from various sources in order to create models that reflect the dynamics of water resources, the quality of their state and their sustainability to external changes. The created models or their individual components can be used in studies related to the interaction of environmental components, forecasting changes in ecosystems, taking into account, for example, climatic conditions, the nature of anthropogenic impacts or natural disasters.

The practical significance of the study lies in the creation of a tool that provides operational interaction between specialized services, public authorities and the population related to the timely detection of negative changes in the states of water bodies. In addition, the obtained results can become the basis for the development of effective water resources management policy provisions, ensuring sustainable development and protection of ecosystems.

2 Materials and Methods

The study of literature sources has shown that the current state of processes in different areas of the economy is characterized by their digital transformation [9-11]. The effectiveness of digital transformation of any process requires the development of models that describe its key characteristics [5, 12]. This can be achieved by the complex application of methods of structuring, decomposition, composition, systematization, analysis, synthesis, formalization, step-by-step refinement, observation, and interviewing. With the help of such methods the peculiarities of water resources monitoring were established. Regulatory legal documents and knowledge, profile specialists were used as objects.

The method of system analysis was used to determine the functionality of the digital system. Decision-making models were established with its help. The results obtained in this way were correlated with the categories of users to whom they are available.

3 Results

Application of research methods that enable to obtain the current state of the water resources monitoring process allowed to establish that stationary observation points are used for monitoring the state of water bodies. Depending on the location and purposes of observation, such points are:

1. In places of spawning grounds or wintering grounds of valuable fish species, as well as in places where the water body flows into the largest river basins.
2. In places in the immediate vicinity of settlements that use water for food and domestic needs; in places where collector-drainage water is discharged; at the border gates of rivers (both those flowing into the territory of Russia and those flowing out of it).
3. In places characterized by moderate pollution (e.g., in small settlements with runoff from agricultural plots, small industrial enterprises).
4. At locations that are not directly affected by pollution.

Monitoring in such places is carried out according to three main indicators of harmfulness: sanitary-toxicological, general sanitary and organoleptic. Water quality is determined by chemical, bacterial, mechanical, radioactive or thermal contamination factors.

Accordingly, the main function of the designed intelligent system is to create an up-to-date interactive map, on which the coordinates of stationary control points and the current state of water are marked. The state of indicators is formed on the basis of the data received from the installed measuring devices. Specialists of specialized agencies can access all data received from observation sources (role in the digital system “Specialist”), while private users can obtain a summary indicator of the water body condition at a specified location (role in the digital system “Unauthorized user”).

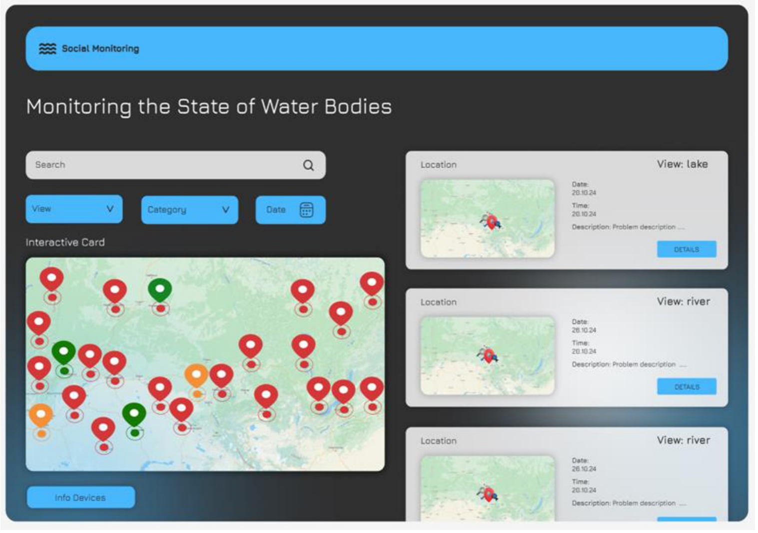

Fig. 1. Fragment of the user interface prototype.

In order to expand the boundaries of water body monitoring, to specify indicators, to detect unauthorized wastewater discharge, illegal activities in the water protection area, the digital system provides the possibility of adding private control data. For this purpose, the system has a user category “Observer”.

For such a user the possibility to view an interactive map with limited access to monitoring data and mark on it the places of detected problems is available. To formally confirm them, it is mandatory to upload a photo or video file with geolocation to the digital system. The received files are analyzed by the neural network to formally confirm the presence of a problem. It is important to note that the status of such a problem requires confirmation. Only in this case the corresponding mark on the interactive map will be placed. For confirmation, the subject matter expert is notified, who subsequently decides on the timing and types of work required to confirm the relevant fact. In this case, the object can be checked remotely (e.g., by using a drone) or in person (e.g., by a forestry staff member).

The "Observer" role can have enhanced functionality in the system. For this purpose, he/she will have to verify his/her user profile in the organization that monitors water bodies. After successful verification of the profile, such a user is given a minimum set of tools to take water measurements. For example, they can be volunteers, activists or concerned citizens who go on a tourist trip or expedition. Also as a user with such a role can be a citizen who, by the nature of his activity or place of residence, is in close proximity to a water body.

In addition, an "Observer" can be a user who has appropriate measurement equipment. For example, a teacher or a student who goes on an expedition during practical training while mastering an educational program in a profile specialty (ecologist, hydrologist, etc.). For this purpose it will be necessary to register the equipment in the system.

At the same time, for the data obtained in this way, the status "User" is set. This means that the level of reliability or authenticity of the downloaded results is reduced due to the lack of profile qualification of the user or its insufficient level. Nevertheless, such results can be used by the intelligent system to assess the state of the water body and to develop the following actions: transfer to a specialist for response, send a request to the user to carry out a repeat measurement with demonstration of the actions (video recording) or ignore.

4 Discussion

Digital transformation of any process is a complex task, the success of which depends on many factors. The fundamental factor for designing a software solution is to create a list of its functionalities associated with the categories of users for whom the development is intended. The analysis of the results of digital systems development has shown that detailed functionalities ensure the creation of a flexible and scalable software product [5, 9, 10, 15]. This is due to the ability to group functions according to certain features to create program modules that work independently of each other, but at the same time ensure the operational state of the entire system. In order to determine the functionality of digital systems, methods are used to obtain a formal description of the subject area [7, 16, 17]. The stated research methods correspond to such a task: with their help the key characteristics related to the monitoring of water bodies are established, the problems and possibilities of using digital means for their solution are determined.

The results obtained in the work can be applied to the methods of object-oriented design and programming to create an intelligent system that provides collection, processing and storage of heterogeneous data and their analysis in order to promptly detect negative impacts on water bodies and form effective recommendations to reduce such impacts [14, 18].

5 Conclusions

Water quality outside the observation sites can vary significantly due to many factors. Determining indicators requires special expeditionary work, which requires a significant amount of resources. Accordingly, preparation for such activities is a lengthy process, which prevents the rapid detection of a problem in a water body. Involvement of the local population is a solution to such a problem.

The creation of a convenient digital service that provides communication between the local population and relevant agencies or organizations makes it possible to record any facts of changes in the state of water bodies and promptly report them. In addition, the community is actively involved in the monitoring process, contributing to raising awareness of the state of water resources and the formation of an active civil society for the protection of aquatic ecosystems.

Software solutions with artificial intelligence functions allow processing large amounts of data for the purpose of timely detection and classification of problems for public authorities, specialized agencies and specialized organizations. Based on the obtained data, a set of recommendations can be formed aimed at taking measures to reduce or neutralize negative impacts on the relevant ecosystems. This approach ensures the preservation of biodiversity and ecological balance of the territories.

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