



EVALUATION OF WATER QUALITY MONITORING STUDIES: CURRENT STATUS AND PRACTICES

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Abstract: Water quality monitoring studies are of great importance for the sustainable use and protection of water resources. These studies entail the periodic measurement of physical, chemical, and biological parameters in water resources. These assessments are particularly crucial for the identification of alterations in surface and groundwater, and for the regulation of biological, chemical, and physical parameters within water bodies. This systematic observation process facilitates the implementation of effective management decisions by providing a comprehensive assessment of the current status of water bodies. The Water Framework Directive is widely acknowledged as a foundational document for the preservation and management of water resources within the European Union. It has played a pivotal role in the development of methodological approaches for the monitoring of water quality and the enhancement of data networks. The directive enables the precise evaluation of water resources contamination and environmental hazards. Water quality monitoring is also crucial for the early detection of water pollution and the timely implementation of interventions. These monitoring processes also reveal the impacts of agricultural, urban, and industrial activities on water resources. The objective of this study is to provide a comparative evaluation of water quality monitoring activities conducted under the European Union Water Framework Directive and those carried out in Türkiye. In this context, the institutional and legal infrastructure in Türkiye has been examined, and the compatibility of existing structures with the Water Framework Directive has been analyzed. In Türkiye, the responsibility for water quality monitoring is divided among various institutional bodies. It is evident that establishing precise responsibilities and operational domains for these institutions will enable more expeditious and effective access to the requisite data. The study also offers solution proposals and policy recommendations for improving water quality monitoring systems in Türkiye.

Keywords: Water quality, Water quality monitoring, European Union water framework directive

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1. Introduction

The global population is increasing, which is expected to result in increased demand for food and water on a global scale. However, in light of the repercussions of climate change on water resources, it is imperative to employ water resources in an efficient manner.

The escalating demand for water has precipitated a series of substantial challenges. This includes the depletion of groundwater resources, the pollution and degradation of aquatic ecosystems, and the contamination of water resources due to various environmental problems. While water is considered a renewable natural resource, there are concerns that its status as a renewable resource may be compromised in certain areas, which could lead to a highly hazardous scenario. This has led to a situation where the provision and development of new water resources are not only increasingly expensive but also appear to be impractical. Consequently, there is an increasing imperative for the preservation of existing water resources in terms of both quantity and quality (Yurtseven et al., 2010).

The preponderance of global food demand is met by irrigated regions. The production of plant and animal products is entirely dependent on water, and the utilization of water in agriculture is paramount to global food security. Water resources management can be defined as the planned development, distribution, and utilization of water resources. Prior to the development of water resources, it is essential to ascertain the type, location, quantity, and quality of existing water resources. Beyond the realm of water management, ensuring the sustainable utilization of water resources is paramount. It is equally crucial to safeguard water quantity and quality, and to implement measures to avert water quality deterioration, such as pollution prevention strategies (Gökalp and Çakmak, 2016).

The most salient challenge confronting contemporary agriculture is the sustainable production of sufficient, healthy food for a growing population while preserving soil and water resources. Inadequate management, operation, monitoring, and evaluation activities in irrigation networks result in the suboptimal performance



of irrigation systems. Monitoring and evaluation stand as pivotal components in enhancing water efficiency in agriculture. The enhancement of water use efficiency in agriculture is contingent upon the advancement of soil and water management, the technology employed, and the efficacy of the monitoring and evaluation system (Torun and Çakmak, 2024).

Globally, water resources that are both safe and suitable for domestic, agricultural, and industrial use account for a mere 2.5% of the total water resources available on the planet (SKYB, 2018). Given the uneven distribution of water resources globally, the ramifications of water utilization on national policies are unavoidable. According to projections by the Turkish Statistical Institute, the population of Türkiye is expected to reach 93 million by the year 2050 (TÜİK Population Projections, 2023-2100). Preserving existing soil and water resources will ensure the availability of 1,069 m³ of usable water per capita in 2050. This value places Türkiye in proximity to the category of water-scarce countries. Furthermore, this projection indicates that the annual availability of water may increase, potentially leading to heightened water consumption across various sectors due to the country's economic growth. This phenomenon is expected to exert mounting pressures on water resources. Consequently, enhancing water efficiency and conserving and utilizing water resources emerge as pivotal strategies to ensure the sustainability of water resources (SYGM, 2021).

It is anticipated that the issue of global food security will be exacerbated by the lack of access to clean and potable water. Ensuring food security is inherently linked to ensuring water security. According to recent estimates, approximately 2.1 billion individuals worldwide lack access to clean drinking water, while 4.4 billion people are confronted with inadequate sanitation. The interconnection between water scarcity, pollution, and limited access to water is well-documented, and the ramifications of these issues are profound. For instance, food production is vulnerable, and migration is a potential consequence (Çakmak and Torun, 2023).

Water resources management is an all-encompassing activity that necessitates the supervision of not only the quantity of water but also its quality. This multifaceted endeavor necessitates the establishment of a multidimensional organizational structure, thereby ensuring the active involvement of a diverse array of stakeholders. In this regard, endeavors aimed at safeguarding water quality assume a pivotal role in the broader context of water management. On a global scale, the "Integrated Water Resources Management" approach has emerged as a primary response to the looming threat of water scarcity. The European Union has adopted this approach, implementing the basin-based management model outlined in the "Water Framework Directive" (2000/60/EC). This directive aims to protect and control the water resources within the EU borders in terms of quantity and quality. The Directive establishes a

comprehensive policy framework for Member States, mandating the protection and management of their water resources in accordance with a uniform standard.

The Sustainable Development Goals encompass a range of water-related targets, including food, energy, ecosystem, and climate change. Conversely, projections indicate that regions encompassing Türkiye will encounter significant challenges in accessing sufficient and reliable water resources in terms of quality and quantity in the imminent future. Consequently, the regular monitoring and evaluation of water resources in terms of quantity and quality has been identified as a critical measure to avert a water crisis and ensure the sustainable utilization of water resources (Gültaş et al., 2025).

In Türkiye, the primary consumers of water resources are as follows: municipalities (35.14%), thermal power plants (46.36%), manufacturing industry workplaces (14.75%), villages (2.05%), organized industrial zones (0.74%), and mining enterprises (0.95%). This data is derived from TÜİK (2022). A pivotal legislative instrument employed for the safeguarding of water resources in Türkiye is the "Water Pollution Control Regulation" (SKKY). This regulatory framework encompasses a comprehensive set of principles and prohibitions aimed at safeguarding water resources, guidelines for wastewater discharge, provisions for wastewater infrastructure facilities, and the mechanisms and principles of monitoring and inspection to prevent water pollution. In our country, the assessment of water resources is limited to physico-chemical parameters, and water quality is classified according to these parameters. However, this approach is inadequate in terms of ensuring the protection and enhancement of water resources and hinders the implementation of effective planning measures.

In this study, the current situation and practices in monitoring water quality studies in Türkiye were evaluated.

2. The Implementation of Institutional and Legal Infrastructure in Water Quality Monitoring

Water management, as defined by the United States Environmental Protection Agency (USEPA), encompasses the deliberate planning, allocation, and utilization of water resources. A critical component of this multifaceted definition pertains to the preservation of water quantity and quality, along with the assurance of its availability for future generations. In this regard, the design and operation of monitoring and evaluation mechanisms in water management should be guided by the objective of fulfilling all data requirements associated with this definition. These data sets should encompass evaluations of existing water resources and available water potential, water quality and its various qualities in terms of impact, efficiency, and sustainability. These

evaluations should be conducted by comparing the data sets with the needs and consumption of different sectors. In Türkiye, the management of water resources is a multifaceted endeavor, entrusted to a diverse array of institutions and organizations that possess a range of roles and functions. The multi-purpose use of water resources (domestic, industrial, irrigation, energy, etc.) and the fact that services related to the provision of water require different areas of expertise cause many institutions to be involved in the water management process. However, despite the efforts of various public institutions to conduct water quality monitoring studies within the scope of their legal authorities, the effectiveness of these studies is constrained by factors such as ambiguity in authority, a lack of coordination and cooperation among institutions, and the resulting duplication of efforts.

In the context of water quality monitoring studies conducted by various institutions and organizations within our nation, a duplicated monitoring approach is employed at consistent locations, with a focus on the assessment of analogous parameters. An evaluation of the laboratory infrastructures reveals that each institution possesses laboratories at the provincial and regional levels. Despite the utilization of analogous devices and analytical methodologies across these entities, inconsistencies emerge in the data obtained through analyses executed with varying methodologies and standards.

The General Directorate of State Hydraulic Works (DSİ) has been conducting water quality monitoring studies since 1978 and implementing Water Framework Directive-compliant monitoring programs since 2015. These programs ensure the monitoring of parameters in accordance with the legislation, taking into account the pressures and impacts on water bodies, and the evaluation of the results within the framework of River Basin Management Plans (RBMP). However, due to a paucity of technical infrastructure, monitoring can only be carried out in rivers. In 2018, the responsibility for water quality monitoring was transferred to the General Directorate of Water Management, and Basin Monitoring Programs are now being developed with consideration for the pressures on water resources and other pertinent factors. These programs offer a comprehensive set of parameters for assessing water quality, delineating the parameters to be monitored, the monitoring points, and the monitoring frequencies. The institutions and organizations responsible for conducting water quality monitoring studies in Türkiye are enumerated in Table 1.

3. Monitoring Water Quality in The European Union Water Framework Directive

The European Union Water Framework Directive (WFD), adopted in 2000, was developed to establish a comprehensive framework for the protection,

improvement, and sustainable management of water resources in Member States. The overarching objective of the Directive is to enhance the ecological status of surface and groundwater bodies and to safeguard water quality. The SCD aims to prevent the degradation of water by natural and anthropogenic influences, establishing specific standards and monitoring programs to evaluate water quality. The monitoring of water bodies is instrumental in determining their ecological status, facilitating the identification of pollutants, biodiversity, and adverse impacts on aquatic ecosystems.

The European Union Water Framework Directive (SCD) acknowledges water quality monitoring as a pivotal element in the preservation and administration of water resources. The Directive delineates water quality monitoring as a mechanism for determining the ecological status of water bodies, detecting pollutants, and achieving environmental objectives. Water quality monitoring is a process that involves the regular assessment of surface and groundwater quality, the evaluation of ecosystem health, and the measurement of biological, chemical, and physical parameters in water bodies. This systematic observation provides precise data on the current state of water bodies, facilitating the implementation of appropriate management decisions.

According to the Water Framework Directive, water quality monitoring activities are classified under two main headings: Surveillance Monitoring and Operational Monitoring (European Commission, 2015). Surveillance monitoring is defined as the long-term observation of natural changes and anthropogenic impacts in surface waters. This type of monitoring is used to assess biodiversity and habitat quality, while determining the ecological and chemical status of water bodies (European Commission, 2015). Conversely, operational monitoring is implemented in regions where there is a potential for pollutants to enter water bodies. This monitoring is particularly crucial in areas with high pollutant loads, as it enables the rapid detection of changes in water quality and the prediction of deleterious effects (Hering et al., 2010).

The Water Framework Directive (WFD) stipulates the intensification of water quality monitoring in designated areas, including protected areas and sensitive water bodies. The Directive stipulates the monitoring of sensitive areas, including drinking water sources, habitat and species protection areas. The necessity of such monitoring is paramount for the preservation of ecosystem integrity and the maintenance of water quality for its manifold uses. Additionally, monitoring is mandatory for bathing water, water bodies utilized for recreational purposes, and the protection of economically significant aquatic species. This comprehensive monitoring framework is instrumental in developing regional water management plans and ensuring the sustainability of water resources.

Table 1. Institutions and organizations conducting water quality monitoring studies in Türkiye

Ministry	Type	Name of Institution
Ministry of Agriculture and Forestry	General Directorate	General Directorate of Water Management
		General Directorate of Nature Conservation and National Parks
		General Directorate of Combating Desertification and Erosion
		General Directorate of Food and Control
	Department Directorate	General Directorate of Fisheries and Aquaculture
		General Directorate of Agricultural Reform
		Department of information Technologies
	Research Institution	TAGEM (General Directorate of Agricultural Research and Policie)
		DSi (General Directorate of State Hydraulic Works)
		MGM (General Directorate of Meteorology)
	Subsidiary Organization	OGM (General Directorate of Forestry)
		SUEN (Water Institute)
		General Directorate of Spatial Planning
Ministry of Environment, Urbanization and Climate Change	General Directorate	General Directorate of Protection of Natural Assets
		General Directorate of Environmental Management
		General Directorate of EIA (Environmental Impact Assessment)
		General Directorate of Construction Works
	Subsidiary Organization	General Directorate of Infrastructure Services
		General Directorate of GIS (Geographical Information Systems)
		iLBANK
Ministry of Energy and Natural Resources	General Directorate	General Directorate of Renewable Energy
		General Directorate of Energy Affairs
	Subsidiary Organization	MTA (General Directorate of Mineral Research and Exploration)
		EMRA (Energy Market Regulatory Authority)
Ministry of Health	Regional Directorates	MTA Regional Directorates
	General Directorate	General Directorate of Public Health
	Provincial Agency	Community Health Centers
		Public Health Directorates
Ministry of Culture and Tourism	General Directorate	General Directorate of Investments and Enterprises
Ministry of Foreign Affairs	General Directorate	General Directorate of Energy, Water and Environmental Affairs
	Subsidiary Organization	Directorate for European Union Affairs

In accordance with the stipulations outlined in the Water Framework Directive, the findings derived from the periodic evaluation of water quality must be meticulously documented and disseminated. This information serves as a crucial foundation for the formulation of water management strategies and the implementation of targeted measures. The analysis of monitoring data facilitates the identification of measures aimed at preventing deterioration, as they emerge during the course of water quality monitoring. Moreover, EU Member States collaborate and formulate common strategies at both regional and national levels to

accomplish the objectives established for the monitoring and management of water quality. This collaborative effort fosters the establishment of an effective management mechanism, thereby ensuring the long-term preservation of water bodies.

The European Union's Water Framework Directive (WFD) establishes the identification and regular monitoring of various parameters for the assessment of water quality. These parameters are used to assess the ecological status, chemical quality, and biodiversity of water bodies (European Commission, 2000). Accurate identification of the factors affecting water quality is

instrumental in the development of sustainable water management and conservation strategies.

3.1. Physicochemical Parameters

- pH level
- Dissolved oxygen
- Temperature
- Electrical conductivity (EC) Total dissolved solids (TDS)
- Nutrients such as ammonia, nitrate and phosphate
- Turbidity
- Chemical oxygen demand (COD) and biological oxygen demand (BOD)

These physicochemical parameters are monitored to assess the basic chemical properties of water and its pollution levels. Of particular relevance are the levels of organic matter, nutrients, and oxygen, which directly impact the biological health of the water.

3.2. Biological Parameters

- Phytoplankton (algae)
- Zooplankton (aquatic animals)
- Benthic organisms (organisms living on the water floor)
- Secondary producers and biodiversity of ecosystems

Biological parameters are critical indicators that assess the ecological health and biodiversity of a water body. These parameters are instrumental in the ongoing monitoring of the health and sustainability of aquatic ecosystems.

3.3. Hydromorphological Parameters

- Water flow velocity and direction
- Water levels
- Physical structure of the water body (e.g. channel depth and width)
- Morphological structure of ecosystems and condition of habitats

Hydromorphological parameters are instrumental in the monitoring of the physical characteristics of a water body. These parameters assess the naturalness of water flow and the physical effects of water, including flood risk.

3.4. Contaminants (Chemical Pollutants)

- Heavy metals (e.g. mercury, lead, arsenic)
- Pesticides and other chemical pollutants
- Industrial waste and toxic substances

The parameters in question are monitored for two primary reasons: first, to detect the entry of pollutants into water bodies; and second, to determine the levels of chemical contamination of water. The presence of pollutants in water bodies can have deleterious effects on water quality and the integrity of ecosystems.

3.5. Nutrients

- Nitrogen compounds (ammonium, nitrate, nitrite)
- Phosphorus compounds

Nutrients can enter water bodies, particularly as a result of agricultural activities and wastewater discharges. Conducting regular monitoring of these parameters is

instrumental in identifying issues such as eutrophication, a phenomenon characterized by an excess of nutrients leading to adverse environmental consequences. The Water Framework Directive requires monitoring of these parameters in order to provide comprehensive information on the ecological status of water bodies. Regular and systematic monitoring of these parameters provides the necessary data for the protection and improvement of water resources.

4. Water Quality Monitoring Studies in Türkiye

Legislators have established legal frameworks to establish the legal and technical principles necessary for the effective and efficient management of surface water resources (i.e., rivers, lakes, streams, reservoirs, coastal, and transitional waters) and groundwater. These frameworks include monitoring, quality classification, and determination in line with sustainable development goals, with the aim of protecting and improving water quality. In this regard, a range of legislative measures have been instituted to safeguard water resources within our nation. Türkiye's legislative harmonization process with the EU Water Framework Directive is presented chronologically in Table 2.

The Regulation on Water Pollution Control is the most significant legislative instrument employed for the protection of water resources. This regulatory framework encompasses a comprehensive set of principles and prohibitions aimed at safeguarding water resources, guidelines for the discharge of wastewater, principles for the issuance of permits for wastewater discharge, concerns pertaining to wastewater infrastructure facilities, and the methodologies and principles underlying monitoring and inspection activities aimed at preventing water pollution. In Türkiye, the current monitoring regime is limited to physico-chemical parameters, and water quality is classified according to these parameters. However, this approach is inadequate for ensuring the protection and enhancement of water resources and represents a significant impediment to effective planning. To address this gap, it is imperative to establish environmental objectives for each water source, encompassing a comprehensive range of quality elements, including chemical, physico-chemical, biological, and hydromorphological aspects.

The purpose of the By-Law on Surface Water Quality Management is to determine, classify, and monitor the biological, chemical, physico-chemical, and hydromorphological quality of surface water resources and coastal and transitional waters. This regulatory framework is designed to safeguard water resources in accordance with the principles of sustainable development, thereby ensuring the attainment of optimal water quality. The by-law encompasses a multifaceted approach, addressing the assessment of existing water

quality, identification of measures for enhancement, and the administration of water resources.

Achieving optimal water quality and quantity is paramount for maintaining good water status. However, the current state of water quality monitoring in Türkiye does not fully align with the stipulations outlined in the Water Framework Directive. Consequently, the establishment of a National Monitoring Network is

imperative to ensure comprehensive and systematic water quality monitoring. Moreover, in order to safeguard surface water resources against the pernicious effects of diffuse and point source pollution, it is imperative to establish receiving environment standards and implement protective measures in accordance with these standards.

Table 2. Progress of Türkiye's legislative alignment with the EU water framework directive: A chronological overview (1999–2023)

Year	Development / Legislative Step	Description
1999	Start of EU Accession Process	Türkiye initiated full membership negotiations with the EU. Harmonization with EU environmental legislation was targeted.
2000	Start of EU Environmental Negotiations	Türkiye began aligning with EU environmental acquis.
2003	Accession Partnership Document and National Program	Harmonization with EU environmental acquis was targeted. Water sector identified as a priority area.
2004	Ministry of Environment and Forestry – EU Alignment Studies	Initiated legal infrastructure work compatible with the EU WFD in the water sector.
2006	Preliminary preparations for Water Management Department	Institutional structuring process began.
2012	Establishment of General Directorate of Water Management (GDWM)	A central authority was established for harmonization with the EU WFD. Assigned duties include basin and water quality management.
2013	Publication of Basin Protection Action Plans and Monitoring Regulation	Studies aligned with the monitoring component of the Directive were carried out.
2014	Preparation of River Basin Management Plans (RBMPs) began	One of the main requirements of the WFD was initiated.
2016	Draft Turkish Water Law prepared	Aimed to create a fully WFD-compliant legal framework, but not enacted.
2017	Strengthening of basin-based monitoring networks	Biological, chemical, and hydromorphological monitoring systems were developed in line with WFD requirements.
2019	RBMPs completed (some basins)	First plans were completed in Gediz, Büyük Menderes, and Meriç-Ergene basins.
2021	Development of Integrated Water Information System (IWIS)	Digital infrastructure was established to align with the EU's principle of knowledge-based management.
2023	Environmental Agency of Türkiye and digital monitoring	Aimed to align with EU environmental data policies through integrated digital systems.

The monitoring and evaluation of groundwater is of significant importance. This involves the continuous observation of the quality and quantity of groundwater, as well as the implementation of measures aimed at preventing and remediating pollution. The deterioration of the chemical status of groundwater, the identification of significant and increasing pollution trends, and the implementation of improvement works in this regard are critical for the protection of water resources. Water contamination resulting from the utilization of plant protection products constitutes a salient concern. The active ingredients present in these products, utilized during agricultural practices, have the potential to

adversely affect the environment, thereby contributing to water contamination. Consequently, there is a need for research and development initiatives aimed at determining the presence of these substances in receiving environments. Such initiatives also aim to develop environmental quality standards and to prevent diffuse water pollution.

In Türkiye, the General Directorate of Water Management is responsible for conducting water quality monitoring studies and determining water bodies. Since 1979, the General Directorate of State Hydraulic Works has been conducting water quality monitoring studies in 25 river basins, adopting a comprehensive approach to

water quality monitoring. These studies persist with the objective of identifying water bodies and establishing monitoring programs.

The effective management of the quantity and quality of groundwater is imperative for meeting the European Union's (EU) requirements for groundwater management. In this regard, the imperative for addressing groundwater contamination and degradation, sustaining its current state of quality, and enhancing its condition where necessary, has been underscored. Consequently, the regulatory framework has been reinforced through the establishment of the "Regulation on the Protection of Groundwater against Pollution and Degradation," thereby ensuring the effective management of this vital resource.

Regular monitoring of both water quality and quantity, as well as the implementation of appropriate measures, are critical for the effective implementation of groundwater management.

The General Directorate of State Hydraulic Works has been conducting water quality monitoring in 25 river basins since 1979 in accordance with Law No. 6200. The most recent regulation, Presidential Decree No. 4 dated 15.07.2018, has expanded the scope of the General Directorate's responsibilities to include the monitoring of surface and groundwater quality. These studies are conducted by the Department of Studies, Planning and Allocations, and the water quality monitoring network has been augmented with approximately 1,375 monitoring points.

General-purpose monitoring stations are equipped with instruments capable of measuring 25 mandatory parameters, including physical and chemical parameters such as biological oxygen demand (BOD), calcium, chloride, dissolved oxygen, electrical conductivity, ammonium, nitrate, nitrite, sulfate, suspended solids, temperature, pH, total dissolved matter, organic matter, and phosphorus. In stations dedicated to the monitoring of drinking water, the measurement of 36 parameters is conducted, encompassing heavy metals, pesticides, hydrocarbons, and other pollutants.

In the context of Türkiye's EU accession process, the environment chapter was initiated for negotiations on December 21, 2009. Concurrently, the General Directorate of Water Management was established within the Ministry of Forestry and Water Affairs in 2011, thereby initiating pivotal reforms in the domain of water management. In 2014, the Regulation on the Monitoring of Surface Waters and Groundwater was established, thereby establishing the principles and guidelines for the development of monitoring programs. Concurrently, the EU Project on Capacity Building on Water Quality Monitoring facilitated the identification of water bodies and the establishment of monitoring programs in six basins (Büyük Menderes, Akarçay, Ergene, Susurluk, Sakarya and Konya Closed). In 2017, the programs underwent a revision that included the addition of protected area monitoring points, which were

designed to represent sensitive water bodies (SYGM, 2025).

In 2018, the General Directorate of Water Management finalized the River Basin Management Plans for the Susurluk, Büyük Menderes, Meric-Ergene, Gediz, and Konya-Kapalı basins. In 2019, the successful completion of water quality monitoring projects in Akarçay, Western Mediterranean, Yeşilırmak and Sakarya basins was documented. In 2020, the scope of these initiatives expanded to encompass the Antalya, Western Black Sea, Eastern Black Sea, Marmara, Kızılırmak and Eastern Mediterranean basins. These projects underscore a comprehensive approach to water quality monitoring (SYGM, 2025).

The General Directorate of State Hydraulic Works has been conducting water quality monitoring activities in 25 river basins since 1979. The most recent regulation has transferred the responsibility for monitoring the quality of surface and groundwater to the Presidential Decree dated July 15, 2018. The network has expanded significantly, reaching approximately 1,375 points. However, challenges such as the absence of biological monitoring, the inability to sample from lakes, and the inadequacy of laboratory infrastructure hinder the effectiveness of water quality monitoring. To address these challenges, it is imperative to expand the scope of biological monitoring, enhance laboratory infrastructure, and augment the number of trained personnel. The overarching framework for the management of groundwater in the region has been delineated by the Regulation on the Protection of Groundwater against Pollution and Degradation, and significant strides are being made to align with the EU's stipulated requirements for groundwater management.

Among the most salient issues encountered in water quality monitoring studies in Türkiye are the dearth of biological monitoring, the inability to take samples from lakes, the inadequacy of laboratories and equipment, and personnel shortages. These obstacles impede the effective monitoring of water quality, resulting in delays in implementing necessary measures. These challenges include difficulties in sampling from water bodies such as lakes and rivers, inability to monitor biological parameters, and limited laboratory capacity. These factors collectively negatively affect the effectiveness of the monitoring network. To address these challenges, it is imperative to enhance the water quality monitoring network, expand the scope of biological monitoring, upgrade the laboratory infrastructure, and augment the number of trained personnel.

The European Union Water Framework Directive is widely acknowledged as a foundational policy document throughout Europe, aimed at safeguarding and collectively managing water resources. In the context of Türkiye's accession process to the European Union, it is imperative to assimilate the principles and requirements of the Directive into national legislation and practices to ensure the sustainable management of water resources.

In this regard, a range of legal and institutional frameworks have been established in our nation, accompanied by numerous studies conducted for the implementation of these frameworks. Presently, the development and harmonization activities for these

studies are ongoing. As illustrated in Table 3, a comparative analysis is presented of the fundamental requirements of the European Union Water Framework Directive and the studies carried out in Türkiye in this context.

Table 3. EU water framework directive requirements and Türkiye's legislative compliance

Field	EU WFD Requirement	Türkiye's Legislative Compliance Status
River Basin Management	Preparation of river basin management plans	✓ Plans prepared for 25 basins, regulations published
Water Quality Monitoring	Monitoring of physical, chemical, and biological parameters	✓ A system compliant with the Surface Water Quality Regulation (2012, 2018) established
Pollution Control	Monitoring of hazardous substances and point sources	✓ Regulation on the Control of Hazardous Substances (2016) enacted
Public Participation	Public involvement in planning processes	△ Limited implementation, legal framework exists
Economic Analysis	Recovery of water service costs	△ Partially compliant, implementation insufficient
Legal Framework (Water Law)	National water legislation	✗ Water Law still in draft stage
Integrated Water Policy	Policy integrated with all relevant directives	△ Fragmented legislation, lack of inter-agency coordination

5. Conclusions and Recommendations

A number of issues have been identified with regard to the quality assurance and evaluation of water resources in Türkiye. Among these issues, institutional challenges, legal inadequacies, staff shortages and the unavailability of adequate technical measurement networks are particularly salient. These deficiencies pose a significant threat to the sustainable management of water resources. Consequently, there is an urgent need to implement fundamental measures to enhance the effectiveness and efficiency of water quality monitoring in Türkiye.

First and foremost, it is imperative to ensure that the institutions and organizations responsible for water quality monitoring and assessment activities operate in a more coordinated manner. Towards this end, the operation of all relevant institutions under a single framework law will eliminate legal gaps and make the management of water resources more systematic. Moreover, the establishment of an institutional infrastructure is imperative to ensure effective coordination and data sharing among all stakeholders. The establishment of such an infrastructure will enhance transparency in the processes of collecting, analyzing, and sharing water quality data, thereby facilitating more expeditious and precise decision-making.

In accordance with the EU Water Framework Directive (WFD), it is evident that an integrated water resources management approach should be incorporated into water quality monitoring and assessment. This approach delineates a comprehensive strategy encompassing all dimensions imperative for the preservation and sustainable management of surface water resources. Adopting a system based on the EU Water Framework Directive for the protection and efficient use of Türkiye's

water resources will ensure an effective monitoring and management process at both local and regional levels.

Türkiye's available water resources are becoming increasingly limited due to factors such as increasing demand, drought, and pollution in basins. In this context, the monitoring and control of water quality assumes paramount importance. However, the nation currently faces deficiencies in its monitoring and evaluation systems. The absence of a unified database or information system, constrained stakeholder access to data, and inadequate inter-institutional coordination have collectively resulted in significant challenges in the effective management of water resources. The following recommendations are proposed to address these issues:

1. The enhancement of institutional capacity: Ensuring effective coordination among the institutions/organizations responsible for water quality monitoring and assessment activities is imperative, as is the establishment of a robust infrastructure for data sharing.
2. The legal infrastructure must be strengthened to protect water quality. To that end, the legal framework should be strengthened and a more comprehensive and functional legal structure should be established by combining relevant laws and regulations.
3. The measurement network must be strengthened. The measurement networks and technical infrastructure necessary for the effective implementation of water quality monitoring and assessment processes should be strengthened.
4. The establishment of a common database or information system is imperative. The establishment of a unified database is imperative to enhance the accessibility and dissemination of

water quality data. This will ensure that all stakeholders have ready access to current data, facilitating its effective integration into decision-making processes.

5. Ensuring coordination: Inter-institutional coordination and cooperation in water resources management and monitoring-evaluation studies should be ensured. The enhancement of these processes can be achieved through the initiation of collaborative academic endeavors and joint projects.

Author Contributions

The percentages of the authors' contributions are presented below. All authors reviewed and approved the final version of the manuscript.

	S.A	E.Y
C	50	50
D	60	40
S	20	80
DCP	70	30
DAI	70	30
L	70	30
W	60	40
CR	20	80
SR	60	40

C= concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision.

Conflict of Interest

The authors declare no conflict of interest.

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