Intelligent Information System for Monitoring the Quality of Drinking Water

https://doi.org/10.31713/MCIT.2024.001

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***Abstract* – The article explores the global issue of water scarcity. Methods are being applied to eliminate water pollution, which can lead to water shortages. Azerbaijan is also one of the countries suffering from this problem. A global approach to the issue is required. Considering the complexity of the problem, a prototype is being developed, and potential solutions are demonstrated on it. The JWR is taken as the prototype object. The conceptual model, functional model, and system architecture have been presented.**

***Keywords* – ecological safety, drinking water, norm bases, functional model, conseptual model.**

I. INTRODUCTION

Recently, two parallel but distinct problems have been emerging in the world: on one hand, large parts of the Earth's surface are becoming submerged due to rising water levels, and on the other, there's a growing issue of water scarcity. The global drought, along with the pollution of water sources, is leading to a reduction in water reserves, causing water shortages and disrupting the natural water cycle. Climate variability in recent years, water consumption by agriculture, industrial waste, and similar factors also contribute to water shortages and even the depletion of water sources. Mismanagement of water resources, improper distribution, or water pollution all play a part in exacerbating the shortage of drinking water. To combat these issues, effective and sustainable water management, the careful use of water resources, and prevention of water pollution are necessary steps. International cooperation plays a significant role in addressing water-related problems.

This issue arises from various causes, such as urbanization and population growth, climate change, water pollution, insufficient infrastructure, water management, and legislation. According to UN reports, currently, one in ten people on the planet suffers from water scarcity. It is predicted that by 2050, global demand for water will increase by 70%.

Azerbaijan is also among the countries facing fresh water shortages. Only 10% of the fresh water resources in the South Caucasus region fall within our share. The country's drinkable water reserves are limited and unevenly distributed. Currently, the surface water resources of the country amount to 30-31 km³, but during dry years, this figure can drop to as low as 20.3 km³. Experts link the decrease in the flow of the Kura River to climate change, reduced precipitation, and an increase in the number of dry days.

The Oghuz-Gabala-Baku water pipeline holds great significance. First of all, a large volume of clean drinking water is delivered to Baku. The majority of Azerbaijan's water resources are formed in foreign countries, but the Oghuz-Gabala-Baku pipeline is a major project built solely on local sources. The construction of this project started almost immediately after the country began receiving its first oil revenues. Experts now acknowledge that if the Oghuz-Gabala-Baku pipeline did not exist today, Baku's water problems would be far more severe.

In addition, it is worth mentioning the construction of the historic Takhtakorpu reservoir. This reservoir has a significant water storage capacity—270 million cubic meters. Moreover, a new concrete canal has been constructed from the Takhtakorpu reservoir to the Jeyranbatan reservoir. The special importance of the Takhtakorpu reservoir lies in the fact that the waters of the Samur River are collected there, naturally purified, and then sent to the Jeyranbatan reservoir from a new reservoir. Previously, water from the Samur River flowed directly through a canal to Jeyranbatan. Without this large water body, providing Baku with drinking water would be impossible today. This is undeniable. Therefore, a lot of work has been done for the fair distribution of the Samur River's waters and for the execution of this project. At the same time, this project has significantly increased the irrigated lands in Shabran, Siyazan, and Khizi regions, providing water to approximately 30,000 hectares of previously unirrigated land, where extensive agricultural work is now being carried out.

The problem isn't only the scarcity of water, but also the high level of pollution in the water entering the country. The rivers entering Azerbaijan from Georgia and Armenia are dangerously polluted. While the rivers are clean in Turkey, they become highly contaminated as they pass through Georgian and Armenian territories. Untreated sewage and industrial waste from Georgia and Armenia flow into the Kura and Araz rivers. The pollution is so extensive that the rivers cannot naturally purify themselves.

One of the major threats to national security is the risk of contamination of drinking water.

Currently, the impact of global problems on politics and international relations is growing stronger. In interstate relations, environmental pollution and control over water resources play a crucial role. These factors have turned into political tools for exerting pressure between countries. In this context, the issue of drinking water has become an important component in today's political relations. A concept known as "water diplomacy" has emerged on the international stage, referring to the use of water resources as a political tool for pressure.[1]

An example of this can be seen in Armenia's occupation of the Sarsang reservoir, which is being used as an instrument of ecological pressure against our regions.

There are a total of 24 reservoirs in Karabakh, of which 3 are in a critical condition. Out of the 22 reservoirs designated for irrigation purposes, 7 are also used for fishing. Additionally, 2 reservoirs serve as sources of energy.

From the information provided above, it is clear that controlling and ensuring the safety of drinking water in the country necessitates the creation of a unified management system. This issue has a global dimension, and addressing it requires the involvement of a large number of specialists and resources. The development of such systems typically begins with the creation of a prototype. In this case, the Jeyranbatan Reservoir (which plays a significant role in the drinking water supply of the Absheron Peninsula) is considered as the prototype.

II. PROBLEM STATEMENT

Ensuring the ecological safety of strategic facilities like reservoirs depends directly on their protection (as physical structures), the monitoring of water input/output parameters, laboratory analyses, and expert evaluations. The goal of this work is to create a centralized management system to oversee these functions.

III. PROBLEM SOLUTION

To protect water resources from pollution and depletion, all water users must comply with the following general rules based on water legislation:

- Must not harm the environment and natural objects, nor violate the rights of other water users;
- Should use water resources efficiently and economically, continuously improving the water quality;
- Must always maintain purification facilities in good working order and enhance their efficiency;
- Take measures to completely eliminate the discharge of wastewater containing pollutants into water resources;
- Account for and analyze the quantity and quality of used and discharged water.

General Requirements and Standards:

1. Drinking water must be chemically safe in terms of epidemiology and radiation;
2. The quality of drinking water that has not yet entered the distribution network must meet hygiene requirements;
3. The composition of drinking water must meet microbiological and parasitological standards.[2,3]

In the Republic of Azerbaijan, the quality indicators of drinking water supplied to consumers are defined according to the Interstate Standard (GOST 2874-82) jointly adopted by CIS countries. According to the GOST standard No. 2874-82, drinking water is analyzed based on over 35 parameters, including organoleptic, physico-chemical, microbiological, parasitological, and radiological indicators.

At the Jeyranbatan Water Reservoir, water is analyzed based on samples taken from seven points (in 2015, when we first began our research, samples were taken from 15 points. Later, some points were decommissioned, so our recent studies now focus on seven points). These points include the Jeyranbatan Water Reservoir (hereafter JWR) Taxtakorpü-Jeyranbatan canal, near the JWR water intake facility, near the JWR southern pump station, JWR southwestern dam seepage water, JWR southern dam seepage water, JWR northeastern dam seepage water, and the entrance to the JWR melioration pump station.

According to standards accepted by the World Health Organization, drinking water is defined by more than 50 parameters, and by European Union standards, more than 75 parameters are specified (information provided by the Ministry of Emergency Situations). For assessing the water in JWR, norm-bases are established for the measured parameters, which are then compared with current measurements. A functional model of the system is built.[4,5]

$$\Big\{\{I_{q_{\text{Л}}}\};\{I_{q_{\text{Г}}}\};\{I_{q_{\text{Е}}}\};\{I_{q_{\text{В}}}\};\{I_{q_i}\};k\{I_{q_i}\};$$
$$;k_j\{I_q\};O\{P_q\}\Big\}\xrightarrow{\{S_{O_q}\}\Rightarrow O\{P_q\}}\{(I_{q^*});k^*(I_{q^*})\}.$$

In the case of the Jeyranbatan Reservoir, various formulas and indicators are used to ensure water quality monitoring. These include:

- $\{I_{q_{\text{Л}}}\}$: The table of maximum allowable concentrations of factors in the water of the Jeyranbatan Reservoir.
- $\{I_{q_{\text{Г}}}\}$: The table of norms for water factors according to GOST (State Standards of CIS countries).

- $\{I_{q_E}\}$: The table of norms for water factors according to the European Union standards.
- $\{I_{q_R}\}$: The table of norms for water factors according to the World Health Organization (WHO).
- $\{I_{q_i}\}$-: The current values of water quality factors at measurement point *i* (i=1, 2,…, 6).
- k$\{I_{q_i}\}$: The coefficient comparing current data $\{I_{q_A}\}$ with the Jeyranbatan Reservoir norms.
- Kj{Iq}: The coefficient comparing current data with WHO, EU, and CIS standards (j=1, 2, 3).
- {Pq}: The set of activated parameters.
- O{Pq}: The set of variations in the activated parameter values.
- {S}: The impact operator.
- {SOq }: The scale of the impact factors.
- **(*)**: The result of the impact of the operator SOq.

A **conceptual model of the system** has been developed.[6]

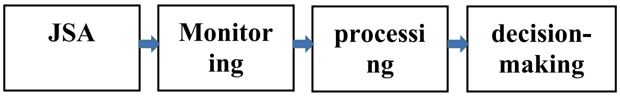


Figure 1. Conceptual model of the system

The module for the Jeyranbatan Reservoir consolidates information ranging from the reservoir's geographical position to physical, chemical, organoleptic, and microbiological parameters of the water. The monitoring module oversees control of informative parameters, measurement methods, and time series creation. The processing module facilitates time series analysis based on various methods, enabling forecasting. The decision-making module formulates instructions based on the current water status and ensures that water quality in the reservoir meets international standards.

Based on functional and conceptual models (Figure 1.), the system's architecture was developed (Figure 2). The monitoring results of the Jeyranbatan Reservoir are divided into three periods: model validation, system testing on new points, and system approval starting in 2022.

For each period, time series data were created for four respective databases. Simultaneously, the current water quality status is compared with baseline standards in real time.

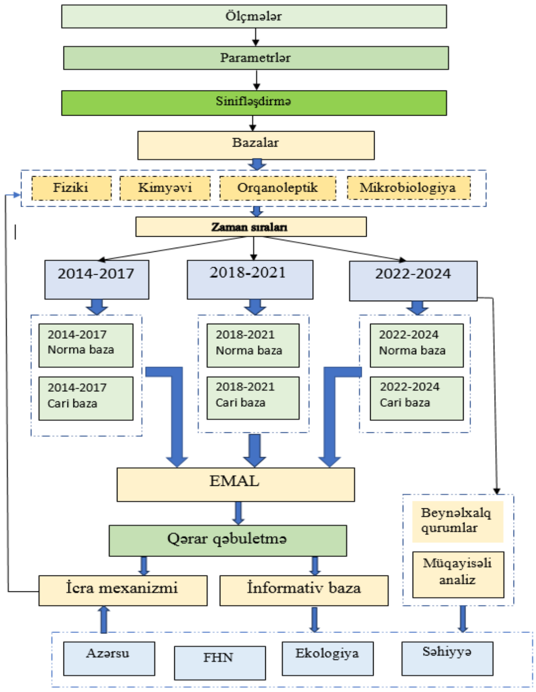
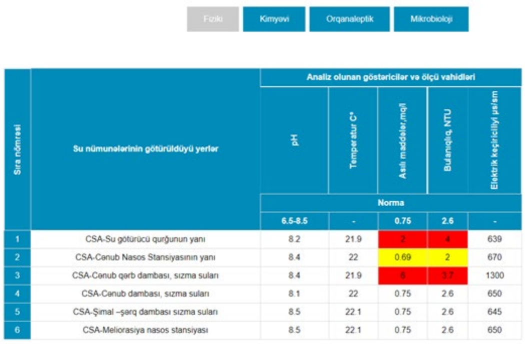


Figure 2. System architecture

The increasing demand for drinking water in Azerbaijan is one of the most critical issues. Existing reservoirs in the liberated territories are being restored, and new ones are being constructed. Considering that the sources of the rivers flowing in our republic are located abroad, security, especially the control of drinking water, must always be maintained. For this reason, the creation of a unified approach and an integrated intellectual control system that ensures the ecological safety of the general reservoirs is essential. From this perspective, it is appropriate to view the developed JWR intellectual information-measurement system as a prototype for the future unified system. [7]

HTML has been used to write the front-end code for the system's software, CSS technology for visual design, and the JavaScript programming language for adding functions. Below are fragments from the program.[8]


Fiziki | Kimyəvi | Orqanaleptik | Mikrobioloji

Sıra nömrəsi	Su nümunələrinin götürüldüyü yerlər	pH	Temperatur C°	Asılı maddələr,mq/l	Bulanıqlıq, NTU	Elektrik keçiriciliyi µs/sm
		Analiz olunan göstəricilər və ölçü vahidləri				
		Norma				
		6.5-8.5	-	0.75	2.6	-
1	CSA-Su götürücü qurğunun yanı	8.2	21.9	2	4	639
2	CSA-Cənub Nasos Stansiyasının yanı	8.4	22	0.69	2	670
3	CSA-Cənub qərb dambası, sızma suları	8.4	21.9	6	3.7	1300
4	CSA-Cənub dambası, sızma suları	8.1	22	0.75	2.6	650
5	CSA-Şimal –şərq dambası sızma suları	8.5	22.1	0.75	2.6	645
6	CSA-Meliorasiya nasos stansiyası	8.5	22.1	0.75	2.6	650

Figure 3. Processing for a single point

Figure 4. Fragment from the comparison performed in the program

It is known that currently water is discharged into the JSA via the Takhtakorpu-Jeyranbatan canal, which comes from the Takhtakorpu reservoir. For this reason, we have taken the Takhtakorpu canal as the main control point for comparisons. A large number of experiments have been conducted. First, the adequacy of the system is tested. Tests are conducted on the measurements from 2014-2017, and the accuracy of the results is checked. Testing pertains to the years 2018-2021, and the approval process to 2022-2024. A comparison and analysis are carried out between 16 overlapping measured parameters and the standards set by the World Health Organization, the European Union, GOST, the Absheron Peninsula, and the CSA. **Result:** The regulation of measurements has been resolved. Thus, appropriate measurement times have been established for parameters that remain constant throughout the measurements, do not change during the seasonal period, and are irregularly affected by environmental factors; the system operates within the network. Interconnected organizations have the ability to engage in continuous exchanges when necessary. The working principle of the created system, the exchange of information, and decision-making functions are an example of paperless technology; the issue of forecasting based on data is solved using dispersion analysis, mathematical statistics, and probability theory methods. The increasing demand for drinking water in Azerbaijan is one of the most important issues. In the liberated territories, existing reservoirs are being restored, and new ones are being constructed. Considering that the origins of rivers flowing through our country are located abroad, safety, especially the control of drinking water, must be continuous. For this reason, it is essential to create a unified approach and a unified intellectual control system that ensures the ecological safety of all reservoirs. From this point of view, it is reasonable to consider the CSA intellectual information-measurement system as a prototype for a future unified system; it has been tested with measurements from 2018-2021 (25 parameters from 6-7 input/output points), and results of approximately 97.0% to 98.2% have been obtained. Processing for the years 2022 to May 2024 was carried out in parallel, and the system successfully passed the approval process. The application of the work has been confirmed by relevant acts [9].

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