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WATER RESOURCES AND ENVIRONMENTAL SAFETY: MODERN PROBLEMS OF RATIONAL WATER USE AND PROTECTION

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Abstract:
Water resources represent one of the most strategically important components of environmental safety, economic stability, and sustainable social development. In regions characterized by arid and semi-arid climatic conditions, the rational use and protection of water acquire particular significance, since water availability directly influences agriculture, industry, public health, biodiversity, and the stability of aquatic ecosystems. This article examines the modern problems associated with the use, management, and ecological protection of water resources in the context of increasing anthropogenic pressure, climate variability, population growth, and the expansion of industrial and agricultural activities. Special attention is given to the relationship between water scarcity, pollution, inefficient consumption, degradation of aquatic ecosystems, and the need to introduce integrated water resource management mechanisms. The study emphasizes that environmental safety in the water sector cannot be ensured only through technical measures; it also requires legal regulation, monitoring systems, ecological education, institutional cooperation, and the use of innovative

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https://eurekaoa.com/index.php/11

technologies for water purification, reuse, and conservation. The article highlights the importance of scientifically grounded approaches to assessing water quality, preventing pollution, optimizing water distribution, and strengthening responsibility for the protection of rivers, reservoirs, groundwater, and other water bodies. The research concludes that sustainable water management should be based on a combination of ecological, economic, technological, and social mechanisms aimed at preserving water resources for current and future generations.

Keywords: Water resources, environmental safety, rational water use, water protection, aquatic ecosystems, water pollution, sustainable management, water quality.

ВОДНЫЕ РЕСУРСЫ И ЭКОЛОГИЧЕСКАЯ БЕЗОПАСНОСТЬ: СОВРЕМЕННЫЕ ПРОБЛЕМЫ РАЦИОНАЛЬНОГО ИСПОЛЬЗОВАНИЯ И ОХРАНЫ ВОДЫ

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Аннотация:
Водные ресурсы являются одним из наиболее стратегически значимых компонентов экологической безопасности, экономической устойчивости и устойчивого общественного развития. В регионах с аридными и полуаридными климатическими условиями рациональное использование и

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

охрана воды приобретают особую актуальность, поскольку обеспеченность водными ресурсами напрямую влияет на сельское хозяйство, промышленность, здоровье населения, биоразнообразие и устойчивость водных экосистем. В данной статье рассматриваются современные проблемы, связанные с использованием, управлением и экологической защитой водных ресурсов в условиях усиления антропогенной нагрузки, климатической изменчивости, роста численности населения, а также расширения промышленной и сельскохозяйственной деятельности. Особое внимание уделяется взаимосвязи между дефицитом воды, загрязнением, неэффективным потреблением, деградацией водных экосистем и необходимостью внедрения механизмов интегрированного управления водными ресурсами. В исследовании подчеркивается, что экологическая безопасность в водной сфере не может быть обеспечена только техническими мерами; она требует также правового регулирования, систем мониторинга, экологического образования, институционального сотрудничества и применения инновационных технологий очистки, повторного использования и сохранения воды. В статье раскрывается значение научно обоснованных подходов к оценке качества воды, предупреждению загрязнения, оптимизации водораспределения и усилению ответственности за охрану рек, водохранилищ, подземных вод и других водных объектов. Сделан вывод о том, что устойчивое управление водными ресурсами должно основываться на сочетании экологических, экономических, технологических и социальных механизмов, направленных на сохранение воды для нынешнего и будущих поколений.

Ключевые слова: водные ресурсы, экологическая безопасность, рациональное водопользование, охрана воды, водные экосистемы, загрязнение воды, устойчивое управление, качество воды.

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https://eurekaoa.com/index.php/11

Introduction

Water resources are a fundamental natural basis of life, economic development, environmental stability, and technological progress. In the modern world, the issue of rational water use has moved beyond the framework of a purely ecological problem and has become one of the central factors of national security, food security, industrial sustainability, public health, and regional cooperation. For countries located in arid and semi-arid zones, including Uzbekistan and other Central Asian states, water is not only a natural resource but also a strategic condition for the functioning of agriculture, energy systems, urban infrastructure, industry, fisheries, and aquatic biodiversity. Therefore, the protection of water resources and the improvement of their management mechanisms are directly connected with the broader concept of environmental safety.

The growing pressure on water systems is caused by several interrelated factors. Population growth increases the demand for drinking water, sanitation, food production, and household consumption. At the same time, agricultural irrigation remains one of the largest consumers of water, especially in regions where crop production depends heavily on artificial irrigation. Industrial development also leads to higher water demand and creates additional risks of chemical, biological, and thermal pollution. Climate change further complicates the situation by changing precipitation regimes, increasing evaporation, intensifying droughts, and reducing the predictability of river flow. These processes make the sustainable management of surface water, groundwater, reservoirs, canals, and collector-drainage systems an urgent scientific and practical task.

Environmental safety in the sphere of water resources requires a comprehensive understanding of both quantity and quality. Water scarcity is dangerous not only because of insufficient volume, but also because limited water reserves become more vulnerable to pollution and ecological degradation. Polluted water reduces the productivity of aquatic ecosystems, worsens sanitary and epidemiological conditions, harms fish resources, affects soil fertility, and increases the cost of

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)
ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

treatment technologies. In this context, rational water use must be interpreted as a system of measures aimed at reducing losses, improving efficiency, preventing pollution, restoring ecosystems, and ensuring equitable access to water for different sectors of the economy.

For technical universities and specialists in the field of water resources, the study of environmental safety is especially important because modern water management depends on engineering solutions, monitoring technologies, hydrological modeling, water treatment systems, digital control, and scientifically based planning. However, technical measures alone are insufficient without ecological assessment, legal responsibility, economic incentives, and public awareness. The main purpose of this article is to analyze the modern problems of rational water use and water protection, to identify key ecological risks, and to justify the need for integrated mechanisms that combine technological innovation, environmental regulation, and sustainable management principles in the water sector.

Methods

The methodological basis of this study is formed by an integrated analytical approach that combines ecological, hydrological, technological, and management-oriented perspectives on water resource protection. Since water resources are connected with natural processes, economic activity, social needs, and technical infrastructure, their rational use cannot be studied through a single narrow method. Therefore, the research applies a complex method of theoretical analysis, comparative assessment, systematization of scientific literature, ecological interpretation of water management problems, and generalization of practical approaches used in the field of environmental safety. This makes it possible to examine water not only as a physical resource, but also as an ecological, economic, and strategic component of sustainable development.

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

The first stage of the research involved the analysis of scientific and methodological literature devoted to water scarcity, water pollution, integrated water resources management, environmental monitoring, and sustainable use of aquatic ecosystems. Special attention was paid to studies that consider the relationship between anthropogenic pressure and deterioration of water quality. The literature review allowed the identification of the most common factors influencing water resources, including excessive irrigation, inefficient water distribution, discharge of untreated wastewater, salinization, accumulation of pollutants, degradation of river ecosystems, and insufficient monitoring of groundwater reserves. This stage helped to establish the theoretical framework for understanding the main risks to environmental safety in the water sector.

The second stage was based on the comparative method. Water resource problems were considered in relation to different sectors such as agriculture, industry, urban infrastructure, fisheries, and public utilities. This comparison made it possible to determine that the causes of irrational water use differ depending on the sector. In agriculture, the main problems are connected with water losses in irrigation networks, outdated technologies, soil salinization, and excessive dependence on traditional irrigation methods. In industry, the most significant risks are related to chemical pollution, insufficient wastewater treatment, and high water consumption in technological processes. In urban areas, the key issues include deterioration of water supply systems, leakage, household wastewater, and the need for stable sanitary control.

The third stage used a systems approach to examine water resources as part of a broader ecological and socio-economic mechanism. This approach made it possible to reveal the interdependence between water availability, ecosystem stability, economic productivity, public health, and environmental regulation. Within this framework, rational water use was analyzed as a combination of preventive, technological, organizational, and educational measures. Preventive measures include pollution reduction and protection of water bodies.

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

Technological measures include water-saving irrigation, wastewater treatment, reuse systems, digital monitoring, and laboratory control of water quality. Organizational measures include planning, institutional cooperation, and legal regulation. Educational measures include raising ecological awareness among specialists, students, water users, and the population.

The final stage consisted of summarizing the obtained analytical results and formulating scientifically grounded conclusions about the mechanisms necessary for improving environmental safety in the water sector. The selected methodology is appropriate for a technical university audience because it connects theoretical ecological principles with practical engineering and management solutions. It also allows the study to emphasize that sustainable water protection requires cooperation between hydrologists, ecologists, engineers, technologists, economists, legal specialists, and decision-makers.

Results

The analysis of modern problems related to water resources and environmental safety shows that the effectiveness of rational water use depends on the coordinated interaction of ecological, technological, institutional, and economic mechanisms. The results indicate that the most serious risks in the water sector are associated with water scarcity, pollution of surface and groundwater, inefficient irrigation practices, degradation of aquatic ecosystems, insufficient wastewater treatment, and weak integration of monitoring data into practical management decisions. These factors do not act separately; they reinforce one another and create complex environmental threats that affect both natural systems and socio-economic development.

One of the main results of the study is the identification of agricultural water use as a key area requiring modernization. In many arid regions, irrigation remains the dominant form of water consumption, while traditional irrigation methods often lead to significant losses through evaporation, filtration, and inefficient

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)
ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

distribution. As a result, water resources are used in larger volumes than necessary, and this increases pressure on rivers, canals, reservoirs, and groundwater reserves. Inefficient irrigation also contributes to soil salinization and the deterioration of land productivity. Therefore, the introduction of water-saving technologies, including drip irrigation, sprinkler systems, automated flow control, and scientifically based irrigation scheduling, can significantly improve the ecological and economic efficiency of water use.

The study also reveals that water pollution remains one of the most dangerous factors threatening environmental safety. Pollution sources include industrial wastewater, agricultural runoff, household sewage, drainage waters, and uncontrolled discharge of chemicals and organic substances. When pollutants enter rivers, lakes, reservoirs, and groundwater systems, they reduce water quality, disturb biological balance, and create risks for human health and aquatic organisms. The deterioration of water quality is especially dangerous in conditions of water scarcity because reduced flow weakens the natural self-purification capacity of water bodies. This means that the protection of water resources must include not only the reduction of water consumption, but also strict control over wastewater treatment and pollutant discharge.

Another important result is the need to strengthen ecological monitoring systems. Sustainable water management requires reliable information about water quantity, water quality, seasonal fluctuations, pollution levels, biological indicators, and the condition of aquatic ecosystems. Without continuous monitoring, management decisions become reactive rather than preventive. Modern monitoring should combine laboratory analysis, field observations, remote sensing, digital databases, geographic information systems, and automated measurement technologies. Such an approach allows specialists to detect environmental risks at an early stage and develop timely measures to prevent ecological damage.

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

The research further demonstrates that environmental safety in the water sector cannot be achieved only through engineering modernization. Although technical solutions are essential, their effectiveness depends on proper institutional coordination, legal regulation, economic incentives, and ecological education. Water users should be encouraged to reduce losses, introduce resource-saving technologies, and comply with environmental standards. At the same time, specialists trained in technical universities should possess not only engineering knowledge, but also ecological thinking, analytical competence, and responsibility for sustainable resource management.

Thus, the results confirm that rational water use is a multidimensional process. It requires the modernization of irrigation and wastewater treatment systems, improvement of monitoring technologies, protection of aquatic ecosystems, optimization of water distribution, and formation of a responsible attitude toward water resources. Only the integration of these mechanisms can ensure long-term environmental safety and stable development of the water sector.

Discussion

The results of the study confirm that the problem of water resources and environmental safety should be considered not as an isolated ecological issue, but as a complex interdisciplinary challenge connected with engineering, economics, public administration, agriculture, industry, education, and social responsibility. Water systems are highly sensitive to both natural and anthropogenic influences. Therefore, any imbalance in water use, pollution control, infrastructure maintenance, or ecological monitoring can lead to long-term consequences. In this regard, rational water use is not limited to saving water; it also includes the preservation of water quality, protection of aquatic ecosystems, prevention of pollution, modernization of technologies, and improvement of institutional mechanisms.

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

One of the most important aspects of the discussion is the relationship between water scarcity and environmental degradation. In arid regions, water deficit increases the vulnerability of rivers, reservoirs, canals, wetlands, and groundwater systems. When the volume of available water decreases, the concentration of pollutants may increase, the self-purification capacity of water bodies weakens, and aquatic organisms experience additional stress. This creates a chain reaction: deterioration of water quality affects biodiversity, fish resources, agricultural productivity, soil condition, and human health. Therefore, environmental safety requires preventive measures that reduce pressure on water systems before irreversible degradation begins.

Agricultural water use remains a central issue because irrigation consumes a significant share of available water resources. Traditional irrigation methods, open canal networks, insufficiently controlled water distribution, and low efficiency of field-level irrigation can cause considerable losses. The modernization of irrigation systems should therefore be viewed as both an economic and ecological necessity. Water-saving technologies, automated regulation, precise hydrological calculations, and digital monitoring can reduce excessive consumption and improve crop productivity at the same time. However, the introduction of these technologies requires investment, qualified specialists, technical maintenance, and adaptation to local natural and economic conditions.

The problem of water pollution also requires a broader interpretation. Industrial wastewater, agricultural runoff, household sewage, and drainage flows represent different types of ecological risk. Each of these sources demands specific control mechanisms, because pollutants may include organic substances, nutrients, heavy metals, oil products, pesticides, salts, and pathogenic microorganisms. Effective protection of water resources should be based on strict wastewater treatment standards, regular laboratory analysis, ecological certification of enterprises, and the use of modern treatment facilities. In addition, the principle of pollution

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)
ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

prevention should be prioritized over the elimination of consequences, because restoring polluted water bodies is usually more expensive and technically more difficult than preventing contamination.

For technical universities, the discussed problem has direct educational and scientific significance. Future specialists in water resources, aquatic bioresources, environmental engineering, hydrotechnics, and water management must be prepared to solve complex problems that require both technical competence and ecological responsibility. The curriculum should strengthen interdisciplinary training by combining hydrology, water chemistry, ecology, engineering design, digital technologies, environmental law, and resource economics. Such preparation will allow graduates to participate effectively in monitoring, planning, designing, operating, and improving water management systems.

Thus, the discussion shows that sustainable protection of water resources requires an integrated model. This model should include engineering modernization, ecological monitoring, legal enforcement, economic motivation, scientific research, and public awareness. Environmental safety in the water sector can be achieved only when water is perceived not merely as a consumable resource, but as a vital ecological system that supports life, production, biodiversity, and future development.

Conclusion

Water resources are one of the most important natural foundations of environmental safety, economic development, social stability, and public health. The analysis carried out in this article shows that the rational use and protection of water cannot be considered only as a technical or administrative task. It is a complex ecological and socio-economic process that requires the integration of scientific knowledge, engineering solutions, legal regulation, institutional cooperation, and responsible behavior of water users. In arid and semi-arid regions, where water scarcity is a permanent factor influencing agriculture,

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)
ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

industry, settlements, and natural ecosystems, the importance of sustainable water management becomes especially high.

The study demonstrates that the main threats to environmental safety in the water sector are connected with excessive water consumption, inefficient irrigation practices, pollution of surface and groundwater, insufficient wastewater treatment, degradation of aquatic ecosystems, soil salinization, and weak monitoring mechanisms. These problems are interrelated and may intensify one another. For example, water scarcity increases the concentration of pollutants, while pollution reduces the amount of water suitable for drinking, irrigation, industrial use, and ecosystem support. Therefore, the protection of water resources must include both quantitative and qualitative measures aimed at preserving water availability and maintaining its ecological condition.

A key conclusion of the article is that rational water use should be based on preventive management. It is more effective to prevent pollution, reduce losses, modernize infrastructure, and improve monitoring than to eliminate the consequences of ecological degradation after they have occurred. Water-saving irrigation technologies, automated control systems, modern wastewater treatment facilities, reuse of treated water, laboratory analysis, digital monitoring, and geographic information systems can significantly increase the efficiency and reliability of water management. However, the success of these measures depends on the professional competence of specialists, the financial capacity of institutions, and the existence of clear environmental standards.

The article also emphasizes the role of education and scientific research. Technical universities should prepare specialists who are able to combine engineering skills with ecological thinking. Future professionals in the field of water resources must understand hydrological processes, water quality indicators, environmental risks, treatment technologies, legal requirements, and economic mechanisms of resource management. Such interdisciplinary training is

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Eureka Journal of Artificial Intelligence and Data Innovation (EJAIDI)

ISSN 2760-5000 (Online) Volume 2, Issue 4, April 2026

https://eurekaoa.com/index.php/11

necessary for developing practical solutions that correspond to modern challenges.

Thus, environmental safety in the field of water resources can be ensured only through an integrated approach. Sustainable water management should unite technology, ecology, law, economics, education, and public responsibility. Water must be treated not merely as a consumable resource, but as a strategic ecological value that determines the quality of life, the stability of ecosystems, and the prospects for future development. Preserving water resources for current and future generations is therefore one of the most urgent tasks of modern environmental policy and technical practice.

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