IRSTI 06.39.27 https://doi.org/10.26577/FJSS2024.v10.i2.6

G. Baikushikova , F. Khamzayeva*

Al-Farabi Kazakh National University, Almaty, Kazakhstan
*e-mail: fatima.kamzaeva@gmail.com

BRIDGING THE GAP IN WATER GOVERNANCE: LESSONS FROM GLOBAL PRACTICES AND THE TRANSITION TO INTEGRATED WATER RESOURCES MANAGEMENT (IWRM)

Received: November 11, 2024
1st Revision: November 24, 2024
Accepted: December 16, 2024

Abstract. This study examines global experiences and best practices in water resources management, emphasizing the transition from traditional control-focused frameworks to Integrated Water Resources Management (IWRM). The analysis underscores the necessity for comprehensive, adaptive strategies in response to climate change, socio-economic shifts, and urbanization. Highlighting the success of collaborative models such as the European Union Water Framework Directive, the research identifies critical differences between the approaches of post-Soviet states and EU nations, particularly in public participation, goal-setting, and implementation strategies. Case studies demonstrate the economic and environmental benefits of innovative methods like wastewater reuse and advanced water purification technologies. The findings advocate for enhanced cooperation among stakeholders, comprehensive policy integration, and the adoption of modern assessment tools to improve water quality and sustainability. This work aims to inform policymakers and practitioners on developing efficient and equitable water governance systems that address current and future challenges.
Keywords*:* *I*ntegrated Water Resources Management (IWRM), sustainable development, adaptive strategies, water framework directive, climate change

Introduction

Water resources management has reached a critical juncture on a global scale, driven by the intersecting forces of rapid urbanization, industrial expansion, and the escalating impacts of climate change. These interconnected challenges place immense pressure on the availability, quality, and sustainability of water resources, making effective governance an urgent priority. Water governance, as the linchpin of sustainable development, requires a multifaceted approach that balances environmental preservation, economic growth, and social equity. The stakes are high: water scarcity threatens livelihoods, food security, and ecosystems, while water mismanagement exacerbates inequality and hinders economic progress. Consequently, there is a growing consensus among policymakers, researchers, and practitioners on the need for innovative strategies that transcend traditional, fragmented methods.

Integrated Water Resources Management (IWRM) has emerged as a comprehensive framework to address these complexities. Rooted in principles of inclusivity, collaboration, and adaptability, IWRM emphasizes the need for cohesive planning that integrates various sectors, such as agriculture, industry, and urban development. This framework aims to harmonize water use across competing demands while ensuring that ecosystems are preserved for future generations. Importantly, IWRM does not operate in isolation; it incorporates the contributions of technology, governance reform, and public participation to create resilient water management systems.

This paper delves into the evolution of water management strategies, focusing on the transition from control-based, centralized approaches to the more adaptive and participatory practices embodied by IWRM. A key highlight is the examination of the European Union's Water Framework Directive, a pioneering initiative that demonstrates the practical application of IWRM principles. This directive represents a milestone in global water governance, showcasing the power of integrated planning, stakeholder engagement, and science-based policymaking. It has not only elevated water quality across EU member states but also set a global benchmark for holistic water management.

Contrasting this with the experiences of post-Soviet nations, the paper explores the barriers that hinder progress toward sustainability in these regions. Often constrained by rigid governance structures and a legacy of control-oriented policies, these countries face significant challenges in aligning with contemporary global standards. Public participation, a cornerstone of effective water governance, remains underdeveloped in many post-Soviet states, further complicating efforts to achieve integrated management. The study highlights the critical need for reforms that promote inclusivity, transparency, and accountability.

Furthermore, this research investigates the transformative potential of advanced technologies in addressing water scarcity and quality challenges. Innovations such as wastewater reuse and advanced purification methods demonstrate substantial economic and environmental benefits. By integrating these technologies into broader water governance frameworks, societies can enhance resource efficiency, reduce environmental degradation, and create sustainable solutions tailored to local contexts.

The convergence of governance, technology, and public engagement lies at the heart of achieving water security in the face of mounting ecological and societal pressures. This paper argues that the path to resilience involves not only the adoption of advanced strategies but also a cultural shift toward recognizing water as a shared, finite resource. By examining case studies and drawing lessons from diverse global practices, this research aims to provide actionable insights for policymakers, practitioners, and stakeholders. Ultimately, it underscores the urgent need for coordinated efforts to secure water resources for present and future generations while navigating the complex interplay of environmental, economic, and social dimensions.

Methodology

The objective of this study is to identify the main challenges in water resources management at the present stage and to provide a brief overview of the best international experience and practice in water resources management, with an emphasis on the transition to integrated water resources management (IWRM). By examining key international frameworks, including the European Union Water Framework Directive, and comparing them with post-Soviet approaches, the study seeks to identify effective strategies for achieving water sustainability and security. Specific objectives include assessing the role of public participation, adaptive management and technological innovation in addressing issues such as climate change, urbanization and water scarcity.

The results of the comparative analysis revealed significant differences in water resource management approaches between the European Union and post-Soviet states. These differences were primarily observed in governance structures, public participation levels, and the overall approach to policy implementation. In the European Union, there is a clear emphasis on results-based planning, which contrasts with the action-oriented commitments more common in post-Soviet countries. This distinction highlights the challenges faced by post-Soviet states in adopting modern, integrated water management frameworks.

The primary sources for the analysis were the European Union Water Framework Directive (WFD) and other relevant EU directives that establish the framework for water governance within member states. Among these directives, the Urban Wastewater Treatment Directive (UWWTD), the Nitrates Directive (ND), and the Drinking Water Directive (DWD) were specifically examined for their focus on water pollution control, nutrient management, and drinking water quality standards. These documents were critical for understanding the regulatory environment and guiding principles that shape water governance within the EU.

Literature Review

Water resources management has undergone significant transformation, evolving from traditional, centralized approaches to adaptive frameworks such as Integrated Water Resources Management (IWRM). This shift reflects the increasing recognition of water's multifaceted role in ecological balance, economic growth, and social equity. The reviewed literature highlights distinct thematic areas within water governance, focusing on geopolitical, economic, technological, and legal dimensions, as well as public participation and collaborative governance.

Several studies explore the geopolitical implications of water management, emphasizing transboundary water cooperation and regional frameworks. For instance, Havekes et al. (2016) outline the foundational principles of effective water governance, such as transparency, accountability, and stakeholder participation, which are critical in addressing transboundary water disputes. Meanwhile, Burghard, Meyer, and Kakabayev (2015) examine water governance in Kazakhstan, highlighting the necessity for regional collaboration and shared water management frameworks to balance agricultural, industrial, and urban demands.

Economic sustainability is a central focus for many researchers. Marques et al. (2024) investigate the integration of water charges policies with watershed plans, demonstrating how financial instruments like water pricing can drive sustainable resource allocation and investment. López-Morales and Rodríguez-Tapia (2019) offer a detailed economic analysis of wastewater reuse in the Mexico Valley Basin, illustrating the potential cost-effectiveness of such strategies in regions facing water scarcity. Similarly, Awad et al. (2019) conduct life-cycle assessments of wastewater treatment technologies, providing insights into cost-efficient solutions for developing countries.

Technological advancements play a pivotal role in addressing water quality and scarcity challenges. Barakat (2011) highlights the potential of adsorption methods for industrial wastewater treatment, showcasing their cost-effectiveness and environmental benefits. Diaz-Elsayed et al. (2019) explore wastewater-based resource recovery technologies, emphasizing their contributions to circular economy goals by recovering energy, nutrients, and water. The application of such technologies is further supported by studies like Macchiaroli et al. (2019), which propose innovative models for selecting urban water infrastructures that balance technical and sustainability criteria.

The importance of collaboration and public participation in water governance is a recurring theme. Margerum and Robinson (2015) discuss the complexities of building collaborative partnerships, identifying trust and dialogue as critical components for overcoming institutional and power barriers. Bekov (2024) examines Kazakhstan's Water Code, underscoring the legal foundations required to support inclusive and participatory water governance. These studies collectively stress the necessity of stakeholder engagement to achieve equitable and sustainable outcomes.

The European Union's Water Framework Directive (WFD) serves as a benchmark for integrated water governance, focusing on achieving ecological and chemical goals through measurable outcomes and stakeholder engagement. Studies emphasize the directive's reliance on modeling tools and risk-based strategies to address water quality challenges. In contrast, post-Soviet governance systems face significant barriers, including fragmented institutional responsibilities and outdated methodologies. Research calls for a transition from pollution indices to integrated ecological indicators to better capture complex ecosystem dynamics.

Despite advancements, persistent challenges include financial constraints, outdated infrastructure, and insufficient cross-sectoral collaboration. The literature highlights the importance of aligning water management strategies with sustainable development goals. This involves integrating flood and drought management programs, leveraging advanced technologies, and fostering societal awareness to address systemic inefficiencies. Case studies from Italy, Egypt, and other regions demonstrate the feasibility of innovative solutions, underscoring the need for adaptive, context-specific approaches to water governance.

From Control to Cooperation: Advancing Sustainable Water Management through Integrated Approaches

The transition from control to cooperation in water management underscores the necessity of dynamically evolving frameworks that integrate both regulatory mechanisms and collaborative strategies. This paradigm shift emphasizes collective welfare and sustainable water security, acknowledging the complex interplay between urbanization, industrial development, and the sustainability of water resources. Rapid urban growth and industrial expansion have intensified both water consumption and wastewater production. However, these challenges, if addressed effectively, can align with broader sustainable development objectives. Industrial water treatment, for instance, has demonstrated considerable potential, both economically and ecologically. Through advanced methods such as adsorption techniques, water quality can be restored with minimal costs, showcasing a promising pathway for resource recycling and environmental conservation (Barakat, 2011).

Despite these advancements, several barriers impede the implementation of advanced water treatment technologies. Financial constraints, inadequate infrastructure, and policy limitations often deter policymakers from embracing comprehensive wastewater management systems. There is a pervasive perception that such systems are prohibitively expensive, yet case studies, including those conducted in

Hamas, Egypt, reveal that investments in full-cycle wastewater treatment yield substantial environmental and economic returns (Awad et al., 2019). Furthermore, selective recovery approaches, which tailor quality standards to specific reuse purposes, present significant economic and environmental benefits. However, these methodologies demand careful selection of technologies and effective pollutant management strategies to optimize their impact.

The intricate relationship between economic factors and environmental sustainability highlights the critical role of integrated frameworks in water resource management. Research underscores the connection between GDP and water stress as determinants of wastewater treatment efficiency and resource reuse. For example, strategic aquifer utilization in the Mexico City Basin has been shown to reduce regional water consumption by 13%, alleviating the burden on purification systems and fostering more effective resource management (López-Morales & Rodríguez-Tapia, 2019). Such integrated approaches must also incorporate societal participation, which is essential for fostering innovation, protecting ecosystems, and engaging the public in sustainable water management practices.

A comparative analysis reveals a stark contrast between modern water management strategies and those employed during the Soviet era. Earlier methodologies relied predominantly on basic pollution indices, which inadequately addressed the complexity of aquatic ecosystems. These simplistic numerical indicators often failed to capture the intricate interdependencies within ecosystems, resulting in a limited understanding of water quality. Visual indicators, such as water color, provided superficial assessments, further emphasizing the need for more sophisticated evaluation metrics. To address contemporary challenges, transitioning to comprehensive indices that incorporate both quantitative and qualitative factors is crucial. By integrating ecosystem dynamics into water quality assessments, modern frameworks can effectively respond to the multifaceted challenges of water management, ensuring sustainability and resilience in the face of evolving global demands (Danilov-Danilyan et al., 2019).

The European Union Water Framework Directive

The European Union Water Framework Directive (WFD) exemplifies a modern, integrated approach to water governance. Adopted in 2000, the directive establishes comprehensive methodologies for assessing and improving water quality across diverse resources, including surface, coastal, and groundwater systems. Its primary objective is achieving «good ecological and chemical status» for all water bodies, with stringent deadlines for implementing necessary measures (European Parliament and Council, 2000).

A distinctive feature of the WFD is its shift from traditional chemical monitoring to biological assessments, prioritizing ecosystem health as an indicator of water quality. Biological assessment methodologies analyze species diversity, ecosystem functionality, and habitat conditions to provide a holistic understanding of water systems. For instance, the return of salmon to the Rhine River has been a symbolic measure of ecological restoration, reflecting broader improvements in water quality.

The European Union (EU) has developed a comprehensive framework for managing and protecting water resources through a series of directives that emphasize sustainability, integration, and adaptive governance. Central to this framework is the **Water Framework Directive (WFD) 2000/60/EC**, which establishes the overarching principles for water policy across member states. Complementary directives, such as the **Urban Wastewater Treatment Directive (UWWTD) 91/271/EEC**, the **Nitrates Directive 91/676/EEC**, and the **Drinking Water Directive (DWD) 98/83/EC**, provide specific guidelines addressing pollution control, nutrient management, and water quality standards.

Adopted on October 23, 2000, **the Water Framework Directive (WFD)** represents a paradigm shift in water management by promoting an integrated and basin-wide approach. Its primary objective is to ensure all EU water bodies–surface, coastal, and groundwater–achieve "good ecological and chemical status" by specified deadlines. The Water Framework Directive (WFD) adopts a multifaceted approach to water resource management, emphasizing three core principles: risk-based management, ecological focus, and stakeholder participation. These principles collectively aim to ensure the sustainable and adaptive governance of water systems across the European Union.

A central tenet of the WFD is the reliance on risk-based management, which involves the systematic identification, assessment, and mitigation of potential threats to water quality and ecosystem health. The directive advocates for the application of **environmental modeling** and **predictive tools** as critical instruments in this process. By simulating various management scenarios, these tools enable the evaluation of intervention outcomes, helping decision-makers to identify strategies with the most favorable ecological, economic, and societal impacts. This proactive and evidence-based approach minimizes uncertainties and enhances the effectiveness of resource allocation.

The WFD moves beyond traditional metrics of water quality, prioritizing **biological indicators** as integral measures of ecological health. Indicators such as species diversity, population dynamics, and the presence or absence of specific taxa provide a more comprehensive understanding of ecosystem conditions compared to chemical metrics alone. For instance, the return of salmon populations to the Rhine River has served as a biological marker of improved water quality and habitat restoration. This ecological focus reflects the directive's commitment to preserving and restoring the structural and functional integrity of aquatic ecosystems, ensuring they provide essential services sustainably.

Recognizing the complexity and interconnectedness of water governance, the WFD emphasizes collaboration among diverse stakeholders (Curşeu, P. L., & Schruijer, S. G. 2017), including public authorities, industry representatives, environmental organizations, and the broader civil society. This participatory approach fosters inclusivity and transparency, ensuring that water management decisions align with societal priorities while addressing local and regional challenges. Moreover, engaging multiple stakeholders enhances the legitimacy of policy decisions and promotes shared responsibility in their implementation.

By integrating these principles, the Water Framework Directive establishes a robust and adaptive framework for achieving sustainable water management outcomes, setting a precedent for other regions aiming to balance ecological, economic, and social objectives. Key milestones for WFD implementation include the identification of competent basin management authorities (2003), characterization of water bodies (2004), and harmonization of national legislation with WFD principles (2005). A critical innovation in the WFD is the classification of water bodies into five ecological states: high, good, moderate, poor, and bad. These classifications rely on integrated assessments of biological, chemical, and hydromorphological parameters. For example, the recovery of salmon populations in the Rhine serves as a biological indicator of improved water quality.

Urban Wastewater Treatment Directive (UWWTD) 91/271/EEC directive focuses on the treatment of urban wastewater to reduce pollution from industrial and domestic sources. Its implementation has led to the widespread adoption of secondary and tertiary treatment technologies, significantly reducing nutrient loads in water bodies. Nitrates Directive The Urban Wastewater Treatment Directive (UWWTD) 91/271/EEC, adopted in 1991, represents a cornerstone of the European Union's efforts to mitigate water pollution originating from urban and industrial wastewater discharges. Its overarching goal is to protect aquatic environments from the detrimental effects of untreated or inadequately treated wastewater by ensuring the adoption of robust treatment standards across member states.

The directive mandates the collection, treatment, and discharge of urban wastewater for agglomerations exceeding specific population thresholds, as well as wastewater generated by certain industrial sectors. A critical focus is placed on areas designated as sensitive zones–regions particularly vulnerable to eutrophication or other ecological damage caused by excess nutrients, such as nitrogen and phosphorus.

The implementation of the Urban Wastewater Treatment Directive (UWWTD) 91/271/EEC has been pivotal in promoting the adoption of advanced wastewater treatment technologies, thereby mitigating pollution from urban and industrial sources.

Secondary treatment, a cornerstone of the directive, employs biological processes to effectively remove organic matter and significantly reduce biochemical oxygen demand (BOD), which is critical for maintaining oxygen levels in aquatic ecosystems. Building on this, tertiary treatment–an advanced stage of wastewater treatment–addresses the removal of nutrients, particularly nitrogen and phosphorus, which are key contributors to eutrophication. These processes have proven indispensable in improving water quality, especially in sensitive zones that are vulnerable to nutrient pollution.

The implementation of these technologies has led to a substantial reduction in nutrient loads discharged into rivers, lakes, and coastal waters, creating a cascading positive effect on the health and resilience of aquatic ecosystems. By controlling nutrient inputs, the directive has not only curbed the proliferation of algal blooms but also supported the recovery of biodiversity, including the return of sensitive species to habitats once deemed inhospitable.

The Nitrates Directive 91/676/EEC represents a pivotal legislative response to the growing issue of water pollution caused by agricultural activities. It aims to safeguard the quality of water resources by addressing nitrate contamination, which poses significant risks to both human health and ecological systems. As a cornerstone of EU environmental policy, the directive establishes a framework for promoting sustainable agricultural practices while protecting surface and groundwater from excessive nutrient runoff.

One of the most important aspects of the directive is the establishment of Nitrate Vulnerable Zones (NVZs), which are areas where agricultural activities significantly threaten water quality due to high levels of nitrate runoff. Within these zones, the directive imposes strict regulations to control the application of nitrogen fertilizers and manage animal manure more effectively. By establishing these zones, the directive aims to reduce the pollution load on water bodies and protect ecosystems from nutrient overloads (Łopata, M., Grochowska, J. K., Augustyniak-Tunowska, R., & Tandyrak, R. 2023), which can lead to harmful algal blooms and the depletion of oxygen levels in water.

The directive's approach is multifaceted. It mandates that farmers reduce the amount of nitrogen-based fertilizers applied to their fields, particularly during times when crops are not able to absorb the nutrients efficiently. This is achieved by setting limits on fertilizer use and encouraging more precise and targeted application methods. Additionally, the directive emphasizes the importance of sustainable manure management. Farmers are required to carefully control the storage and spreading of animal manure, ensuring that it is done in a way that minimizes the risk of nitrates leaching into the soil and, subsequently, into groundwater systems. Proper manure management practices are essential to reducing nitrate pollution, as improperly stored or applied manure can contribute significantly to nitrate contamination.

Moreover, the directive encourages crop and soil management practices aimed at reducing nutrient runoff. These practices include crop rotation and the use of cover crops, which help retain nutrients in the soil and prevent erosion. Such agricultural techniques enhance soil fertility while simultaneously reducing the amount of nitrogen that leaches into water sources. By promoting these methods, the directive helps farmers maintain productive and sustainable agricultural systems without compromising water quality.

Since its implementation, the Nitrates Directive has led to notable improvements in water quality across the EU, particularly in regions where agriculture is intensive. It has helped mitigate the effects of nutrient pollution by reducing nitrate concentrations in both groundwater and surface water bodies. In doing so, it has contributed to improving the health of aquatic ecosystems and ensuring the safety of drinking water supplies. However, the directive is not without its challenges. The issue of diffuse pollution from agricultural runoff remains complex, as it is difficult to pinpoint and control at the individual level. Effective implementation requires continuous monitoring, enforcement of regulations, and adaptation to regional environmental conditions.

In conclusion, the Nitrates Directive 91/676/EEC has played a crucial role in addressing nitrate pollution across Europe, fostering more sustainable agricultural practices while protecting water resources. While progress has been made, there is still much work to be done, particularly in ensuring consistent enforcement and addressing emerging environmental pressures such as climate change. The directive remains an essential tool in the EU's efforts to balance agricultural productivity with environmental sustainability, and its success depends on the ongoing collaboration between governments, farmers, and environmental stakeholders.

The Drinking Water Directive (DWD), formally known **as Directive 98/83/EC,** was established by the European Union to ensure that water supplied for human consumption meets the highest standards of safety and quality. Adopted in 1998, this directive set out to safeguard public health by regulating the quality of water intended for drinking, recognizing water as one of the most vital and fundamental resources. The primary goal of the DWD is to ensure access to safe drinking water across the EU, protecting consumers from waterborne diseases and harmful contaminants.

A central component of the DWD is the establishment of stringent water quality standards, which specify the maximum allowable concentrations of various pollutants in drinking water. These standards cover a broad range of contaminants, including microbiological substances, chemicals, and radioactive elements, ensuring that water quality remains within safe limits. The directive sets specific limits for substances such as lead, nitrates, pesticides, and coliform bacteria, all of which pose potential health risks if present in excessive concentrations. These standards are designed to protect vulnerable populations, including children and the elderly, who are at greater risk of adverse health effects from contaminated water.

The monitoring and testing requirements outlined in the DWD are another key aspect of the directive. Water suppliers are mandated to conduct regular testing of drinking water to ensure that it consistently meets the established quality standards. This includes routine testing for microbiological contaminants, such as E. coli, as well as chemical pollutants. Water suppliers are also required to keep detailed records of these tests, and the results must be made publicly available to consumers, ensuring transparency and fostering trust in the safety of drinking water. In this regard, the DWD emphasizes the importance of public access to information, which is crucial for raising awareness and empowering individuals to make informed decisions about their water supply.

The directive also highlights the role of infrastructure and maintenance in ensuring the delivery of safe drinking water. It mandates that water supply systems, including pipes, storage tanks, and treatment facilities, are properly maintained and operated to prevent contamination. Regular inspection and maintenance of these systems are necessary to prevent any disruptions in water quality, which can occur due to aging infrastructure or unforeseen events such as natural disasters. In some cases, water suppliers may be required to implement corrective measures, such as upgrading old infrastructure, to meet the directive's standards.

One of the significant developments in the DWD is the emphasis on risk management. The directive encourages a preventative approach to managing water safety by promoting the Water Safety Plan (WSP) methodology. This methodology involves identifying potential hazards in the water supply system, assessing the risks associated with these hazards, and implementing appropriate measures to prevent or mitigate those risks. By adopting a proactive approach, the DWD aims to reduce the likelihood of contamination and ensure the continued safety of drinking water sources.

Furthermore, the revision of the Drinking Water Directive in 2020 (Directive (EU) 2020/2184) introduced a series of important updates, aiming to strengthen the protection of public health and improve water quality across Europe. This revision includes new provisions related to the reduction of lead concentrations in drinking water, the monitoring of new and emerging contaminants, and the improvement of accessibility to drinking water in public places. The revised directive also highlights the need for better protection of water resources from pollution and emphasizes the role of sustainable water management practices.

While the DWD has been successful in improving the quality of drinking water across the EU (Heidari, B., Randle, S., Minchillo, D., & Jaber, F. H. 2023) challenges persist, particularly in the context of aging infrastructure, climate change, and emerging contaminants. Issues such as the increasing presence of microplastics, pharmaceuticals, and other trace chemicals in water sources require ongoing monitoring and innovation in treatment technologies. Additionally, the potential impacts of climate change, including droughts and flooding, may affect the availability and quality of water resources, posing new challenges for drinking water safety.

In conclusion, the Drinking Water Directive (98/83/EC) plays a pivotal role in ensuring the safety and quality of drinking water in the European Union. By setting clear standards for water quality, promoting transparency in monitoring, and encouraging proactive risk management, the directive has significantly contributed to public health protection across the EU. However, as new challenges arise, the directive must continue to evolve, incorporating the latest scientific knowledge and technological advancements to address emerging threats and ensure the long-term sustainability of water resources.

While the European Union's water directives – notably the Water Framework Directive (WFD) 2000/60/EC, the Urban Wastewater Treatment Directive (UWWTD) 91/271/EEC, the Nitrates Directive (ND) 91/676/EEC, and the Drinking Water Directive (DWD) 98/83/EC – collectively represent a comprehensive and progressive approach to water governance. These directives are not only designed to manage water resources efficiently but also reflect a significant shift from traditional, fragmented management systems to more integrated, sustainable practices based on ecological integrity, public health, and collaboration between various stakeholders.

The Water Framework Directive (WFD), as the cornerstone of EU water policy, lays down a robust foundation for managing water across member states. By focusing on achieving good ecological and chemical status for all water bodies, it provides a framework that prioritizes ecological health while incorporating social, economic, and environmental factors. This holistic approach is particularly relevant in the context of Integrated Water Resources Management (IWRM), a concept that promotes the sustainable management of water resources through coordinated action across sectors, scales, and stakeholders. The UWWTD, ND, and DWD complement the WFD by addressing specific issues related to wastewater treatment, nutrient pollution, and drinking water safety. Each of these directives introduces regulations that contribute to reducing environmental pressures on water systems, such as nutrient overloading, pollution from wastewater, and harmful chemicals in drinking water.

The transition from traditional control-based management to integrated, goal-oriented strategies within the EU's water directives provides a compelling model for water governance that can inform practices in other regions, including post-Soviet countries. While there are differences in water governance approaches due to historical, cultural, and political contexts, the EU directives highlight the importance of developing adaptive, science-based frameworks that align with both ecological imperatives and societal needs. For post-Soviet states, learning from the EU's success in setting clear standards, fostering collaboration, and emphasizing transparency in water quality monitoring could help overcome the challenges of fragmented water management and unsustainable practices.

The effectiveness of these EU water directives underscores the importance of policy harmonization, where governance frameworks align with environmental sustainability goals, and the need for stakeholder collaboration. The implementation of these directives, backed by sound scientific research and consistent monitoring, has proven to be essential in mitigating pollution, improving water quality, and preserving aquatic ecosystems. These lessons offer valuable insights into the importance of creating policies that can adapt to emerging challenges while ensuring that water resources are managed in a way that benefits both current and future generations.

In summary, the EU's water governance model, shaped by these directives, serves as a powerful example of how integrated water management frameworks can lead to improved environmental outcomes. By harmonizing policy frameworks with ecological and societal needs, these directives contribute to long-term environmental sustainability and offer a pathway for achieving IWRM goals globally. Their successful implementation offers valuable lessons that can guide other regions, including post-Soviet states, in their transition towards more sustainable, adaptive, and inclusive water management practices.

Addressing Challenges in Post-Soviet States

Post-Soviet states face a multitude of challenges when attempting to adapt their water governance systems to global standards of sustainable management. These countries, while navigating the legacies of centralized, top-down governance, struggle with both institutional inertia and a lack of adaptive frameworks. The historical focus on control-oriented policies in these nations has led to rigid, inflexible water management structures that are ill-suited for addressing contemporary environmental challenges such as climate change, pollution, and resource scarcity. In contrast to the European Union's results-based planning framework, which emphasizes measurable objectives and long-term environmental sustainability, many post-Soviet countries continue to follow action-based commitments. This means that rather than focusing on specific, attainable goals, they concentrate on a series of activities that may lack strategic coherence or the capacity to achieve meaningful outcomes.

One of the most critical challenges for post-Soviet states is the absence of clear, measurable objectives in their water management frameworks. Without well-defined, quantifiable targets, water management initiatives often suffer from poor allocation of resources, making it difficult to evaluate success or failure. In many cases, policies are designed without an understanding of their long-term environmental or social impact, contributing to a cycle of ineffective governance. The lack of measurable goals also complicates efforts to integrate adaptive management strategies, where policies and actions are adjusted based on ongoing feedback and emerging challenges.

The rigid governance structures inherited from the Soviet era exacerbate the issue, as water management remains highly centralized, with decision-making power concentrated in the hands of a few national actors. This centralization often leads to a disconnection from local realities, where water issues are best understood and addressed. Local communities (Yasuda, Y., & ., Demydenko, Y., 2024), who are often the most impacted by water quality and availability, are frequently excluded from the decision-making process. The lack of stakeholder engagement prevents water management policies from being more inclusive, transparent, and tailored to the diverse needs of affected populations. This results in policies that may be ineffective or irrelevant at the local level, thereby reducing their long-term sustainability.

To address these significant governance gaps, Integrated Water Resources Management (IWRM) offers a compelling alternative. The IWRM approach emphasizes the need for a holistic, cross-sectoral perspective on water resources that balances social, economic, and environmental objectives. One of the key features of IWRM is its ability to incorporate risk assessments into water management planning, enabling countries to anticipate and mitigate potential risks associated with water scarcity, pollution, and climate variability. This approach fosters more adaptive management–a process of continuous learning and adjustment in the face of uncertainty and changing conditions.

In countries such as Belarus, Azerbaijan, and Kazakhstan, substantial progress has been made in integrating IWRM principles into national water governance frameworks. Legislative reforms in these countries have paved the way for more collaborative and decentralized water management practices. However, these transitions remain a work in progress, and considerable efforts are required to bridge the gaps between policy, practice, and community involvement. For example, Kazakhstan's Government (2019) has worked to implement river basin management, a central component of IWRM, but challenges remain in fully realizing the potential of this approach due to institutional fragmentation and insufficient local capacity.

The shift toward IWRM in post-Soviet states also necessitates technological innovations that can bolster water quality monitoring, resource management, and decision-making. Tools such as real-time water quality monitoring systems, geographic information systems (GIS), and environmental modeling are crucial in supporting data-driven decisions. These technologies can help track pollutants, forecast water availability, and assess the effectiveness of water treatment practices. By incorporating such technologies into national and local water governance, post-Soviet states can make more informed decisions that support both sustainability and resilience.

Additionally, data transparency and open access to information are essential for fostering trust and participation among stakeholders. Providing access to water data can empower local communities, businesses, and civil society organizations to participate in water management decisions and advocate for their interests. This openness can also stimulate innovation, as different actors–ranging from governments to private entities–can contribute to solutions that might otherwise have been overlooked in a more closed, centralized system.

Post-Soviet countries have much to gain from aligning their water governance systems with global best practices, particularly those established within the European Union's water directives, such as the Water Framework Directive (WFD). While the EU's directives focus on achieving a good ecological and chemical status for water bodies, they also emphasize the need for a strong legal and institutional framework, stakeholder engagement, and effective implementation strategies. By drawing on the experience of EU member states, post-Soviet countries can harmonize their policies, learn from successes and failures, and ultimately create more sustainable and effective governance systems. However, this alignment will require overcoming political, cultural, and institutional barriers that may resist reform.

Effective water governance in post-Soviet (Altingoz, M. S. 2022) countries will require multi-level governance structures that facilitate coordination between national, regional, and local authorities. The decentralized, participatory approach inherent in Integrated Water Resources Management (IWRM) necessitates strong coordination and communication across all levels of government. For instance, national ministries may be responsible for setting legal frameworks and broad policy goals, but local authorities and regional agencies must take the lead in implementing these policies and addressing localized water challenges. Coordination between levels of government is also essential for monitoring water quality, managing water allocations, and ensuring that national strategies are appropriately tailored to regional and local needs.

At the same time, effective policy coordination must extend beyond national borders. In regions such as Central Asia, shared water resources cross multiple countries, requiring cross-border cooperation for effective governance. Collaborative transboundary water management agreements–such as those seen in the Aral Sea Basin–are necessary to prevent resource conflicts and ensure the equitable distribution of water resources.

Results

Effective water resources management is increasingly recognized as a cornerstone of sustainable development, requiring the integration of environmental, economic, and social dimensions. By examining global practices, this study highlights the transition toward integrated approaches such as IWRM, alongside the technological and policy innovations driving progress. The findings provide insights into both successful frameworks and persistent challenges, offering valuable lessons for advancing sustainable water governance.

Integrated Water Resources Management (IWRM) represents a sophisticated and dynamic paradigm aimed at harmonizing environmental preservation, economic progress, and societal well-being within an integrative framework. This model comprehensively addresses the intricate interdependencies of water systems, emphasizing their indispensable role in sustaining ecological functions, fostering economic productivity, and supporting human livelihoods. The European Union's Water Framework Directive (WFD) exemplifies the operationalization of IWRM principles, serving as a benchmark for comprehensive water management. By mandating sustainable water use practices, promoting multi-level collaborative governance, and establishing stringent water quality standards, the WFD highlights the centrality of balancing ecological integrity with socio-economic imperatives. Additionally, it prioritizes ecosystem restoration and underscores the ethical imperative of intergenerational equity, ensuring that finite water resources are managed responsibly to benefit both current and future populations. The directive's robust framework for stakeholder engagement underscores the significance of participatory governance as a means to address the multifaceted and intersectoral challenges inherent in water resource management, thereby fostering transparency, inclusivity, and adaptive capacity.

Technological innovations significantly enhance the efficacy of IWRM by addressing critical issues related to water treatment and resource optimization. Advanced techniques such as adsorption, selective reuse, and desalination exemplify the potential to tackle complex water quality challenges while reducing environmental impacts. Italy and Egypt, for instance, have demonstrated how integrating these technologies into national water policies can yield substantial benefits. By mitigating pollution levels and enhancing water reuse capacities, these advancements not only contribute to ecological balance but also generate economic advantages. The adoption of circular water management models–centered on reducing waste, recycling water, and recovering valuable byproducts–offers industries a path toward cost efficiency while minimizing their environmental footprint. These models also align with global sustainability objectives, showcasing how innovation can drive progress in water management practices.

Despite these advancements, the implementation of IWRM in post-Soviet states is often hindered by systemic barriers, including centralized control structures, antiquated assessment methodologies, and insufficient public engagement. Centralized governance models in these regions frequently limit the adaptability and inclusiveness essential for effective water management. Traditional reliance on simplistic pollution indices further exacerbates challenges by failing to capture the intricate dynamics of aquatic ecosystems. Moreover, these countries face additional hurdles such as outdated infrastructure and a pressing need for modernization, which often necessitate substantial financial investment. Addressing these issues is critical, yet the scale of the required resources may surpass domestic capacities, highlighting the potential role of external donors in providing financial and technical assistance. Reforming institutional frameworks, updating assessment tools, and fostering international collaboration are imperative steps toward aligning post-Soviet practices with global standards, enabling these nations to strengthen their capacity for sustainable resource management.

The integration of economic and environmental considerations amplifies the transformative potential of IWRM. Efficient resource management practices and innovative water-saving strategies demonstrate the capacity to mitigate scarcity while supporting urban resilience. For instance, through investments in infrastructure, policy reform, and public awareness campaigns, nations have significantly reduced water consumption and improved overall resource efficiency. Such examples underscore the symbiotic relationship between sustainable water management and economic prosperity. Nations prioritizing the sustainable use of water resources often experience enhanced economic growth, increased water security, and greater resilience to the impacts of climate change.

Public engagement emerges as a cornerstone of effective IWRM governance. The European Union's participatory frameworks illustrate how transparent and adaptive decision-making processes can foster trust, accountability, and innovation. By involving citizens, industry representatives, and environmental organizations, the EU ensures that water management strategies reflect the diverse interests and needs of its stakeholders. In contrast, post-Soviet nations must address the deficit of public involvement to unlock the full potential of sustainable water management. Expanding participatory mechanisms can bridge the gap between policy and practice, fostering a sense of ownership and collective responsibility among stakeholders. This inclusive approach is essential for driving long-term ecological and economic stability, as it empowers communities to actively contribute to the preservation and enhancement of water resources.

To conclude, Integrated Water Resources Management (IWRM) offers not merely a methodology but a paradigm shift in how societies approach the critical task of water governance. Its emphasis on integration reflects the interconnected nature of water systems, where ecological, social, and economic dimensions are inseparably linked. IWRM's transformative potential lies in its ability to provide adaptive and context-specific solutions that address the complexity of contemporary water challenges. By fostering synergy among technological advancements, institutional reform, and stakeholder collaboration, IWRM establishes a foundation for sustainable water use that is both resilient and forward-looking.

The global discourse around water governance underscores the growing recognition of water as a finite yet indispensable resource, whose equitable management is central to achieving broader development goals. While regions such as the European Union have pioneered effective implementation models, their experiences underscore the necessity of strong governance, inclusive participation, and sustained investment. For post-Soviet states and other regions grappling with systemic and infrastructural deficiencies, the pathway forward entails more than replicating existing frameworks–it requires tailoring IWRM principles to local contexts while addressing entrenched institutional barriers and capacity gaps.

Beyond technical and policy solutions, the success of IWRM hinges on cultivating a societal ethos that values water stewardship as a shared responsibility. Public education, cross-sectoral dialogue, and global cooperation are indispensable for fostering a collective commitment to water sustainability. In this regard, the role of international donors and organizations extends beyond financial assistance; it includes facilitating knowledge transfer, capacity-building, and fostering partnerships that can accelerate progress.

As the pressures of climate change, urbanization, and population growth intensify, IWRM's principles offer a roadmap not only for navigating immediate challenges but also for building adaptive capacities that ensure long-term water security. The integration of cutting-edge technologies, coupled with policies that prioritize both equity and efficiency, will be essential for transforming water governance into a cornerstone of sustainable development. Ultimately, the promise of IWRM lies in its ability to balance competing demands while safeguarding the ecological integrity and economic vitality that underpin human well-being.

Discussion

The findings confirm the critical role of integrated and adaptive approaches in addressing global water challenges. The EU Water Framework Directives serve as a model for effective water governance, emphasizing measurable outcomes, biological assessment, and stakeholder collaboration. By setting clear goals and leveraging modeling tools, this framework ensures transparency, accountability, and ecological sustainability.

In contrast, post-Soviet states face systemic barriers to adopting integrated practices. Limited public engagement, fragmented responsibilities, and outdated methodologies underscore the need for policy reform. Transitioning from control-based to results-driven management requires not only legislative changes but also cultural shifts toward inclusivity and cooperation.

Technological advancements present promising solutions to water quality and resource efficiency challenges. Adsorption methods for industrial wastewater and selective reuse strategies align with the principles of IWRM, offering scalable and sustainable alternatives. However, financial and infrastructure barriers must be addressed to facilitate broader implementation, particularly in developing and transitional economies.

The analysis also highlights the interconnectedness of economic development and water resource sustainability. Investments in comprehensive management systems and advanced technologies yield measurable improvements in water quality, ecosystem health, and economic resilience. For example, integrated wastewater recovery strategies in Southern Italy provided greater ecological benefits than traditional discharge methods, showcasing the value of forward-thinking solutions.

Lastly, the study underscores the importance of public engagement in achieving water management goals. Societal awareness, coupled with participatory decision-making processes, fosters accountability and enhances the legitimacy of water governance frameworks. Encouraging cross-sector collaboration among policymakers, industries, and communities is essential for transitioning to inclusive and adaptive water management systems.

Conclusion

In conclusion, this study emphasizes the critical importance of transitioning to Integrated Water Resources Management (IWRM) as a transformative and adaptive framework to tackle the complex challenges of modern water governance. As the world faces accelerating pressures from climate change, urbanization, and socio-economic shifts, the need for comprehensive, inclusive, and flexible water management strategies has never been more pressing. By integrating technological innovations, fostering inclusive governance, and balancing environmental, economic, and social priorities, IWRM offers a holistic approach to sustainable water governance, ensuring the resilience of water systems in the face of global uncertainties.

The European Union's Water Framework Directivs serve as a prime examples of a successful IWRM implementation, showcasing the potential of integrated planning, collaborative governance, and science-based policy development. The WFD's emphasis on adaptive management, stakeholder engagement, and the preservation of water quality highlights its effectiveness in navigating the complexities of water governance, offering a global benchmark for other regions to emulate. These lessons underline the importance of adaptive strategies, transparent decision-making, and accountability, which are pivotal to successful water management.

In contrast, post-Soviet states face substantial challenges in adopting such integrated frameworks. Fragmented institutional structures, outdated water management practices, and limited public participation pose significant barriers to progress. Additionally, these countries struggle with the aging and deteriorating state of their water infrastructure, which further exacerbates the difficulty of transitioning to modern, sustainable water systems. Addressing these barriers requires not only significant financial investments but also targeted institutional reforms that promote transparency, inclusivity, and cooperation among stakeholders.

Furthermore, the adoption of advanced technologies–such as wastewater reuse, desalination, and circular water models–offers promising solutions to enhance resource efficiency and address water quality issues in post-Soviet nations. However, financial constraints necessitate external support from international donors and cross-sector partnerships to facilitate the necessary technological and infrastructural upgrades. By aligning national policies with global best practices and promoting collaboration across sectors, these regions can overcome systemic barriers and unlock the transformative potential of IWRM.

Ultimately, this research underscores the interdependent relationship between ecological integrity, economic resilience, and social equity in water governance. The sustainable management of water resources is critical not only for addressing current needs but also for securing the well-being of future generations in the face of growing global challenges. By embracing adaptive, inclusive, and forward-thinking approaches, policymakers and practitioners can build resilient water management systems that foster economic prosperity, safeguard environmental resources, and ensure equitable access to water for all. In doing so, they will pave the way for long-term sustainability, improving both local and global water security in an increasingly interconnected world.

References

European Parliament & Council of the European Union. (2000). Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for community action in the field of water policy. Official Journal of the European Communities, L 327, 1-73.

European Parliament & Council of the European Union. (1991). Directive 91/271/EEC of the European Parliament and of the Council concerning urban wastewater treatment. Official Journal of the European Communities, L 135, 40-52.

European Parliament & Council of the European Union. (1991). Directive 91/676/EEC of the European Parliament and of the Council concerning the protection of waters against pollution caused by nitrates from agricultural sources. Official Journal of the European Communities, L 375, 1-8.

European Parliament & Council of the European Union. (1998). Directive 98/83/EC of the European Parliament and of the Council on the quality of water intended for human consumption. Official Journal of the European Communities, L 330, 32-54.

Yasuda, Y., Demydenko, Y., Faloutsos, D., & Tremblay-Lévesque, L. C. (2024). Multistakeholder regional dialogues as catalysers for transboundary water cooperation. *Water International*, *49*(3-4), 540-552.

Havekes, H., et al. (2016). *Building blocks for good water governance*. Water Governance Centre (WGC).

Marques, G. F., et al. (2024). "Integrating water charges policies and watershed plans for improved investment and financial sustainability in water resources management." *Water International*, 49(3–4), 392–409.

Burghard, S. M., Meyer, L., & Kakabayev, A. (2015). *Integrated water resources management in Kazakhstan*. Kokchetau: Mir Pechati.

Barakat, M. A. (2011). "New trends in removing heavy metals from industrial wastewater." *Arabian Journal of Chemistry*, 4(4), 361–377.

Margerum, R. D., & Robinson, C. J. (2015). "Collaborative partnerships and the challenges for sustainable water management." *Current Opinion in Environmental Sustainability*, 12, 53–58.

Awad, H., Alalm, M. G., & El-Etriby, H. K. (2019). "Environmental and cost life cycle assessment of different alternatives for improvement of wastewater treatment plants in developing countries." *Science of the Total Environment*, 660, 57–68.

Macchiaroli, M., et al. (2019). "Urban water management in Italy: An innovative model for the selection of water service infrastructures." *WSEAS Transactions on Environment and Development*, 15, 463–477.

Diaz-Elsayed, N., et al. (2019). "Wastewater-based resource recovery technologies across scale: A review." *Resources, Conservation and Recycling*, 145, 94–112.

López-Morales, C. A., & Rodríguez-Tapia, L. (2019). "On the economic analysis of wastewater treatment and reuse for designing strategies for water sustainability: Lessons from the Mexico Valley Basin."*Resources, Conservation and Recycling*, 140, 1–12.
Bekov, K. A. (2024). "Legal foundations of the Water Code of Kazakhstan." *Eurasian Scientific Journal of Law*, 4(5), 7–18.
Cur□eu, P. L., & Schruijer, S. G. (2017). Stakeholder diversity and the comprehensiveness of sustainability decisions: the role of collaboration and conflict. *Current Opinion in Environmental Sustainability*, *28*, 114-120.
Łopata, M., Grochowska, J. K., Augustyniak-Tunowska, R., & Tandyrak, R. (2023). Possibilities of Improving Water Quality of Degraded Lake Affected by Nutrient Overloading from Agricultural Sources by the Multi-Point Aeration Technique. *Applied Sciences*, *13*(5), 2861.
Heidari, B., Randle, S., Minchillo, D., & Jaber, F. H. (2023). Green stormwater infrastructure: A critical review of the barriers and solutions to widespread implementation. *Wiley Interdisciplinary Reviews: Water*, *10*(2), e1625.
Altingoz, M. S. (2022). *Water diplomacy in post-Soviet geographies: analyzing multiple scales of cooperative potential*. University of Delaware.

Information about authors:
Baikushikova Gulnara *– PhD, associate professor, Al-Farabi Kazakh National University, (Almaty, Kazakhstan, e-mail: baikushikova.gulnara@kaznu.edu.kz*)
Khamzayeva Fatima *(corresponding author) – Master's degree student, Al-Farabi Kazakh National University, (Almaty, Kazakhstan, e-mail: fatima.kamzaeva@gmail.com*)