

REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation for the degree of doctor of sciences

**DEVELOPMENT OF AN INTELLIGENT INFORMATION
SYSTEM FOR MONITORING THE ENVIRONMENTAL
SAFETY OF THE JEYRANBATAN RESERVOIR**

Speciality: 1203.01- Computer sciences

Field of science: Technical sciences

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GENERAL DESCRIPTION OF THE WORK

The relevance and elaboration degree of the topic. 96.4% of the total volume of water in the hydrosphere is accounted for by the World Ocean, while the majority of water bodies on land consist of glaciers and groundwater. Freshwater suitable for consumption constitutes only 2.5% of the total volume of all water in the hydrosphere. In agriculture, particularly in irrigated farming, the consumption of non-recoverable water is extremely high¹. High per capita water consumption is a characteristic feature of countries engaged in irrigated agriculture.

Countries such as Turkmenistan, Uzbekistan, Kyrgyzstan, Kazakhstan, Tajikistan, Iraq, and Pakistan are notable examples. All of these countries are already facing a significant shortage of water resources. Like many other countries, the Republic of Azerbaijan also grapples with the pressing issue of water scarcity.

It is possible to refer to several declarations related to environmental security and directly aimed at addressing it, such as the United Nations Declaration on the Human Environment², the Rio Declaration on Environment and Development³, the United Nations Millennium Declaration⁴, and the Johannesburg Declaration on Sustainable Development⁵.

The most recent event on this topic was the 29th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 29), held in Baku from November 12 to 24.

At the session of the conference held on November 21, 2024, nearly 50 countries signed the COP29 Declaration on Water for Climate Action. The declaration emphasizes the integration of water-related impact reduction and adaptation measures into national climate strategies, such as Nationally Determined Contributions (NDC) and National Adaptation

¹ G.M.Alfonso, M.Sonia, T.Julia // Efectos de la descarga en la calidad del agua a lo largo de un rio mediterraneo: El rio Guadaira (Sevilla) 2004. no. 1-2. P.. 65-78

² United Nations Declaration on the Human Environment
http://www.un.org/ru/documents/decl_conv/declarations/declarathenv.shtml

³ Rio Declaration on Environment and Development
http://www.un.org/ru/documents/decl_conv/declarations/riodecl.shtml

⁴ United Nations Millennium Declaration
http://www.un.org/ru/documents/decl_conv/declarations/summitdecl.shtml

⁵ Johannesburg Declaration on Sustainable Development
http://www.un.org/ru/documents/decl_conv/declarations/decl_wssd.shtml

Plans (NAP). To support these efforts, the signatory countries commit to collaborating on strengthening scientific research related to the factors and impacts of climate change on water resources and watersheds. This also includes the exchange of information and the development of new climate plans for watersheds. Commenting on the launch of the Water for Climate Action initiative, COP29 President Mukhtar Babayev stated: 'Water plays a pivotal role in the connection between the climate, biodiversity, and desertification crises. "The UN Deputy Secretary-General and Executive Director of UNEP, Inger Andersen, also remarked: "*As the impacts of the climate crisis continue to escalate, the management of freshwater ecosystems is now more crucial than ever*"⁶.

One of the sources that maintain water resources is reservoirs. Reservoirs can be classified into different types based on their characteristics, such as by their bed type, water filling methods, geographical location, position within a river basin, and regulation methods of their flow, among others.

In terms of operation, the hydrological regime of reservoirs, meaning the parameters and technical means required for their operation, are controlled by humans. Nevertheless, over time, these artificial structures have found their place in the overall water cycle.

The consumption side is represented by surface water runoff, groundwater runoff, and surface evaporation from the reservoir. When referring to the structure of the water balance of an arbitrary basin, the relationships between various types of inflows and outflows are considered.

Azerbaijan is among the countries with insufficient water supply. Approximately 80% of the country's drinking and irrigation water comes from transboundary rivers—namely the Kura, Araz, and Samur—which enter Azerbaijan from neighboring countries such as Turkey, Russia, Georgia, and Iran. The per capita water availability in Georgia is 5 to 7 times higher than in Azerbaijan, and in Armenia it is 2.5 to 3 times greater. Given our large population, vast territory, irrigated lands, and the volume of water used in industry, this situation is understandable. The widespread arid zones across the country also contribute to increased natural evaporation. One of the most serious threats to national security is the risk of contamination of drinking water.

The impact of global problems on international relations is steadily

⁶ COP29 Declaration

<https://cop29.az/en/media-hub/news/nearly-50-countries-sign-baku-declaration-on-water-for-climate-action-as-cop29-concludes-thematic-day-calendar>

increasing. Control over water resources has become a matter of strategic importance in intergovernmental relations. Through such means, states have begun to exert pressure on one another. In this context, access to safe drinking water has emerged as one of the key components of modern political relations. The concept of 'water diplomacy' has arisen on the international stage as water is increasingly used as an instrument of political leverage.

Object of the research. The object of this dissertation is the Jeyranbatan Reservoir (JR), which is under the authority of the Water Resources State Agency of the Ministry of Emergency Situations of the Republic of Azerbaijan.

Subject of the research. The subject of this research is the structural design, functional principles, data processing mechanisms, and decision-making algorithms of the intelligent information system developed for monitoring ecological safety at the JR.

The purpose of the research is the development and implementation of an intelligent information system for monitoring the environmental safety of the Jeyranbatan Reservoir.

Tasks of the research. The primary task of this study is to develop an integrated approach aimed at improving the quality of drinking water and ensuring its ecological safety. To achieve this goal, the following tasks of the research are outlined:

- Analysis of the main factors affecting the quality of drinking water and identification of ways to improve this quality;
- Establishment of real-time monitoring of parameters at the water intake and discharge points;
- Alignment of monitoring results with laboratory analyses and their processing in a comprehensive manner;
- Identification of technological solutions for transferring and storing collected data in a centralized management system;
- Application of an expert system approach for assessing the ecological status and safety level of the water;
- Design and development of a prototype of an intelligent information system that integrates all the above functions and ensures centralized management.

General research methodology. In solving the main research problem, mathematical statistics, analysis of variance, time series, as well as data and methods from the fields of chemistry, medicine, and other sciences were used.

The main provisions to be defended.

- Evaluation of ecological, natural-geographical, and anthropogenic factors affecting the Jeyranbatan Reservoir (JR) and substantiation of their impact on water quality;
- Classification of drinking water quality indicators into physical, chemical, organoleptic, and microbiological categories, and analysis of long-term monitoring data;
- Establishment of normative databases based on time series, application of statistical analyses, and implementation of reliability criteria;
- Justification for the development of an intelligent information system for water quality control and preparation of a functional model;
- Development of a multi-modular conceptual model, formulation of the system's functional and structural architecture;
- Development of software based on HTML, CSS, and JavaScript technologies.

Scientific novelty of the research:

1. A functional and conceptual model of the Jeyranbatan Reservoir (JR) intelligent measurement system aimed at ensuring the ecological safety of drinking water has been developed. The model integrates functional blocks for evaluating water quality parameters based on the norms and standards set by international organizations (WHO, CIS, EU). As a result of the modeling, a multi-modular system architecture has been established, and software has been developed for its implementation.

2. The operation of the Jeyranbatan Reservoir (JR) system over a network has been ensured, thereby creating continuous information exchange opportunities between various organizations and institutions. The system contributes to the digital transformation in the field of ecological monitoring by managing the information flow, performing analysis, and decision-making functions based on paperless technologies.

3. In the future, the developed JR intelligent system is planned to be integrated into a unified intellectual monitoring system ensuring the ecological safety of reservoirs across the country. The future application of this system will contribute to the formation of a large-scale monitoring network, real-time decision-making, and enhanced efficiency in water resource management.

The results obtained in this dissertation have been validated by the relevant official documents.

Theoretical and practical value of the research. In terms of practical significance, the system regulates the frequency of

measurements, performs routine calculations, allows for comparative analysis in parallel, and ensures paperless technology. Based on the architecture of the developed system, it is clear that this system can be adjusted and operated by correcting measurement parameters for other reservoirs. Considering that the sources of the rivers in our country are located abroad, security, especially control over drinking water, must always be maintained. The Jeyranbatan Reservoir (JR) intelligent information-measurement system can be considered as a prototype of a unified system, and it is advisable to conduct future research based on this system.

Approbation and Application of the Research: The main provisions of the dissertation have been discussed at the seminar of the "Intelligent Information Processing Systems" laboratory of the Institute of Control Systems of the Ministry of Science and Education, at the institute's scientific seminar, as well as at the following international and national conferences and symposiums:

- Riyaziyyatın tətbiqi məsələləri və yeni informasiya texnologiyaları III Respublika Elmi Konfransı, - Sumqayıt, Azərbaycan: 15-16 dekabr 2016;

- Симпозиум Методы измерений и математическое моделирование физических процессов: биофотоника, оптика и радиолокация. Астрахань, 10–15 сентября 2018;

- Международная Конференция Актуальные проблемы современного образования. Синергетические подходы в решении проблем науки, культуры и современного образования, Астрахань 2021;

- Importance of Soft Skills for Life and Scientific Success: Proceedings of the 1st International Scientific and Practical Internet Conference, Ukraine, Kiev, March 1-2, 2022;

- Dedicated to the 100th anniversary of the Azerbaijan National Leader Heydar Aliyev The Fourth International Student Research and Science Conferences, Baku, 12 April - 3 may, 2023;

- 5th International Conference on Problems of Cybernetics and Informatics (PCI), 28-30 Aug. 2023.

- X Межд. Научно-прак. Конф. Актуальные проблемы современного образования Россия, Астрахань, 27-28 сентября 2024 г.

- VII International Scientific-Practical Conference Modeling, control and information technology Ukraine, Rivne, November 7-9 2024.

An intelligent information system has been developed to ensure the

ecological safety of the Jeyranbatan Reservoir (JR), and it was tested at Hydrotex LLC during 2021-2023 (The comparative analysis of water composition at the Jeyranbatan Reservoir was conducted in 2020, and the development of the intelligent information system for ensuring the ecological safety of the Jeyranbatan Reservoir was confirmed by the Acts issued on November 16, 2022, and November 23, 2023).

Publication: A total of 14 scientific papers have been published based on the dissertation work, including 6 articles [3, 4, 5, 8, 11, 14], 5 conference materials [2, 6, 10, 12, 13], and 3 theses [1, 7, 9]. 2 articles are included in the РИИЦ database, 1 article is included in the SCOPUS database, one conference material is included in the Web of Science database, and 3 conference materials are included in the РИИЦ database.

The name of the institution where the thesis was performed: The thesis was performed at the "Intelligent Information Processing Systems" Laboratory of the Institute of Control Systems, Ministry of Science and Education of the Republic of Azerbaijan.

Structure and Volume of the Dissertation: The dissertation consists of an introduction, 4 chapters, the main findings, a list of 110 references, and an appendix. The total volume of the dissertation is 143 pages, with the main content comprising 11 tables, 34 figures, and a total of 143 pages (165,331 characters). The breakdown of the sections is as follows: title page - 380 characters, table of contents - 1,811 characters, introduction - 17,874 characters, Chapter 1 - 43,097 characters, Chapter 2 - 27,293 characters, Chapter 3 - 40,935 characters, Chapter 4 - 34,571 characters, and the main findings - 1,561 characters.

CONTENT OF THE WORK

In the introduction the relevance of the work is outlined, the objective of the study, the problem to be solved, and the sub-problems are formulated. The theoretical and practical significance of the work is explained, and the main provisions to be defended are discussed.

The first chapter of the dissertation is devoted to information technologies in the management of ecological safety of reservoirs.

In paragraph 1.1, the issue of the structure and analysis of water bodies is examined in a generalized manner. The morphology, ecological characteristics, and usage of water bodies, including lakes and reservoirs, are explained.

Paragraph 1.2 addresses environmental protection and ecological security issues. Ecological security is one of the most important challenges faced by the globalized world since the 1980s. Regarding this issue and directly aimed at its resolution, the United Nations Environmental Protection Declaration, the Rio de Janeiro Environment and Development Declaration, the United Nations Millennium Declaration, and the Johannesburg Declaration on Sustainable Development of Ecological Security can be cited as examples.

Paragraph 1.3 examines natural and artificial water bodies. The construction of reservoirs is an example of technogenic intervention in nature. The goal is to prevent the unequal distribution of natural water resources in space and, particularly, over time. From this perspective, the significance of protecting water, especially drinking water, is emphasized. The water issue is not limited to springs, rivers, etc. A special focus is given to the role of reservoirs.

Paragraph 1.4 examines the reservoirs located in Azerbaijan, mentioning the names of the 11 largest reservoirs by volume. Initial information is provided about the Jeyranbatan Reservoir (JR), which supplies drinking water to Baku, Sumgayit, and part of the Absheron Peninsula, and ranks 7th in the country by volume.

Paragraph 1.5 discusses the diversity of substances in water and, considering the relevance of various organizations to the issue, it is advisable to use the theory of distributed databases and systems for information processing and analysis. Information is provided about existing systems, including telecommunication networks, computer networks, routing issues, distributed databases, etc..

Paragraph 1.6 provides information about the problem, the formulation of the issue aimed at solving the problem, and its justification. The creation of an intellectual information system with a unified approach to drinking water in the republic is deemed advisable. Such a system could even be included as a component of the Electronic Azerbaijan State Program.

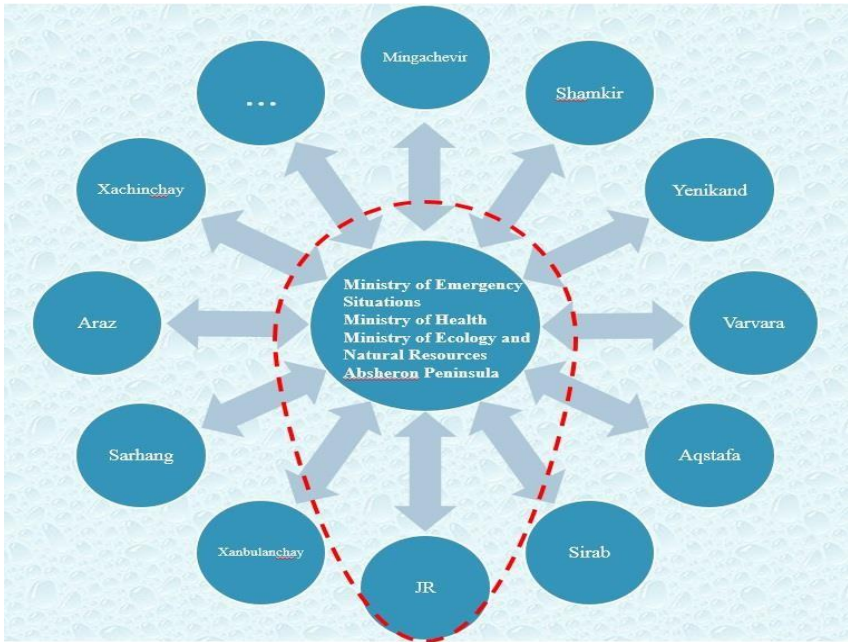


Figure 1. Selection of the Prototype Model in the Unified System

In the dissertation, the prototype for the creation of such a unified system is proposed. The JR located on the Absheron Peninsula has been selected as the prototype.

Problem Statement: Development of an intellectual measurement system for information ensuring ecological safety of water in the JR. Sub-problems for solving the issue are outlined:

1. Sub-problems for execution are specified: classification of input and output parameters;
2. Development of norm bases that determine the quality of water;
3. Selection and justification of measurement tools and mathematical apparatus for data processing;
4. Establishment of distributed databases (physical, chemical, organoleptic, microbiological) and justification of their technology;
5. Development and justification of the conceptual and functional models of the system;
6. Interaction of components, information exchange between them, and their functional capabilities;
7. Development of the architecture of the intellectual information system;

8. Development of software;
9. Testing and conducting experiments on the intellectual information system;
10. Conducting expert evaluations and system assessment.

The main goal of the work is to determine ways to improve the quality of drinking water and ensure its ecological safety.

II chapter is dedicated to the formation of the information environment for the measured indicators in JR. In paragraph 2.1, general rules and regulations are provided based on water legislation to ensure the protection of water resources from pollution and depletion, meeting all the demands of water usage. Afterward, the climatic conditions of the Absheron Peninsula and the water sources included in JR are taken into account, and the requirements for drinking water are explained. According to the Republic of Azerbaijan's standards, drinking water provided to consumers must comply with the DUST 2874-82 standard, meeting organoleptic, physicochemical, and sanitary-bacteriological norms.

In paragraph 2.2, the indicators that fall under the physical, chemical, organoleptic, and microbiological factors are listed. The initial data for JR in the first phase, from 2014 to 2017, includes 24 parameters collected from 22 sampling points. In the second phase, from 2018 to 2021, 24 parameters are collected from 6-7 sampling points, and they are categorized into the four classes mentioned above. During the observation years, time series are used to regulate the established standards and current indicator sets, depending on the measurement intervals.

In paragraph 2.3, a brief description is provided of the components of time series, including trend, cyclical, seasonal, and irregular, and a general regression equation for multivariate time series is proposed. For each class, corresponding time series are constructed (norms and actual values).

In paragraph 2.4, data bases that meet all the established requirements have been created, and forms for them have been designed. Based on this, five types of relational databases have been developed for the indicators measured in JR. Each database consists of two parts. The first part includes the standard measurements for the location where the samples were taken, and the second part includes the actual measurements. For example, Table 1 provides a database of indicators/norms for chemical indicators measured in JR.

Table 1.

A fragment of the database for chemical indicators measured in Jeyranbatan Reservoir.

Water abstraction point			JR - By the water intake	JR - By the south pumping	JR - Southwest dam, effluent	JR - South dam, effluent	JR - Northeast dam, effluent	JR - Melioration pumping	
Parameters									
Sulfides (S ²⁻)	Analysis result		XX	XX	XX	XX	XX	XX	
	norma		-	-	-	-	-	-	
Dissolved gases	O ₂ mg/l	Analysis result	XX	XX	XX	XX	XX	XX	
		standart	W<4, S>4	W<4, S>4	W<4, S>4	W<4, S>4	W<4, S>4	W<4, S>4	
	O ₂ %	Analysis result	XX	XX	XX	XX	XX	XX	
		standart	-	-	-	-	-	-	
	CO ₂	Analysis result	XX	XX	XX	XX	XX	XX	
		standart	-	-	-	-	-	-	
	Chlorine (Cl ₂), mg/L	Free	Analysis result	XX	XX	XX	XX	XX	XX
			standart	0,3-0,5	0,3-0,5	0,3-0,5	0,3-0,5	0,3-0,5	0,3-0,5
Total		Analysis result	XX	XX	XX	XX	XX	XX	
		standart	<1,2	<1,2	<1,2	<1,2	<1,2	<1,2	
..		

Chapter Three addresses the development of an intelligent information system for monitoring the quality of drinking water in the Jeyranbatan Reservoir. To solve this problem, measurement tools, mathematical apparatus, and information technologies are applied within the data processing systems and decision-making processes in JR. The concept of ecological safety of JR includes the following:

- Protection of the reservoir as a physical object;
- Organization of control over water inflow/outflow;
- Laboratory testing;
- Expert evaluation.

In paragraph 3.2, methods for initial data processing after measurements are selected.

After verifying the measurement indicators using several statistical methods (such as analysis of variance, variation analysis, etc.), the resulting

data enables more accurate forecasting. The dissertation provides a classification of these methods.

If the number of measurements is small (e.g., once or twice a month), the Mann–Whitney criterion is applied. In cases where the number of measurements is large (e.g., daily or every other day), the indicators are analyzed using analysis of variance (ANOVA) based on a single parameter.

During the data processing in the dissertation, critical values are calculated using ANOVA for all collected data. Comparative analysis of data collected from two points for the same parameter is carried out using the Student's *t*-test. Seasonal comparisons are conducted using the Mann–Whitney criterion. Confidence interval methods are used to assess the reliability of changes in indicators.

In paragraph 3.3, the application of selection and decision-making theory in management tasks is discussed in the context of ensuring the ecological safety of water in the JR, along with the conditions and procedures for conducting expert evaluations. Considering the variability range of parameters that determine the quality of drinking water, a large number of alternative vectors are generated in a general description. Formally, these can be conceptualized as a criterion space.

In this case, the alternatives are not mathematical abstractions but physical system states—specifically, the condition of water in the JR depending on various parameters. To construct the set of alternative states, all possible solutions must be collected, the measured parameters must be normalized, and each state must be evaluated according to relevant criteria. At this stage of the process, expert knowledge is utilized.

Paragraph 3.4 explains the issue of assessing the quality of drinking water. This assessment can be carried out through comparative analysis of the water's current condition with the standards established by globally recognized organizations. For this purpose, a functional model for evaluating water quality is developed.

Naturally, the centralized management of these processes requires the creation of an intelligent system. However, such a system must be equipped with various subsystems for different purposes, support systems, relevant knowledge bases, and databases. The dissertation proposes an approach to building such a system. First and foremost, a systematic approach to the object is necessary. In other words, it is essential to study natural and anthropogenic factors that affect the reservoir's ecosystem and may negatively influence its operation and safety.

Based on the ecosystem of the Absheron Peninsula, the concept of "drinking water standards" slightly differs geographically from the average indicators of the JR. These standards have been defined by international organizations such as the World Health Organization (WHO), the European Union (EU), and the Interstate Council for Standardization, Metrology, and Certification of the CIS (EASC CIS). The comparison of the norm-based indicators developed in Chapter II with the measured parameters in the JR allows for an understanding of the current state of water. Ultimately, only a comparative analysis with internationally recognized standards can provide a definitive evaluation of the drinking water's quality.

To achieve this, a normative base was developed that includes requirements set by the WHO, EU, EASC CIS, average indicators for the Absheron Peninsula, and measured water parameters in the JR. The number of overlapping indicators across these standards amounts to 16.

Accordingly, a functional framework is established to enable the comparison of the Jeyranbatan Reservoir (JR) with other relevant institutions and international standards.

$$\{\{I_{q_A}\}; \{I_{q_T}\}; \{I_{q_E}\}; \{I_{q_B}\}; \{I_{q_i}\}; k\{I_{q_i}\}; k_j\{I_{q_j}\}; O\{P_{q_j}\}\} \{S_{O_q}\} \Rightarrow O\{P_{q_j}\} \\ \rightarrow \{(I_{q^*}); k^*(I_{q^*})\},$$

$\{I_{q_A}\}$ - Table of the Maximum Permissible Concentrations of Components in the Water Composition of the Jeyranbatan Reservoir;

$\{I_{q_T}\}$ - Table of Normative Limits for Water Quality Indicators in Accordance with GOST Standards Adopted by the CIS;

$\{I_{q_E}\}$ - Table of Standard Limits for Water Quality Parameters in Accordance with European Union (EU) Regulations;

$\{I_{q_B}\}$ - Table of Water Quality Standards Based on WHO Guidelines for Drinking-water Quality;

$\{I_{q_i}\}$ - Table of Current Concentrations of Water Quality Indicators at Sampling Locations i (where $i = 1, 2, \dots, 6$);

$k\{I_{q_i}\}$ - $\{I_{q_A}\}$ - Coefficient of Comparison Between Current Measurements and the Jeyranbatan Reservoir Standards;

$K_j\{I_{q_j}\}$ - Comparison Coefficient of Current Water Quality Values Relative to the Respective Standards of the World Health Organization (WHO), the European Union (EU), and the CIS GOST Regulations ($j = 1, 2, 3$);

$\{P_{q_j}\}$ - Set of Excited Parameters;

$O\{P_{q_j}\}$ - Set of Variation Values of Excited Parameters;

$\{S\}$ - Effect Operator;

$\{S_{O_q}\}$ - Spectrum of Influence Factor Values;

(*) – { S_{Oq} } - Resulting Effect of the Operator.

In paragraph 3.5, considering the parameters measured at the Jeyranbatan Reservoir (JR) and the functional model, a system concept is proposed, based on which the architecture of the measurement-information system controlling water safety is constructed. The results of the conducted measurements (factors affecting water quality) are divided into three periods. The first period relates to the validation of the model adequacy (22 sampling points, 17 parameters, 2014–2017), the second to system testing based on new points (6–7 points, 2018–2021), and the third period (6–7 points, 2022–2024) is currently in the approval phase. The latest measurements include 24 parameters.

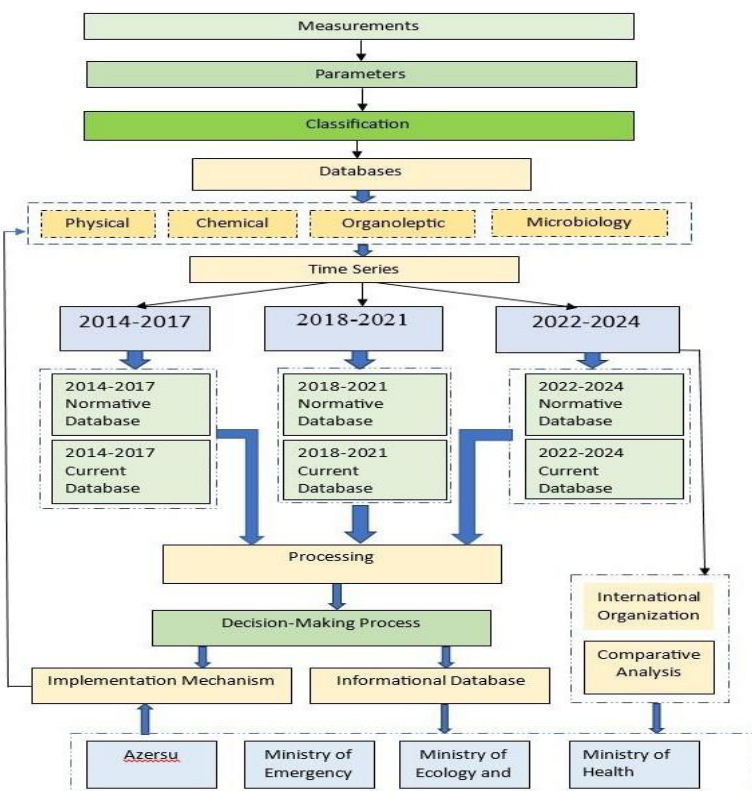


Figure 2. System Architecture

The main feature of the system is that it operates within a network and has the capability to process data and automatically transmit results.

The unified water monitoring and management system is proposed as a control concept aimed at ensuring the operational and coordinated activities of agencies directly responsible for the quality of drinking water in Azerbaijan. This system envisions direct access for relevant state institutions such as the Ministry of Emergency Situations, the Ministry of Health, the Ministry of Ecology and Natural Resources, and Azersu Open Joint Stock Company.

Water samples taken from the Jeyranbatan Reservoir (JR), as well as measurement results independently conducted by any organization and integrated into the system, can be processed automatically upon entry. From the moment data is entered into the system, analysis results are automatically directed to all relevant agencies. Each agency can monitor all parameters and observe deviations from standards in real time. Additionally, each agency receives specific alert signals concerning the parameters for which they are responsible. This approach enables agencies both to monitor the overall situation and to make prompt decisions within their functional domains. Consequently, this not only saves time but also eliminates the need for excessive emails, faxes, or telegrams. Thus, based on pre-trained data, the system performs the following functions:

- Detects deviations of various parameters from the established standards;
- Identifies indicators that may pose potential threats to water safety;
- Analyzes relationships among parameters that interact and potentially alter the situation;
- Provides information on preliminary intervention measures based on expert recommendations.
- In such cases, the system automatically generates an alert signal and sends notifications to the relevant authorities. As a result, immediate intervention in hazardous situations becomes possible, and potential risks are mitigated in a timely manner. This approach holds significant strategic importance for safety in drinking water supply and public health.

Paragraph 3.6 is dedicated to the development of the system's software. The program was developed and compiled using the Visual Studio Code platform. The front-end of the software was coded using the HTML programming language. Since HTML is a programming language that enables the creation of structured and accessible content, it plays a primary role in the design of lists, tables, paragraphs, and other elements. The overall appearance of the program — including headings, layout style,

fonts, and other visual effects — is provided through CSS (Cascading Style Sheets). CSS enables the creation of a visually appealing and functional user interface. To ensure the proper and efficient functioning of the program’s features, the JavaScript programming language was used. JavaScript’s single-threaded execution model—that is, executing code line by line without moving to the next line until the current one is fully completed—allows for clearer and more controlled program logic.

The program opens with the main page. On the main page, the names of the Jeyranbatan Reservoir (JR) and the water sampling points are displayed. Each point is represented by buttons with dropdown menus. When any of these buttons is clicked, a table showing the names of the observation points is opened. In the table, points with parameter values deviating from the norm, based on analysis results for the corresponding month, are visually distinguished. Specifically, if the value of a given parameter exceeds the norm, the row corresponding to that point is highlighted in red; if it falls below the norm, it is marked in yellow. This approach enables the prompt identification of potentially hazardous or non-standard conditions.

Fiziki
Kimyevi
Organoleptik
Mikrobioloji

Sıra nömrəsi	Su nümunələrinin götürüldüyü yerlər	Analiz olunan göstəricilər və ölçü vahidləri				
		pH	Temperatur, C°	Aşılma dərəcəsi, meq/l	Bulanlıq, NTU	Elektrik keçiriciliyi, jəlf/cm
		Norma				
		6.5-8.5	-	0.75	2.6	-
1	CSA-Su götürücü qurğunun yanısı	8.2	21.9	3	4	639
2	CSA-Cənub Nasos Stansiyasının yanısı	8.4	22	0.69	2	670
3	CSA-Cənub qərb dambası, sızma suları	8.4	21.9	4	3.1	1300
4	CSA-Cənub dambası, sızma suları	8.1	22	0.75	2.6	650
5	CSA, Şimal –qərb 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. The page displayed in the program based on various analysis results.

In the table, the color of one or more rows corresponding to one or several observation points may change. Each of these rows is presented as a separate pop-up window. Since the main functional purpose of the system is the prompt identification of deviations from the norm, the user is

primarily interested in the rows marked in red. When one of these rows is selected, a separate page opens displaying the analysis results related to that point. If all the results presented on this page exceed the norm, all the relevant cells are shown in red. In the top-left part of the pop-up window, there are month and year selectors for the user to choose the date, while in the top-right part, special buttons for returning to the main page and for comparison functions are located.



Figure 4. Monthly analysis results

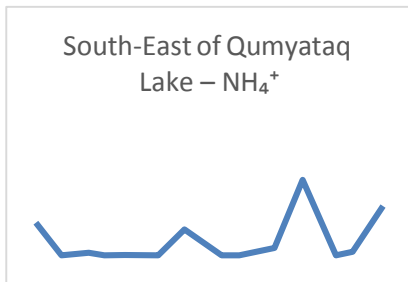
Using the “Compare” button, it is possible to visually track the difference between the indicators obtained for the current month and the accepted norm values in the form of a graph. This functional feature clearly shows how much and in which direction (excess or deficiency) the measurements of any parameter deviate from the norm, facilitating the analytical evaluation of the results. Additionally, the user can select any month and year to obtain a graph comparing the current month’s indicators with both previous periods’ data and the norm values. If the current month’s indicators fall within the norm, the rows are displayed without color, and this comparison can also be followed via the graph.

Chapter 4 is dedicated to conducting experiments using the system for monitoring water safety in the JR.

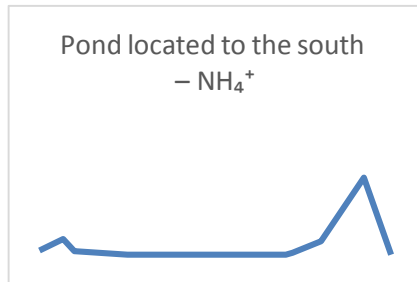
In paragraph 4.1, to verify the adequacy of the intelligent information-measurement system to reality, measurements from the JR taken between 2014 and 2017 were used. For this purpose, corresponding databases were processed for data obtained from 22 points along the specified timeline. Based on water samples taken from these points, analyses were conducted on 17 parameters, and the results were divided into current and norm databases for experimentation. The obtained analysis results were further divided by days, months, seasons, and years, and various treatments were performed using mathematical statistics (analysis

of variance) and mathematical analysis methods. To provide a clearer visual representation of the processing results, the outcome of each treatment was monitored graphically. It is known that the indicators of analysis results taken from different points for a single parameter are not the same. The presence of these differences complicates the acceptance of a final overall result for the entire JR. For this reason, cumulative results were also calculated for all points where analyses were taken, and their graphs were monitored as well. For example, let us observe the graphical monitoring of analysis results for several parameters from different points.

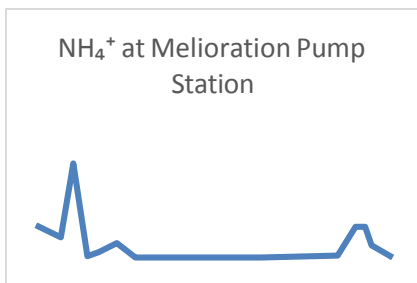
Graphs of NH_4^+ for 7 points, both individually and cumulatively, are presented in Figures 4.4 and 4.5. Due to the absence of water samples, no measurements were taken between July 16, 2014, and July 16, 2015, at the following locations: Melioration Pump Station inlet, western direction sewage pond, South Pump Station outlet, South Pump Station inlet, Ceyranbatan-Taxta Bridge canal, collector, western direction sewage pond, Shore Pump Station outlet, Samur Absheron canal, northeast pond, near the water intake facility, floating pump station outlet (cumulative indicator), floating pump station inlet (cumulative indicator), and vacuum pump station inlet.



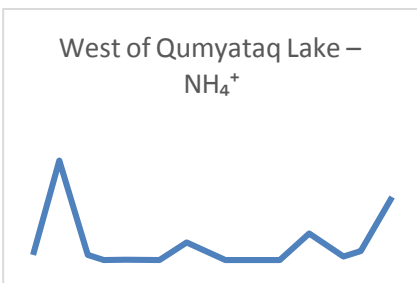
a.



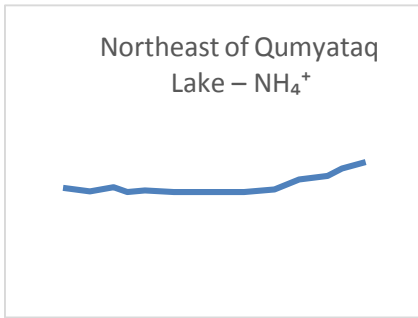
b.



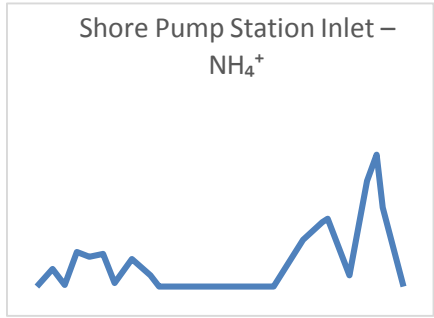
c.



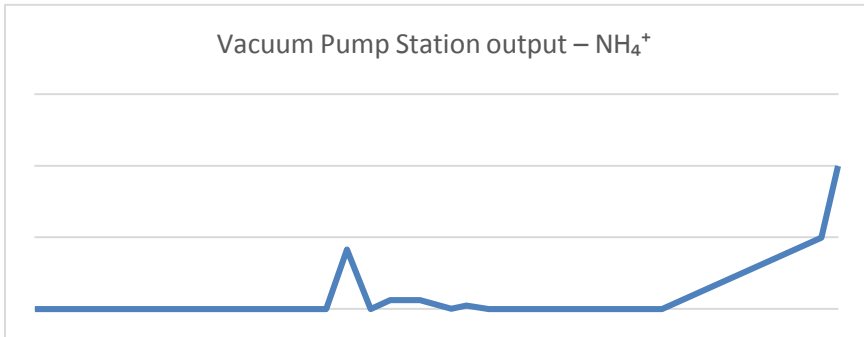
d.



e.



f.



g.

Figure 5. Graph of NH₄⁺ obtained from water samples taken from 7 points

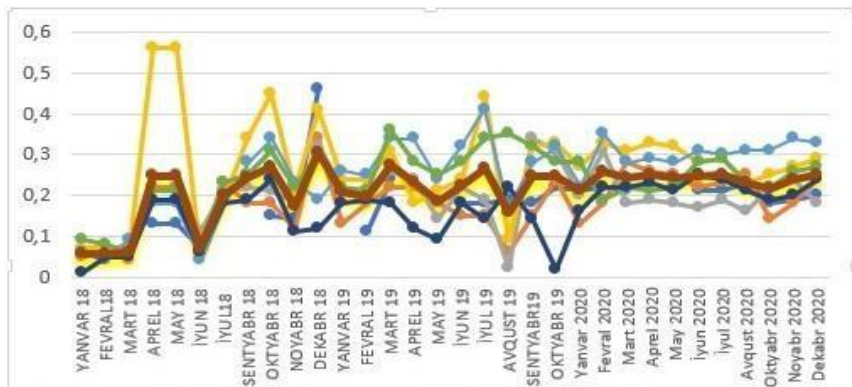


Figure 6. Cumulative graph of NH₄

Observations showed that the trends of individual indicators differ

from the cumulative trends. The accuracy of the results obtained by the system and the decisions made were verified, and the system's adequacy was confirmed.

Paragraph 4.2 describes in detail the testing of the system for water quality monitoring carried out in the JR between 2018 and 2021, as well as the validation conducted during 2022–2024. It is first noted that the number of water sampling points was expanded and new time series were established.

It is then stated that, based on this data, statistical processing (mean value, variance, t-test, ANOVA, etc.) was carried out, and the results confirmed the accuracy of the system. The main water quality parameters at various monitoring points—especially turbidity indicators—were compared, statistically significant differences were identified, and in some cases, it was proven that these differences were not random. As a result, the system successfully passed the testing phase, and it was deemed appropriate to proceed to the validation stage based on scientific grounds.

As an example of the statistical processing performed, the following figure presents a sample analysis showing the mean and variance indicators calculated based on the measurements conducted in the JR during 2018–20

Однофакторный дисперсионный анализ							
ИТОГИ							
Группы	Счет	Сумма	Среднее	Дисперсия			
Столбец 1	32	207,8	6,49375	27,80383065			
Столбец 2	32	136,2	4,25625	7,96641129			
Дисперсионный анализ							
Чник вари	SS	df	MS	F	P-Значение	F критическое	
Между гр	80,1025	1	80,1025	4,478722853	0,038341247	3,995887126	
Внутри гр	1108,878	62	17,88512097				
Итого	1188,98	63					

Figure 7. A sample analysis of the mean and variance indicators calculated based on the conducted measurements

As part of the research, turbidity indicators of water at monitoring points located near the Taxtakörpü and South Pump Stations were compared, and a one-way analysis of variance (ANOVA) was conducted to determine whether a statistically significant difference existed. As a result of the analysis, the empirical F_{value} was found to be $F_e = 4.478$, while the

critical F_{value} was $F_{\text{crit}} = 3.996$. At the same time, the P_{value} was **0.038**, which is below the significance level of **0.05**.

These results indicate that there is a statistically significant difference in turbidity indicators between the two monitoring points. In other words, the turbidity levels of the water near the Takhtakorpu and South Pump Stations are different, and this difference is not due to random variation. This variation is likely related to the specific geographical characteristics of these locations, the water flow trajectory, and anthropogenic factors.

In paragraph 4.3, the effects of parameters measured in the JR on the human body were investigated. Water quality must comply with normative standards because factors such as mineralization, chlorine content, contamination by heavy metals, pH level, and electrical conductivity directly affect human health. For example, if mineralization is too high or too low, it can cause health problems. Mineralization above 1000 mg/L not only alters the taste of water but also reduces its ability to quench thirst, contributes to the formation of calculi and kidney stones, and in some cases, has harmful effects on the body. When the dry residue (mineralization level) is below 100 mg/L, it can lead to iodine deficiency. Such water has an unpleasant taste and, with prolonged use, may cause metabolic disorders as well as endocrine diseases. Chlorination is essential for water disinfection, but excessive chlorine can be harmful to health. Some of the potential harmful effects of chlorinated water include asthma symptoms, food allergies, bladder and rectal cancer, among others. When heavy metals and pH levels deviate from the norm, they can cause various diseases. Since heavy metals primarily enter the water through sewage and these problems have been addressed, no such indicators were observed during 2018–2020. Monitoring in the JR shows that during 2018–2020, these parameters were generally within the norm, and the water was safe for human consumption.

The presence of various age groups of river crayfish is an indicator of the ecological health of the JR and confirms good water quality⁷. At the same time, the increase in fish populations is a positive signal for maintaining the biological balance of the water reservoir and the healthy functioning of the ecosystem.

Paragraph 4.4 provides a comparative analysis and review of the JR indicators against those of international organizations.

⁷ Report on the research conducted by the Institute of Zoology of ANAS on August 7, 2017, based on the contract signed with the Ministry of Emergency Situations, the State Agency for Water Resources, and Hydrotech LLC.

Table 2.

Expert evaluation in comparison with international organizations

No	Parameters	Unit of measurement	WHO	EU	GOST	Absheron	JR
1	Odor (20°; 60°)	point	-	-	2	0	2
2	Taste	point	-	-	2	0	Notmeasured
3	Color	Pt-CO scale	degree	15	20	20	0
	2. Bixromat CO şkalası üzrə	Dichromate CO scale	degree	15	20	20 (35)	0
4	Turbidity (Formazin)	NTU	5 (1)	4	2.6	0	2.6
5	Hardness (total)	meq/l	-	1.2	7.0	5	7.0
6	Electrical conductivity, 20°	µS/cm	-	2 500	-	450	Norm -no
7	Hydrogen carbonate, HCO ₃	Mq HCO ₃ -L	-	>30	-	130	Norm - no
8	Hydrogen	PH	-	6.5 –8.5	6 – 9	7.5	6.5-8.5
9	Aluminum(Al)	mg/l	0.2	0.2	0.5	0.1	Not measured
10	NH ₃ and NH ₄ ⁺	mg/l	1.5	_____	0.5	0-0.17	0.5
11	Arsenic (As)	mg/l	0.01	0.01	0.05	0	Not measured
12	Iron (Fe ₂ ⁺ ,Fe ₃ ⁺)	mg/l	0.3	0.2	0.3	0-0.03	Not measured
13	Silver (Ag)	mg/l	-	0.01	0.05	0	Not measured
14	Hydrogen sulfide (H ₂ S)	mg/l	0.05	-	0.003	0	Not measured
15	Bisulfide ion (HS ⁻)	mg/l	-	-	3.0	0	Not measured
16	Chloride (Cl ⁻)	mg/l	250.0	250.0	350.0	29-154	>350
17	Chlorine 1. Free residual	mg/l	-	-	0.3 – 0.5	0.3	0/3-0/5
18	Chlorine 2. Fixed residual	mg/l	-	-	0.8 – 1.2	0.5	>1.2
19	Chlorate ion (ClO ₃ ⁻)	mg/l			20.0	10.0	Not measured
20	Potassium (K ⁺)	mg/l		10.0	_____	10	Not measured
21	Calcium (Ca ₂ ⁺)	mg/l		100.0	250	60	Norm - no
22	Manganese (Mn, total)	mg/l	0.1	0.05	0.1(0.5)	0.005-0.02	Not measured
23	Copper (Cu, total)	mg/l	1.0	2.0	1.0	0-0.03	Not measured
24	Molybdenum (Mo, total)	mg/l	0.07	-	0.25	0.01	Not measured
25	Magnesium (Mg ₂ ⁺)	mg/l	-	50	50	18.24	Norm - no
27	Sodium (Na ⁺)	mg/l	200	200	200	45-97	Not measured
28	Nickel (Ni)	mg/l	0.02	0.02	0.1	0.01	Not measured
29	Nitrates (NO ₃ ⁻)	mg/l	50		45	3	4.5
30	Nitrites (NO ₂ ⁻)	mg/l	3	0.5	3	0	3.3
31	Polyphosphate ion (PO ₄ ³⁻)	mg/l	-	-	3.5	1.1	3.5
32	Strontium (Sr ₂ ⁺)	mg/l	-	-	7.0	3	Not measured
33	Zink	mg/l	5.0	5.0	5.0	0.01-0.9	Not measured
34	Sulfates (SO ₄ ²⁻)	mg/l	250	250	500	85-210	Not measured
35	Cyanides (CN ⁻)	mg/l	0.07	0.05	0.035	0.003	Not measured

Based on the table, a comparative analysis of water quality indicators was conducted. The analysis was performed individually for various parameters. The table presents standard and actual values for physical characteristics of water (color, turbidity, taste, odor), chemical composition (macro- and microelements), and toxicological indicators (heavy metals, cyanides, etc.). The comparison is made both with international standards (WHO, EU, ISO) and local benchmarks (Absheron Peninsula and JR).

Physical characteristics– Odor and Taste: In the Absheron region and JR, no odor or taste was detected (0 points), which is favorable for drinking water. According to WHO standards, the acceptable level for taste and odor is 2 points, which is considered satisfactory. Color and Turbidity: The color and turbidity levels in JR and Absheron are minimal (color: 0, turbidity: 0 and 2.6 NTU), indicating high optical quality of the water.

Chemical composition– Hardness (Total Hardness): The hardness is 5 mg-eq/L in Absheron and 7.0 mg-eq/L in JR. According to WHO, a value up to 7.0 mg-eq/L is acceptable, but it is at the upper limit. High hardness may impact health with prolonged use. Electrical Conductivity: In JR it is 450 $\mu\text{S}/\text{cm}$, indicating low mineralization. The EU standard allows up to 2500 $\mu\text{S}/\text{cm}$, which reflects high mineralization. pH (Hydrogen index): In all sources, pH values are within the 6.5–8.5 range, which is optimal for drinking water. Bicarbonates and Sulfates: Bicarbonate levels in JR are not measured, and sulfate data is not provided. In Absheron, bicarbonates are high (130 mg/L). Toxic elements and heavy metals Arsenic (As): Not detected in either Absheron or JR, which is positive since arsenic is highly toxic. Aluminum, Iron, Copper: In JR, most of these are either not measured or found at minimal levels. Iron in Absheron ranges from 0–0.03 mg/L, which is significantly below WHO and ISO norms. Silver, Nickel, Molybdenum, Manganese: Mostly either very low or not measured. Manganese in Absheron is within 0.005–0.02 mg/L, which is within normative limits. Cyanides: In JR, cyanides are at 0.003 mg/L, which is below the WHO limit (0.07 mg/L). Ammonia and Ammonium ($\text{NH}_3/\text{NH}_4^+$): 0.5 mg/L in JR, within normative limits. Nitrates and Nitrites: In JR, nitrate is at the threshold value of 45 mg/L, and nitrite slightly exceeds the WHO limit (3.3 mg/L vs. 3 mg/L), posing a potential risk. Polyphosphates: 3.5 mg/L in JR, within the normative level.

Halogens and their compounds Chlorides and Chlorate ion: Chloride in JR is >350 mg/L, which exceeds the WHO standard (350 mg/L). Chlorate is not measured, which may hide a potential risk. – Free and Combined Chlorine: Both indicators are within normative

intervals, indicating that residual chlorine used for disinfection is at an acceptable level.

Other Anions and Cations. Calcium and Magnesium: Magnesium value is unavailable for JR, but in Absheron, magnesium is 18.24 mg/L, indicating moderate mineral content. Potassium and Sodium: No data for JR. In Absheron, sodium ranges from 45–97 mg/L – not at a hazardous level. Zinc and Strontium: Zinc in JR ranges from 0.01–0.9 mg/L, well below the standard limit.

As a result, although the water samples from JR and Absheron generally comply with international and national standards, certain parameters are observed to be near the threshold or exceeding the norms: indicators such as nitrite, chloride, and residual combined chlorine in JR have either exceeded the limits or approached the maximum allowable values.

The table indicates that data for several indicators were not measured. This creates a gap in terms of fully assessing water quality. In terms of physical and optical indicators, the waters of JR and Absheron demonstrate high quality.

A comparative analysis is carried out with current measurements, and the results are presented in the form of tables and diagrams. For example:

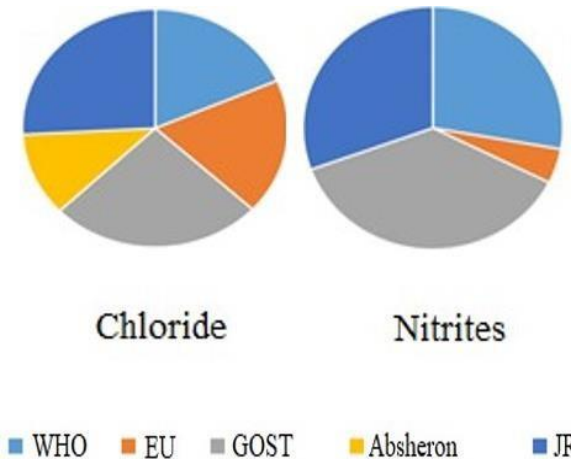


Figure 8. Comparative diagrams: a) chloride; b) nitrite

The water quality parameters measured for JR (formerly JR) have been compared with the standards of the World Health Organization (WHO), the European Union (EU), and GOST. The values of chloride and

nitrite in JR are within international norms and at safe levels. In some cases, higher levels have been observed in the Absheron Peninsula, which can be attributed to industrial activity, municipal waste, and soil structure.

Each chapter begins with a brief introduction and ends with a short summary of the topics covered.

CONCLUSION

1. In the JR, water quality parameters are classified into physical, chemical, organoleptic, and microbiological categories in accordance with normative and legislative requirements, and based on multi-point observations over various years, predictive models for water quality have been developed using applied statistical and probabilistic methods [1,2,5,9].

2. Based on an architecture designed in accordance with the functional and conceptual model, an intelligent information system ensuring the ecological safety of water in the JR has been developed, along with its software. The system has been implemented as a digital platform operating in real-time mode, based on networked, paperless technologies, and enabling uninterrupted information exchange among various institutions [3,4,6,12].

3. Measurement frequencies for these categories were optimized based on water variability. The system's functional capabilities were tested using real monitoring data collected between 2014 and 2024, and as a result of comparative analyses conducted across different input-output points and parameters, it was proven that the system operates at a high level of adequacy and reliability ($\approx 97-98\%$). This demonstrates that the system is fully suitable for practical application [8,10,14].

4. Considering the relevance of drinking water safety in the country and the dependence on transboundary water sources, the system serves as a promising intelligent platform for ensuring centralized and unified ecological monitoring across national reservoirs, and it may form the basis for a large-scale monitoring network in the future. Additionally, the normative requirements for water in the JR are compared with the drinking water standards established by international organizations, enabling an assessment of the system's compliance level and effectiveness [7,11,13].

The main content of the dissertation is published in the following scientific works:

1. Hidayətzadə S.Q. Ceyranbatan su anbarının mikrobioloji və parazitoloji göstəricilərinin zaman sıraları üsulu ilə proqnozu // Riyaziyyatın tətbiqi məsələləri və yeni informasiya texnologiyaları III Respublika Elmi Konfransı, - Sumqayıt, Azərbaycan: 15-16 dekabr 2016, - s. 40-42.
2. Абдуллаева Г.Г., Гидаятзаде С.Г. Разработка баз данных различного назначения для системы безопасности Джейранбатанского водохранилища // Международный Симпозиум «Методы измерений и математическое моделирование физических процессов: биофотоника, оптика и радиолокация», - Астрахань: 2018. Том 2, - стр.85-89. **(РИНЦ)**
3. Гидаятзаде С.Г. Концептуальная модель управления параметрами экологической безопасности питьевой воды в джейранбатанском водохранилище // - Москва: Интернаука: научный журнал 2019. №7 (89), Часть 1, с. 52-57.
4. Gidayatzada S.G. Comparative analysis of qualitative indicators of Ceyranbatan reservoir // – Baku: Informatics and control problems, - 2019. vol 39(2), - s. 117-124.
5. Гидаятзаде С.Г., Н.Г.Гейдарова, Э.С.Велиева. Анализ микробиологического состава воды джейранбатанского Водоохранилища азербайджанской республики // - Ukraine, Kiev: American scientific journal, - 2020. № (34), Vol.2, - с. 9-13.
6. Гидаятзаде С.Г. Мультиагентный подход организации мониторинга Джейранбатанского водохранилища Азербайджанской Республики // Межд.Конф. Актуальные проблемы современного образования. Синергетические подходы в решении проблем науки, культуры и современного образования – Астрахань: 2021. № 8 (30), с. 30-37. **(РИНЦ)**
7. Abdullayeva G.G., Gidayatzada. S.G. An intelligent Information system for ensuring the safety of the Ceyranbatan Reservoir // Importance of Soft Skills for Life and Scientific Success: Proceedings of the 1st International Scientific and Practical Internet Conference, - Dnipro, Ukraine: - 2022, pp. 5.
8. Gidayatzada S.G. Analysis of physical and chemical properties of drinking water in Jeyranbatan water reservoir // Industrial Chemistry open access, - 2022 vol. 8 issue 5.

<https://www.omicsonline.org/open-access/analysis-of-physical-and-chemical-properties-of-drinking-water-in-the-jeyranbatan-reservoir-121737.html>

9. Gidayatzada S.G. Ceyranbatan su anbarında içməli suyun fiziki və kimyəvi xassələrinin analizi // Dedicated to the 100th anniversary of the Azerbaijan National Leader Heydar Aliyev The Fourth International Student Research and Science Conferences, - Baku: 2023, pp. 423-424.
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11. Abdullayeva G.G., S.G. Gidayatzada. Approach To The Automatization Of Environmental Safety Monitoring Of Drinking Water In The Ceyranbatan Reservoir // Transylvanian Review, - 2023. Vol. 31 No. 2. **(SCOPUS)**
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12. Гидаятзаде С.Г. Интеллектуальная измерительно-информационная система обеспечения экологической безопасности питьевой воды // X Межд. Научно-прак. Конф. «Актуальные проблемы современного образования», - Астрахань, Россия: 27-28 сентября 2024, с. 10-14. **(РИНЦ)**
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DOI: 10.31713/mcit.2024.001
14. Гидаятзаде С.Г. Система Мониторинга Экологической Безопасности Питьевой Вод //- Ростов-на-Дону, Россия: Нанотехнологии: Наука и Производство, - 2024 № 6/г. с.68-75. **(РИНЦ)**



The defense will be held on June 30, 2025, at 15:00 at the meeting of the Dissertation Council ED 1.20 of the Supreme Attestation Commission under the President of the Republic of Azerbaijan, operating at the Institute of Control Systems of the Ministry of Science and Education of the Republic of Azerbaijan.

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