



WATER QUALITY MONITORING SYSTEMS: A COMPARATIVE EVALUATION OF LEGISLATIVE FRAMEWORKS EUROPEAN AND BRAZILIAN

Camila Evelyn Rodrigues Pimenta¹
Júlia Szeles²
Gábor Várbiro³

ABSTRACT

Objective: The aim of this study is to identify the similarities and differences in water quality monitoring systems in Brazil and Hungary, analyzing their regulatory frameworks, methodologies used, and parameters assessed. In addition, it seeks to assess the effectiveness of these approaches in the protection and sustainable management of water resources, considering the challenges and advances of each country.

Theoretical Framework: This study is based on models and regulations that guide the monitoring of water quality. The Water Framework Directive (WFD), applied in the European Union, establishes the assessment of the ecological status of water bodies based on biological, physical-chemical and hydromorphological indicators. In Brazil, the National Water Resources Policy (Law No. 9.433/1997) and CONAMA Resolution No. 357/2005 regulate the management and classification of water quality, adopting a decentralized model based on river basins. The research is also based on the theory of environmental indicators, which emphasizes the importance of physical-chemical and biological parameters in assessing the health of aquatic ecosystems. This approach allows for a comparative analysis between Brazil and Hungary, contributing to the improvement of water monitoring and management policies.

Method: This comparative study analyzes water quality monitoring systems in Brazil and Europe-Hungary based on a law review and secondary data from official bodies such as the ANA and the WFD. Data collection involved the analysis of physical-chemical, biological and hydromorphological parameters, as well as legislation and institutional reports. The comparison was made considering monitoring frequency, regulatory guidelines and water management challenges, with the aim of identifying good practices and opportunities for improvement.

Results and Discussion: The results showed that Hungary adopts an integrated ecological approach according to the WFD, while Brazil uses the IQA, which focuses on physical-chemical parameters. Hungary has a higher frequency of monitoring, allowing for more detailed assessments. The discussion highlights how regulatory differences impact water management, with the European Union ensuring greater standardization. In Brazil, challenges such as decentralization and a lack of up-to-date data limit the effectiveness of monitoring. The study's limitations include its reliance on secondary data. Even so, the findings suggest that Brazil could adopt aspects of the European approach to improve water governance.

Research Implications: The practical and theoretical implications of this study focus on comparisons of water quality monitoring systems between Europe/Hungary and Brazil. The results can influence water management practices, environmental policies and the implementation of more effective monitoring systems. The implications are relevant to areas such as environmental governance, sustainability, conservation of aquatic ecosystems and the development of regulations and public policies for the protection of water quality.

Originality/Value: The present study, add to the literature by a comparison of water quality monitoring systems in Hungarian and Brazilian rivers, providing differences and similarities in the respective legal framework. The importance and contribution of this study is clearly demonstrated in its ability to inform public policy on environmental monitoring practices as well as the insights it provides about potential interventions for the implementation of effective water quality protection systems in Brazil/Hungary.

¹ University of Debrecen, Debrecen, Hungary. E-mail: camilla.evelyn94@gmail.com
Orcid: <https://orcid.org/0000-0002-0159-7879>

² HUN-REN Centre for Ecological Research, Institute of Aquatic Ecology, Department of Tisza Research, Debrecen, Hungary. E-mail: szelesjulia94@gmail.com Orcid: <https://orcid.org/0009-0004-9571-6200>

³ HUN-REN Centre for Ecological Research, Institute of Aquatic Ecology, Department of Tisza Research, Debrecen, Hungary. E-mail: varbirog@gmail.com Orcid: <https://orcid.org/0000-0001-5907-3472>



Keywords: Environmental Policies, Water Management, Comparative Legal Study, River Water Quality.

SISTEMAS DE MONITORAMENTO DA QUALIDADE DA ÁGUA: UMA AVALIAÇÃO COMPARATIVA DAS ESTRUTURAS LEGISLATIVAS EUROPÉIA E BRASILEIRA

RESUMO

Objetivo: O objetivo deste estudo é identificar as semelhanças e diferenças nos sistemas de monitoramento da qualidade da água no Brasil e na Hungria, analisando seus marcos regulatórios, metodologias utilizadas e parâmetros avaliados. Além disso, busca-se avaliar a eficácia dessas abordagens na proteção e gestão sustentável dos recursos hídricos, considerando os desafios e avanços de cada país.

Referencial Teórico: Este estudo é baseado em modelos e regulamentos que orientam o monitoramento da qualidade da água. A Water Framework Directive (WFD), aplicada na União Europeia, estabelece a avaliação do estado ecológico dos corpos d'água com base em indicadores biológicos, físico-químicos e hidromorfológicos. No Brasil, a Política Nacional de Recursos Hídricos (Lei nº 9.433/1997) e a Resolução CONAMA nº 357/2005 regulamentam a gestão e a classificação da qualidade da água, adotando um modelo descentralizado baseado em bacias hidrográficas. A pesquisa também se baseia na teoria dos indicadores ambientais, que enfatiza a importância dos parâmetros físico-químicos e biológicos na avaliação da saúde dos ecossistemas aquáticos. Essa abordagem permite uma análise comparativa entre o Brasil e a Hungria, contribuindo para o aprimoramento das políticas de monitoramento e gestão da água.

Método: Este estudo comparativo analisa os sistemas de monitoramento da qualidade da água no Brasil e na Europa-Hungria com base em uma revisão da legislação e em dados secundários de órgãos oficiais, como a ANA e a WFD. A coleta de dados envolveu a análise de parâmetros físico-químicos, biológicos e hidromorfológicos, além de legislação e relatórios institucionais. A comparação foi feita considerando a frequência de monitoramento, as diretrizes regulatórias e os desafios da gestão da água, com o objetivo de identificar boas práticas e oportunidades de melhoria.

Resultados e Discussão: Os resultados mostraram que a Hungria adota uma abordagem ecológica integrada de acordo com a WFD, enquanto o Brasil usa o IQA, que se concentra em parâmetros físico-químicos. A Hungria tem uma frequência maior de monitoramento, o que permite avaliações mais detalhadas. A discussão destaca como as diferenças regulatórias afetam a gestão da água, com a União Europeia garantindo maior padronização. No Brasil, desafios como a descentralização e a falta de dados atualizados limitam a eficácia do monitoramento. As limitações do estudo incluem sua dependência de dados secundários. Mesmo assim, os resultados sugerem que o Brasil poderia adotar aspectos da abordagem europeia para melhorar a governança da água.

Implicações da Pesquisa: As implicações práticas e teóricas deste estudo se concentram nas comparações dos sistemas de monitoramento da qualidade da água entre a Europa/Hungria e o Brasil. Os resultados podem influenciar as práticas de gestão da água, as políticas ambientais e a implementação de sistemas de monitoramento mais eficazes. As implicações são relevantes para áreas como governança ambiental, sustentabilidade, conservação de ecossistemas aquáticos e desenvolvimento de regulamentações e políticas públicas para a proteção da qualidade da água.

Originalidade/Valor: O presente estudo contribui para a literatura com uma comparação dos sistemas de monitoramento da qualidade da água nos rios húngaros e brasileiros, apresentando diferenças e semelhanças nas respectivas estruturas legais. A importância e a contribuição deste estudo são claramente demonstradas em sua capacidade de informar a política pública sobre as práticas de monitoramento ambiental, bem como os insights que ele fornece sobre possíveis intervenções para a implementação de sistemas eficazes de proteção da qualidade da água no Brasil/Hungria.

Palavras-chave: Políticas Ambientais, Gestão da Água, Análise Normativa, Qualidade da Água nos Rios.



SISTEMAS DE CONTROL DE LA CALIDAD DEL AGUA: UMA AVALIAÇÃO COMPARATIVA DE LOS MARCOS LEGISLATIVOS EUROPEO Y BRASILEÑO

RESUMEN

Objetivo: El objetivo de este estudio es identificar las similitudes y diferencias en los sistemas de monitoreo de la calidad del agua en Brasil y Hungría, analizando sus marcos regulatorios, metodologías utilizadas y parámetros evaluados. Además, pretende evaluar la eficacia de estos enfoques en la protección y gestión sostenible de los recursos hídricos, teniendo en cuenta los desafíos y avances de cada país.

Marco Teórico: Este estudio se basa en modelos y normativas que orientan el monitoreo de la calidad del agua. La Directiva Marco del Agua (WDF), aplicada en la Unión Europea, establece la evaluación del estado ecológico de las masas de agua a partir de indicadores biológicos, físico-químicos e hidromorfológicos. En Brasil, la Política Nacional de Recursos Hídricos (Ley nº 9.433/1997) y la Resolución nº 357/2005 de la CONAMA regulan la gestión y clasificación de la calidad del agua, adoptando un modelo descentralizado basado en cuencas hidrográficas. La investigación también se basa en la teoría de los indicadores ambientales, que destaca la importancia de los parámetros físico-químicos y biológicos para evaluar la salud de los ecosistemas acuáticos. Este enfoque permite un análisis comparativo entre Brasil y Hungría, contribuyendo a la mejora de las políticas de control y gestión del agua.

Método: Este estudio comparativo analiza los sistemas de monitoreo de la calidad del agua en Brasil y Europa-Hungría a partir de una revisión de la legislación y de datos secundarios de organismos oficiales como la ANA y la WDF. La recogida de datos consistió en el análisis de parámetros físico-químicos, biológicos e hidromorfológicos, así como de la legislación y los informes institucionales. La comparación se realizó teniendo en cuenta la frecuencia de los controles, las directrices normativas y los retos de la gestión del agua, con el fin de identificar buenas prácticas y oportunidades de mejora.

Resultados y Discusión: Los resultados mostraron que Hungría adopta un enfoque ecológico integrado conforme a la WDF, mientras que Brasil utiliza el IQA, que se centra en los parámetros físico-químicos. Hungría tiene una mayor frecuencia de control, lo que permite realizar evaluaciones más detalladas. El debate pone de relieve cómo las diferencias normativas afectan a la gestión del agua, ya que la Unión Europea garantiza una mayor normalización. En Brasil, problemas como la descentralización y la falta de datos actualizados limitan la eficacia del control. Las limitaciones del estudio incluyen su dependencia de datos secundarios. Aun así, los resultados sugieren que Brasil podría adoptar aspectos del enfoque europeo para mejorar la gobernanza del agua.

Implicaciones de la investigación: Las implicaciones prácticas y teóricas de este estudio se centran en la comparación de los sistemas de monitorización de la calidad del agua entre Europa/Hungría y Brasil. Los resultados pueden influir en las prácticas de gestión del agua, las políticas medioambientales y la aplicación de sistemas de vigilancia más eficaces. Las implicaciones son relevantes para áreas como la gobernanza ambiental, la sostenibilidad, la conservación de los ecosistemas acuáticos y el desarrollo de normativas y políticas públicas para la protección de la calidad del agua.

Originalidad/Valor: El presente estudio se suma a la bibliografía mediante una comparación de los sistemas de control de la calidad del agua en los ríos húngaros y brasileños, aportando diferencias y similitudes en el marco jurídico respectivo. La importancia y la contribución de este estudio se demuestra claramente en su capacidad para informar a las políticas públicas sobre las prácticas de monitoreo ambiental, así como las ideas que proporciona sobre las posibles intervenciones para la aplicación de sistemas eficaces de protección de la calidad del agua en Brasil/Hungría.

Palabras clave: Políticas Medioambientales, Gestión del Agua, Estudio Jurídico Comparado, Calidad del Agua Fluvial.

RGSA adota a Licença de Atribuição CC BY do Creative Commons (<https://creativecommons.org/licenses/by/4.0/>).





1 INTRODUCTION

As the essential natural resource for life on Earth, water is responsible for maintaining ecosystems, biodiversity, and ecological processes (Jewitt, 2002). In addition, freshwater ecosystems play a significant part in the evolution of civilizations. This environment's ecosystem services are diversified, including energy generation (hydroelectric), recreation, transportation, fishing, water consumption, and agriculture, among others (Vihervaara *et al.*, 2010 as quoted in Espécie *et al.*, 2019). However, with population growth and increasing industrial expansion, physical, chemical, and biological degradation has increased, reducing the quality of this ecosystem (Duda & El-ashry, 2000 as quoted in Boon & Raven, 2012). Urban growth has caused water-related challenges for cities worldwide in recent decades, including water scarcity, poor water quality, flooding, and energy shortages (Chung *et al.*, 2021). One of the concerns related to the aquatic environment is the health of the rivers because, with the alteration of land use and the anthropogenic effects, this environment has been more and more degraded (Lee *et al.*, 2020), thus losing several ecosystem services (Akhtar *et al.* 2021). The anthropogenic activities have caused a decline in river quality worldwide to where river basin management is needed, as new regulations and policies according to the current situation of each ecosystem (World Water Assessment Program, 2017).

This study is focused on standards and regulations that guide the monitoring of water quality in Hungary and Brazil. Hungary as a model of the adaptation of the European guideline, called the Water Framework Directive (WFD), an important legislative framework in the European Union that aims to achieve good ecological status for all bodies of water establishing the evaluation of the ecological status of water bodies based on biological, physical-chemical and hydromorphological indicators in the EU member states. The WFD involves the categorization of water bodies and the definition of reference conditions to evaluate deviations from these guidelines. Multivariate analysis and historical data are used to assess benthic ecological status, showing the potential of these methodologies in practical applications (Muxika *et al.*, 2007; Bald *et al.*, 2005). In Brazil, the management and classification of water quality is based on the National Water Resources Policy (Law No. 9.433/1997) and CONAMA Resolution No. 357/2005, adopting a decentralized model based on river basins. The research is also based on the theory of environmental indicators, i.e. physical-chemical and biological parameters are central for the use in measuring the health status of aquatic ecosystems. The method allows for mutual assessment between Brazil and Hungary, as well as encourages improved water monitoring and policies — in general.



Water quality assessment and monitoring are crucial for regulating and controlling water resource management initiatives. Understanding river response's ecological status to multiple stressors is a requirement for river restoration and management (Fan *et al.*, 2020). Analysis of the nutrient enrichment in the water bodies (based on category, type, and geographic location) is required to determine the water quality (Shortle *et al.*, 2020). Confounding variables' effects on the interaction between nutrients and biology must also be considered (Wang *et al.*, 2007).

In Brazil and Hungary, different regulatory and methodological approaches are applied to assess river quality, reflecting not only the different environmental contexts but also the political and institutional guidelines of each country. Although both countries have structured monitoring systems, the way in which water quality parameters are defined, measured and managed varies significantly. These differences can influence decision-making and the effectiveness of water conservation strategies.

Despite the existence of several studies on water quality, there are still gaps in practice regarding the updating of research and its application in monitoring systems in water management (Ahiablame *et al.*, 2012; Cosgrove & Loucks, 2015; Wang *et al.*, 2021). While the European Union states members adopt the Water Framework Directive (WFD) as its main regulatory instrument, Brazil follows national guidelines based on the National Water Resources Policy. However, few analyses assess the convergences and divergences between these systems (Dapena *et al.*, 2017; De Brito & De Azevedo, 2020), as well as the practical challenges faced in implementing monitoring policies.

This study aims to give a better comprehension of water quality monitoring practices in different regulatory systems. By comparing the Brazilian and Hungarian regulatory systems, to identify good practices that can be applied in different realities, as well as pointing out possible improvements to existing systems. This study therefore provides an analysis that can be used by both environmental managers and researchers, promoting a more integrated and efficient approach to water resource conservation.

2 METHODOLOGY

This comparative study analyzes water quality monitoring systems in Brazil and Hungary based on a law and regulations review and secondary data from official institutions responsible for the monitoring system such as the National Water and Basic Sanitation Agency (ANA) and the Water Framework Directive (WFD).

The methodology of this study is structured in three main stages: (3.1) analysis of the



legislative frameworks for monitoring water quality, and (3.2) comparison between the legislative frameworks, with an emphasis on the implications for environmental management and conservation of water bodies.

2.1 ANALYSIS OF LEGAL FRAMEWORKS

A review was carried out of the legislation on water quality monitoring systems in both Brazil and Hungary, considering the country's legislation and the guidelines for monitoring aquatic environments. In the Hungarian context, the EU directives were analyzed, in particular the e WFD, which establishes the requirements for monitoring and managing water quality. For Brazil, the National Water Resources Policy, Law No. 9.433/1997, and the guidelines of the National Sanitation Information System (SNIS) were evaluated. The comparative analysis took into account aspects such as the parameters monitored, sampling methods, monitoring frequency and quality standards established in both regions.

2.2 COMPARISON ANALYSIS

The comparison between the monitoring systems was carried out using a qualitative. The qualitative analysis involved comparing the legislative frameworks and the suitability of monitoring practices to the environmental objectives set in each region. Also was evaluated the data from the institutions, based on data on water quality parameters, using statistical techniques to assess the efficiency of the systems in terms of spatial coverage, temporal resolution and data accuracy. In addition, the implications of implementing public policies in each region for improving water quality and protecting aquatic ecosystems were explored

3 RESULTS AND DISCUSSIONS

3.1 ANALYSIS OF LEGAL FRAMEWORKS

3.1.1 Brazilian Legislation

According to the Brazilian Federal Constitution of 1988 Article 225. (Brazil, 1988) “Everyone has the right to a healthy, ecologically balanced environment, which is a shared resource and a prerequisite for a high standard of living. As such, the government and the



community are obligated to protect and maintain this environment for both current and future generations.”

The Water Law, in Brazil, also known as Law No. 9.433 of 1997 (Brazil, 1997), is the main legal document governing the management of water resources, this document determined the National Water Resource Policy and the National Water Resource Management System (Singreh) (Araújo *et al.*, 2015). This federal law provided the essential tools for the comprehensive management of Brazil's water resources and refers to the framing of water bodies according to classes of usage while discussing the monitoring of water quality.

The National Water Resource Policy's guiding pillars are outlined in this law, which declares that managing water should provide for diverse uses, be decentralized, engage the government, consumers, and communities, and use water for human and livestock consumption in the event of water scarcity. Water is also a public commodity and a natural finite resource with economic value. The National Water Resource Policy also hold jurisdiction over watersheds (Araújo *et al.*, 2015). Water management has always been subject to significant political interference, some of which has even affected technical considerations. The institutional framework of Brazil's National Water Agency demonstrates progress in safeguarding water management entities from political intervention.

As described by Araújo *et al.* (2015), the organizations listed below constitute Brazil's National Water Resource Management System: (a) Federal decision-makers include the National Water Resources Council and the Ministry of the Environment (MMA/SRHU), as well as managers of water resources like the National Water and Basic Sanitation Agency (ANA) (CNRH). (b) Each State has a State Environment Secretariat that is responsible for the state's policy-making body; (c) Municipalities, which are executive delegatory entities, set policy at the regional level (municipalities and hydrographic areas), while water management agencies, which manage water resources, are deliberative bodies.

In accordance with the National Environmental Council's rule (CONAMA Resolution No. 357, Brazil 2005), there are five freshwater usage classes (special, 1, 2, 3, and 4) with associated upper and lower limitations for more than 200 physical, chemical, and microbiological characteristics of the water. Although the Program to Stimulate the Disclosure of Water Quality Data (Qualiágua - ANA) in Brazil's context of national water management calls for sampling in more protected areas, the resolution that establishes the reference values for the various water quality parameters does not differentiate between the various Brazilian ecoregions or river basins (CONAMA Resolution No. 357/2005, Brazil, 2005).

The National Water and Basic Sanitation Agency (ANA), which oversees the Qualiágua



program, is attempting to encourage, level, and standardize the monitoring and dissemination of data on water quality across the nation by establishing strategic sampling locations and the minimal water quality variables that must be tracked. The Aquatic Life Protection Index (IVA), which is based on the concentration of substances that have toxic effects on aquatic organisms, in addition to pH, dissolved oxygen, and trophic state, is the only approach to aquatic life despite the various variables and indexes that are proposed in the program's scope. Consequently, neither the biological communities themselves nor any ecological process is evaluated (ANA, 2021).

3.1.2 European and Hungarian Legislation

Since 2000, the European Union (EU) has been implementing a challenging water policy known as the Water Framework Directive (WFD) to minimize stresses and achieve a high or good ecological status for all European water bodies. This policy aims to safeguard and develop water resources and aquatic ecosystems to achieve this goal, EU Member States have to assess the biological condition of rivers, lakes, and coastal waters on their respective soils and come up with ways to lessen substantial anthropogenic pressures that have an impact on status. (Ramos-Merchante & Prenda, 2017).

Based on techniques for evaluating biological quality components, the ecological status is a synthetic design that depicts the condition of water bodies from high, good, moderate, poor, to bad based on Biological Quality Elements (BQE) which are the flora, phytoplankton, invertebrate fauna, and fish fauna. In combination with information on physical-chemical and hydromorphological conditions (Kristensen *et al.*, 2018).

The WFD, the EU's water legislation, provides a general definition of the ecological status after which each Member State builds national evaluation procedures. The ecological state assessment has been based on comprehensive Environmental Quality Standards (EQS), expert opinion, pressure evaluations, or mixtures of the above depending on the Member State (Grizzetti *et al.*, 2017). This framework provides a typological framework for describing naturally occurring freshwater surface water bodies utilizing two systems (system A and system B; referring to the two types of water bodies: rivers and lakes, respectively). System A includes mandatory features (altitude, geology, and size) while System B includes optional (physical and chemical such as slope or substrate composition) elements that are thought to be major drivers of the structure and composition of aquatic biotic assemblages (Kaponyi, 2013).

According to Csink & Kovács (2013) the Constitutional Court states that the obligation



of the Republic of Hungary to ensure that the State does not lessen the level of the protection of nature as provided by law unless doing so is unavoidable in order to uphold any other fundamental right or constitutional value is included in the right to a healthy environment as defined in Art. 18 of the Constitution, even in this case, the degree of protection cannot be decreased beyond what is necessary to accomplish the desired result. In order to preserve the natural environment that supports human existence, the protection provided by the legislation must be strict and prevent environmental damage.

On January 1, 2012, began with the implementation of the Hungarian Fundamental Law. Legislation on the environment and environmental-economic issues is affected and has importance by the Fundamental Law's rules. Hungary has been a member of those nations since 1972 whose constitutions make specific reference to environmental protection. The legislator is not required to abide by the scientific advice or to provide the greatest level of protection since other factors, such as other constitutional principles, the question of practicality, as well as economic and social policy objectives, should also be considered (Fodor & Bujdos, 2013).

One of the most important statements made by the Constitutional Court is the "non-derogation principle." According to this principle, it is prohibited to lower the degree of environmental protection (or environmental standards) already established and mandated by law, as doing so would result in permanent environmental damage. In the opinion of Fodor & Bujdos (2013), the provisions of the Hungarian Fundamental Law that deal with water recognize the earlier concept of protection: even though resource access is mentioned in relation to drinking water (since water is one of the most closely related services of the environment), it is indirectly related to the idea of sustainability.

Hungary has two important provisions: Article XXI and Article P; The purpose of Article P is to safeguard natural resources, however, it only lists two broad criteria that are not just related to the environment, such as the notion that natural resources are a part of the nation's shared history and must be protected and nurtured for future generations. Even then, Article XX does not go thus far in protecting drinking water, Article XXI recognizes and guarantees to all citizens the right to a healthy environment (Fodor & Bujdos, 2013).

3.1.3 Brazil Monitoring Regulation

The National Water and Basic Sanitation Agency (ANA) receives reports from several Brazilian states about the quality of surface water in their jurisdictions. ANA launched the National Network for Water Quality Monitoring (RNQA), which relies on a strategy of



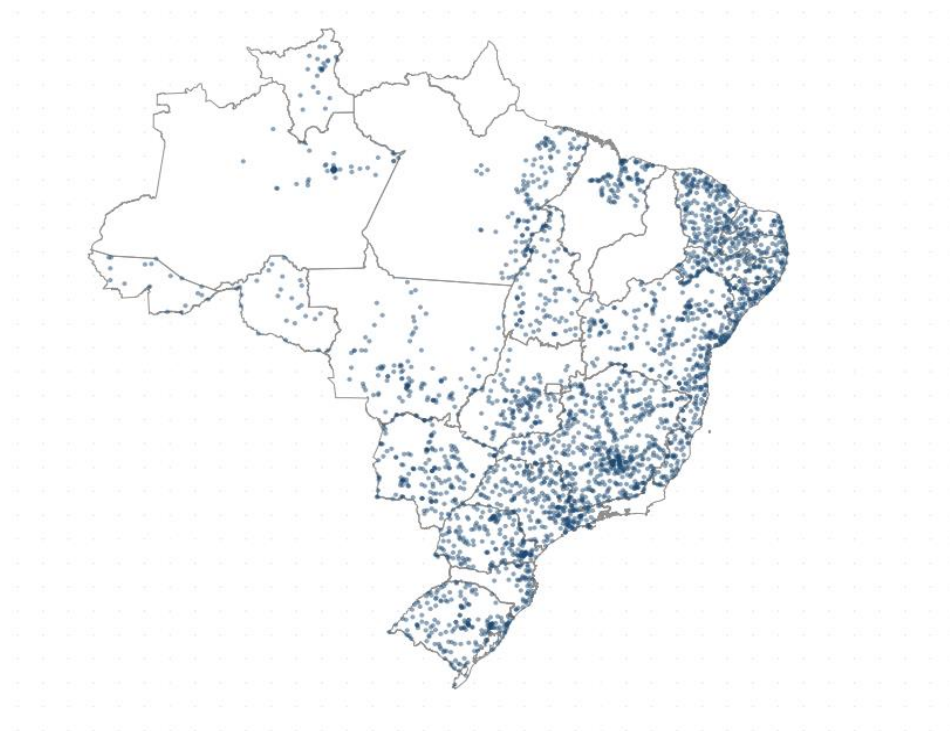
cooperation among the operators of the monitoring networks, standardizing and expanding monitoring on a national level.

The Water Quality Index (IQA) is adapted from the index developed by the National Sanitation Foundation and is the country's primary measure of water quality (Noori *et al.*, 2019). The IQA was created to assess the quality of untreated raw water intended for use in public supply, the calculation parameters are mostly indications of pollution brought on by the discharge of residential sewage, it is obtained by adding physical, chemical, and biological parameters found in water samples (Cicilinski & Filho, 2020; Ferreira *et al.*, 2015).

The total sum of the indicators measured results in the classification of water quality, on a scale ranging from: High, Good, Moderate, Poor, and Bad. The IQA is based on the current legislation, using 9 IQA parameters: Water Temperature, pH, Dissolved Oxygen, Biochemical Oxygen Demand, Thermotolerant Coliforms, Total Nitrogen, Total Phosphorus, Total Residue, and Turbidity. In 2020, there were 2.938 monitoring points and in 2023 the number of monitoring points increased to 3.4221, with 98.917 observations of IQA between 2010 to 2023 (Figure 1).

Figure 1

Monitoring site in operation in 2022 in Brazil.



Source: ANA, 2023.



In Brazil, the IQA boundaries are defined by the CONAMA n° 357/2005, which establish different standards of quality for the water bodies, the division into two groups related to the natural characteristics of Brazilian regions (Table 1). Group two is the Northern region and western part of Brazil, in this group, the water bodies have the features: the presence of soils rich in organic matter, water with low buffering capacity and generally lower pH (naturally acidic – 4.0 to 9.0) which consists of the States: Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Maranhão (Western part). The first group is the other regions in Brazil, in this group the water bodies have the features: different types of soils, less acidic (pH range of 6.0 to 9.0) and high buffering capacity, consisting of the States: Alagoas, Bahia, Ceará, Espírito Santo, Goiás, Maranhão (Eastern part), Mato Grosso do Sul, Minas Gerais, Paraíba, Pernambuco, Piauí, Paraná, Rio de Janeiro, Rio Grande do Norte, Rio Grande do Sul, Santa Catarina, São Paulo, Sergipe, Tocantins.

The CONAMA n° 357/2005 resolution also classified the rivers regarding the water uses, as Class 1: with high requirement, for supply for human consumption and conservation of aquatic environments; to Class 4 less requirement, for navigation and dilution of pollutants (Figure 3). At the Federal level, some rivers that are not categorized under this classification have no obligation of monitoring, depending on the integrated water resources management of the States or the institutions that find the relevance of this water resource (Veiga & Magrini, 2013; Miranda & Reynard, 2020; Nicollier *et al.*, 2022). Some States in Brazil have state environmental agencies or universities that often monitor the rivers in their territory regardless of their classification by CONAMA, for example, CETESB (SP), IGAM (MG), IEMA (ES) and some academic research and do analysis with more parameters.

3.1.4 Hungarian Monitoring Regulation

The dataset is based on river body categories (stipulated by the WFD) in Hungary with their Biological Quality Element (BQE), i.e. Macroinvertebrates EQR values and correlated nutrient concentration (Table 1) In the WFD the objective is achieving the “Good” ecological and chemical quality status for all water types. The rivers need to achieve this for the conservation of the aquatic ecosystems.

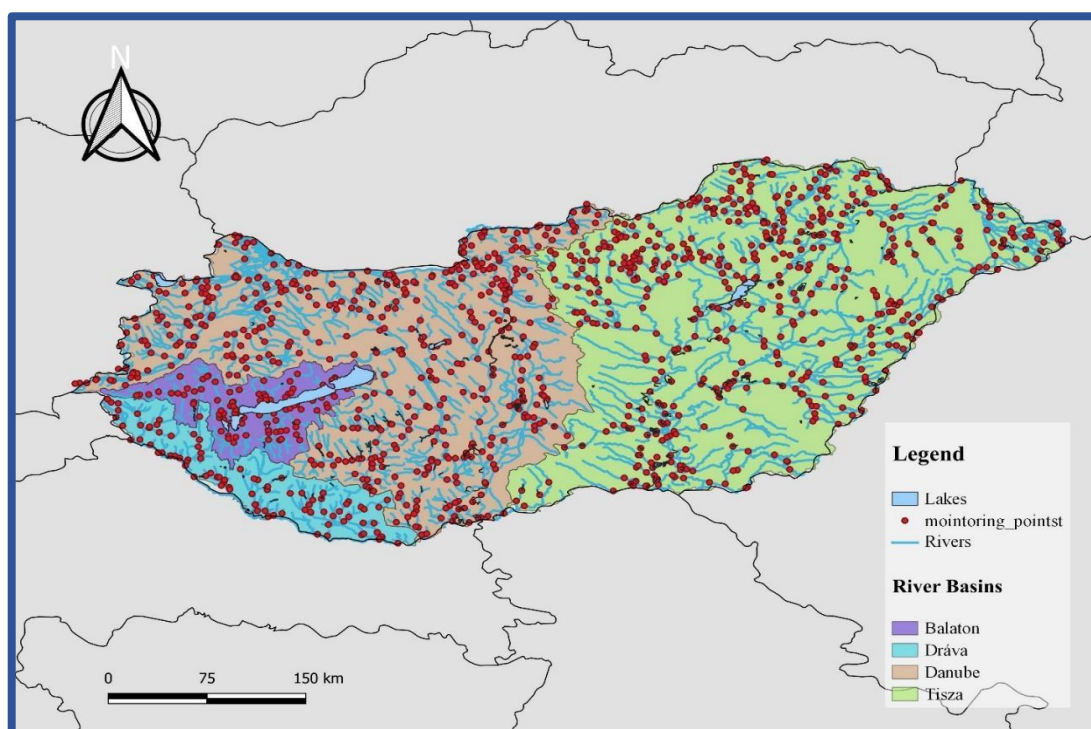
The data were collected at 879 river monitoring sites (Figure 2) twice a year; at each location, water samples were collected for analysis. According to the National Monitoring Program structure, the first samples were collected in the spring, usually between April/May, and the second ones were collected in the early fall, generally in September.



By following the WFD, all water types are intended to have "good" ecological and chemical conditions. The EQR evaluates different types of water bodies (lakes, transitional and coastal waters, and rivers), and uses a reference value given by the biological elements corroborated by physical and chemical and hydromorphological quality parameters. The score that summarizes the difference between observed and predicted BQEs is named the ecological quality ratio (EQR).

Figure 2

Monitoring sites in Hungary



For the monitoring, Hungary had 879 river monitoring sites, the data collection occurs twice a year (1° April/May and 2° the early fall, generally in September) Using 9 parameters: Biological Oxygen Demand (mgL-1; "BOD"), Chemical Oxygen Demand (mgL-1; "COD"), Dissolved oxygen (mgL-1; "DO"), Ammonium (mgL-1; "NH₄-N"), Phosphate (mgL-1; "PO₄"), Total Phosphate (mgL-1; "TP"), Total Nitrogen (mgL-1; "TN"), Total Organic Carbon (mgL-1; "TOC") and Conductivity ($\mu\text{S cm}^{-1}$), the Hungarian boundaries are under the WFD as demonstrated on table 1.



3.2 COMPARISON AND ANALYSIS

The quality of water in rivers is more than an environmental issue; it's a reflection of how we value life and the future of generations to come. In Brazil, natural wealth coexists with historical challenges of supervision and implementation of laws, while Hungary, with its European tradition, is advancing in rigorous standards of water protection. Despite the geographical and cultural differences, both countries share the same goal: to ensure that rivers continue to be a source of life, not of concern. This discussion invites us to reflect on how legislation can evolve to protect not only water but also the balance between progress and nature.

Table 1 shows the boundaries on both countries and Table 2 and 3, demonstrate the difference between Brazil and Hungary monitoring characteristics and the similarity in their legislation.

Table 1

The boundaries in the two countries. The Brazilian division according to CONAMA n° 357/2005 and the boundaries established to the groups and the Hungarian boundaries established by WFD.

Group	IQA Brazil	EQR Hungary
Group 1	91 – 100 / High 71 – 90 / Good 51 – 70 / Moderate 26 – 50 / Poor 0 – 25 / Bad	0.8 – 1.0 / High 0.6 – 0.8 / Good 0.4 – 0.6 / Moderate 0.2 – 0.4 / Poor 0.0 – 0.2 / Bad
Group 2	80 – 100 / High 52 – 79 / Good 37 – 51 / Moderate 20 – 36 / Poor 0 – 19 / Bad	

Table 2

Legal Frameworks between Brazil and Hungary regarding the monitoring characteristics.

Brazil	Hungary
The Brazilian constitution of 1988 article 225, caput	The Fundamental Law - Article XXI and Article P
Water Resources Law (Law No. 9.433/97)	The Water Act (Act LVII of 1995)
Environmental Policy Act (Law No. 6.938/81)	The Environmental Protection Act (Act LIII of 1996)
Solid Waste Policy (Law No. 12.305/10)	Waste Management Act (Act CLXXXV of 2012)
National Water Resources Management System (Law No. 9.433/97)	Government Decree No. 314/2005 (requirements of the European Union's Water Framework Directive)

Table 2 discusses the similarities in legal frameworks between Brazil and Hungary. The comparison between Article 225 of the 1988 Brazilian Constitution and Article XXI of the



Hungarian Basic Law reveals a theoretical convergence in accepting the right to a healthy environment as essential for quality of life and collective well-being. The Brazilian Constitution states, “everyone has the right to an ecologically balanced environment, which is a common good and essential to a healthy quality of life, and the public authorities and the community must defend and preserve it for present and future generations”. The Hungarian Basic Law says, “everyone has the right to a healthy environment”, assured by the state by “protecting the natural environment, promoting sustainable development and ensuring that future generations can also enjoy a healthy environment”. Both statements take together the panoramic vision in which environmental protection and human development are embedded, which makes clear that the State and society have an obligation to natural resource preservation.

Brazil's Water Resources Law (Law No. 9.433/97) and Hungary's Water Law (Law LVII of 1995) reveal similar approaches, but with different nuances, in the management and protection of water resources. Article 1 of the Brazilian law states that “the National Water Resources Policy is based on the following foundations: I - water is a public domain asset; II - water is a limited natural resource, endowed with economic value; III - in situations of scarcity, the priority use of water resources is human consumption and animal desiccation; IV - the management of water resources must always provide for the multiple uses of water.” Article 1 of the Hungarian law states that “water is a natural resource of public interest, essential for life, the protection and sustainable use of which are obligations of the state and citizens”. Both laws recognize water as a public good and an essential resource. Still, while Brazilian legislation emphasizes the economic value of water and the prioritization of human consumption in situations of scarcity, Hungarian law highlights the shared responsibility between the state and citizens in the protection and sustainable use of water resources.

Brazil's National Environmental Policy (Law No. 6.938/81) and Hungary's Environmental Protection Law (Law LIII of 1996) also reveal a common basis for concern about environmental protection. Article 2 of the Brazilian law states that “the purpose of the National Environmental Policy is to preserve, improve and restore environmental quality that is conducive to life, to ensure conditions in the country for socio-economic development, the interests of national security and the protection of the dignity of human life”. Article 1 of the Hungarian law states that “environmental protection aims to guarantee a healthy environment for present and future generations, promoting sustainable development and the conservation of natural resources”. Both laws recognize the importance of a healthy environment for quality of life and socio-economic development, but while Brazilian legislation emphasizes the need to balance environmental protection with economic development and national security, Hungarian



law places greater emphasis on the concept of sustainability and intergenerational responsibility.

Brazil's National Solid Waste Policy (Law No. 12.305/10) and Hungary's Waste Management Law (Law CLXXXV of 2012) both have river water quality as a priority since inadequate solid waste management is one of the main sources of water pollution. Both laws are intended to avoid water body contamination practices, including but not limited to the environmentally acceptable disposal of waste (hazardous and non-hazardous), promoting recycling and reverse logistics. Both acknowledge the importance of sustainable waste management for water quality maintenance, continued availability of human consumption, biodiversity and economic use as well as the necessity to implement integrated and effective public policies.

Comparing Brazil's 1997 Law No. 9.433/97 (National Water Resources Management System) with Hungary's Government Decree No. 314/2005 (cumulative implementation of the European Union Directive on Water Framework) they have many parallels in terms of objectives and principles, though there are differences in geopolitical (as well as associated regulatory) settings. Both adopted documents consider water as a primary natural resource, that is both essential and scarce and must be managed in an integrated way. Article 1 of the Brazilian law reads "water is a public good" and "the management of water resources must always provide for the multiple uses of water". Likewise, the Hungarian Decree No. 1 defines the objectives of water management as well with the aim that all water bodies are in a "good ecological and chemical state" ensuring sustainable use of our water resources. The two texts put high attention to the safeguarding of aquatic ecosystems and strive for a finding in the middle that confluent sensu corresponds to the use versus preservation. Moreover, both the Brazilian legislation and the Hungarian Decree are based on an integrated and participatory basis: river basin committees as co-constitutive institutions of developing management in Brazil, The Hungarian Decree comply with the Water Framework Directive principle (incoming from CE in EU) of improving participation and good practice regulation more general at river basin scale. The data illustrates that water sustainability is sought with theoretical and practical convergence focusing on water as an important resource that needs to be preserved equitably and responsibly.



Table 3

Differences in Water Quality Monitoring in Brazil and Hungary

	Brazil	Hungary
Monitoring Infrastructure	Network of water quality monitoring stations (urban areas majority)	Extensive monitoring network (both natural and urban areas)
Monitoring Parameters	Biological Oxygen Demand, Chemical Oxygen Demand, Total Suspended Solids, and Fecal Coliforms	Wide range of parameters, including heavy metals, pesticides, and other organic pollutants
Monitoring Frequency	Quarterly or semi-annual basis	Monthly or even weekly
Data Availability	Not Always available to the public (some States) or not updated	Under Request
Water Resources	Large country with abundant water resources, including the Amazon River and the Guarani Aquifer	Landlocked country with a limited amount of surface water and mostly relies on groundwater resources

Table 3 shows the differences in monitoring in both countries. The monitoring in Brazil demonstrated on the table is based on national guidelines; as mentioned, some states carry out more complex water analysis and others just follow the national guidelines. In Brazil, according to the ANA Conjuncture Report (2023) and the Digital Water Quality Report, more than 70% of the monitoring locations' water quality indices are considered “Good” status in the country. According to the ANA report (2023), in 2021 and 2022 the median values of the parameters were calculated with two observations minimum in this two-year period, this number of observations was adopted due to the repercussions of the COVID-19 pandemic effects on monitoring networks functionality, particularly in 2021 when there were significant effects on sample gathering was significantly affected.

The final ecological quality ratio (EQR) is the result of the comparative score between observed and expected BQEs. In accordance with Smith's (2009) recommendations which are based on the work of Jolicoeur (1990), the correlation value is $R > 0.6$. To establish a good correlation between the EQR values and the nutrient concentration, the R^2 value should be > 0.36 . Phillips *et al.* (2018) described the EQR calculation as based on the thresholds, as obligatory by the Water Framework Directive.

In the WFD, some EU countries' reports show that 38% of water bodies are in good chemical status, while 16% of the water bodies have an unidentified chemical state and 46% are not reaching good chemical status. According to the 3rd River Basin Management Plan around 37% of the surface water bodies are in good or high ecological status. The nations indicated that atmospheric deposition and discharge by urban wastewater treatment facilities



are the primary forces preventing the achievement of good status, but these are not the only problems.

In Hungary, most of the pressures on water bodies are related to domestic wastewater, industrial wastewater, and livestock farming, this type of influence is considered diffuse pollution. These sources are responsible for several impacts, such as nutrient enrichment, chemical pollution, and altered habitats due to morphological changes. Kristensen *et al.* (2018) described that the benthic invertebrates are sensitive to diverse pressures, such as organic increase causing oxygen deficiencies, habitat changes, acidification, fine sediments, and agricultural pesticide emissions; thus, they are considered excellent bioindicators of the quality of environments.

The majority of EQR values were achieved below the Hungarian nutrient threshold level in the correlation between nutrient parameters. The Mountain Streams and Lowlands had EQR values above 0.6, being classified as a Good status and for Hilly ones were between 0.4 to 0.6, showing a Moderate status. Overall, the water bodies in Hungary are in moderate or good ecological status corresponding to an inadequate conservation status on the other river types, Hungary needs more strict restrictions. The BOD, PO₄-P, TOC, and Conductivity were the best-performing nutrient indicators. Waterbodies with moderate or good ecological quality are considered to have insufficient conservation status for river types.

In the Brazilian case, in 2017, more than 70% of the monitoring locations' water quality indices were considered to be of high quality, according to the National Water and Basic Sanitation Agency (ANA) conjuncture report (2021). In research by the SOS Mata Atlântica Foundation (2017), which looked at 184 rivers, it was shown that just 2.5% of the locations had acceptable quality, while 27.5% had bad or extremely bad quality. The survey indicated that 70% of the sites were in normal condition. An integrated approach is required in order to make some progress in raising environmental consciousness in Brazil.

4 CONCLUSION

The results found in this study could provide input for improving public policies and water resource management strategies. Both countries need an improvement in monitoring and conservation actions. Brazil has a necessity of the participation of the States in the monitoring helping to disseminate their data to the public and update their databases. Unfortunately, some reports are not as clear as the data and the analysis, so the reader can better understand the situation in their country. Inadequate budget, poor infrastructure, and trouble coordinating



across several agencies and stakeholders are some of the issues both nations confront when it comes to water quality monitoring. Both nations are thus attempting to solve these issues and enhance their surveillance systems.

In conclusion, in order to improve water safety and raise environmental consciousness in Brazil and Hungary, certain measures need to be implemented. This would necessitate an integrated approach including researchers, water industry stakeholders, and government representatives.

ACKNOWLEDGEMENTS

I would like to express my gratitude to the Stipendium Hungaricum program for the financial support that made this study possible. I would also like to thank the DRI - Department of Tisza Research at Danube Research Institute in Hungary for the institutional support and the infrastructure made available for the development of this research.

REFERENCES

- Act CLXXXV of 2012 on waste
(2012) Hungarian Official Journal / Magyar Közlöny
Act. No. 160 from 30th November, 26904-26947
- Act LIII. of 1996 on Nature Conservation in Hungary. 2025, www.asser.nl/upload/eel-webroot/www/documents/HUN/hungary%20Nature%20Conservation%20law.htm. Accessed 10 Jun. 2023.
- Act LVII of 2013 on the Protection of Waters. Available at: http://net.jogtar.hu/jr/gen/hjegy_doc.cgi?docid=A1300057.TV. Accessed 9 Jun. 2023.
- Act XLIII of 1996 on the General Rules of Environmental Impact Assessment. Available at: http://net.jogtar.hu/jr/gen/hjegy_doc.cgi?docid=99600043.TV. Accessed 5 Jun. 2023
- Agência Nacional De Águas E Saneamento Básico - ANA (BRASIL). Conjuntura dos recursos hídricos no Brasil 2023: informe anual. Agência Nacional de Águas e Saneamento Básico. Brasília: ANA, 2024.
- Agência Nacional De Águas E Saneamento Básico - ANA (BRASIL). Conjuntura dos recursos hídricos no Brasil 2021: informe anual. Agência Nacional de Águas e Saneamento Básico. Brasília: ANA, 2022.
- Ahiablame, L. M., Engel, B. A., & Chaubey, I. (2012). Effectiveness of low impact development practices: literature review and suggestions for future research. *Water, Air, & Soil Pollution*, 223, 4253-4273.



- Akhtar, N., Syakir Ishak, M. I., Bhawani, S. A., & Umar, K. (2021). Various natural and anthropogenic factors responsible for water quality degradation: A review. *Water*, 13(19), 2660.
- Araújo, R. S., da Gloria Alves, M., de Melo, M. T. C., Chrispim, Z. M., Mendes, M. P., & Júnior, G. C. S. (2015). Water resource management: A comparative evaluation of Brazil, Rio de Janeiro, the European Union, and Portugal. *Science of the Total Environment*, 511, 815-828. (CONAMA Resolution No. 357, Brazil 2005)
- Assessment, M. E. (2005). *Ecosystems and human well-being: wetlands and water*. World Resources Institute.
- Atlântica, S. M. (2017). *Análise da qualidade da água. Projeto observando os Rios*.
- Bald, J., Borja, Á., Muxika, I., Franco, J., & Valencia, V. (2005). Assessing reference conditions and physico-chemical status according to the European Water Framework Directive: a case-study from the Basque Country (Northern Spain). *Marine pollution bulletin*, 50 12, 1508-22. <https://doi.org/10.1016/J.MARPOLBUL.2005.06.019>.
- Boon, P., & Raven, P. (Eds.). (2012). *River conservation and management*. John Wiley & Sons.
- BRASIL. Constituição (1988). In Presidência da República. Retrieved from: <http://www.planalto.gov.br/ccivil_03/constituicao/constitui%C3%A7ao.htm>
- BRASIL. Lei n. 9.433, 8 jan. 1997. Institui a Política Nacional de Recursos Hídricos. *Diário Oficial da União*. Brasília. 1997.
- BRASIL. Resolução CONAMA 357, de 17 de março de 2005. Conselho Nacional de Meio Ambiente. Retrieved from: <www.mma.gov.br/port/conama/res/res05/res35705.pdf>.
- Chung, M. G., Frank, K. A., Pokhrel, Y., Dietz, T., & Liu, J. (2021). Natural infrastructure in sustaining global urban freshwater ecosystem services. *Nature Sustainability*, 4(12), 1068-1075.
- Cicilinski, A., & Filho, J. (2020). A new water quality index elaborated under the brazilian legislation perspective. *International Journal of River Basin Management*, 20, 323 - 334. <https://doi.org/10.1080/15715124.2020.1803335>.
- Cosgrove, W. J., & Loucks, D. P. (2015). Water management: Current and future challenges and research directions. *Water Resources Research*, 51(6), 4823-4839.
- Csink, L., & Kovács, J. T. (2013). Paradigm shift in the Constitutional Character of Environment.
- Dapena, A., Morollón, F., Pires, M., & Gomes, A. (2017). Convergence in Brazil: new evidence using a multilevel approach. *Applied Economics*, 49, 5050 - 5062. <https://doi.org/10.1080/00036846.2017.1299101>.
- De Brito, P., & De Azevedo, J. (2020). Charging for Water Use in Brazil: State of the Art and Challenges. *Water Resources Management*, 34, 1213 - 1229. <https://doi.org/10.1007/s11269-020-02501-y>.



- Espécie, M., Carvalho, P., Pinheiro, M., Rosenthal, V., Da Silva, L., De Carvalhaes Pinheiro, M., Espig, S., Mariani, C., Almeida, E., & Sodré, F. (2019). Ecosystem services and renewable power generation: A preliminary literature review. *Renewable Energy*. <https://doi.org/10.1016/J.RENENE.2019.03.076>.
- European Commission. (2000). Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy (Water Framework Directive). *Official Journal of the European Communities*, L 327, 1-72.
- European Commission. (2013). Directive 2013/39/EU of the European Parliament and of the Council of 12 August 2013 amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy. *Official Journal of the European Union*, L 226, 1-17.
- Fan, J., Wang, S., Li, H., Yan, Z., Zhang, Y., Zheng, X., & Wang, P. (2020). Modeling the ecological status response of rivers to multiple stressors using machine learning: A comparison of environmental DNA metabarcoding and morphological data. *Water Research*, 183, 116004.
- Ferreira, K., Lopes, F., Andrade, E., Meireles, A., & Da Silva, G. (2015). Adapting the National Sanitation Foundation water quality index to the Brazilian semiarid. *Revista Ciencia Agronomica*, 46, 277-286. <https://doi.org/10.5935/1806-6690.20150007>.
- Fodor, L., & Bujdos, Á. (2013). Right to environment and right to water in the Hungarian Fundamental Law. Szabó M & Greksza V, (eds), *Right to water and the protection of fundamental rights in Hungary*, Pécsi Egyetem, Pécs, 34-48.
- Grizzetti, B., Pistocchi, A., Liqueste, C., Udias, A., Bouraoui, F., & Van De Bund, W. (2017). Human pressures and ecological status of European rivers. *Scientific reports*, 7(1), 1-11.
- Hungarian Government Decree 71/2011. (VIII. 3.) on the Environmental Quality Objectives of Surface Waters. Available online (in Hungarian): http://njt.hu/cgi_bin/njt_doc.cgi?docid=137882.396585. Accessed 10 Jun. 2023
- Hungarian Ministry of Agriculture. (2014). Decree No. 40/2014. (II. 26.) FM. Budapest, 2014. (In Hungarian)
- Hungarian National Water Management Authority (NVF). (2010). Decree No. 21/2010. (II.26.) KÖM. Budapest, 2010. (In Hungarian)
- Hungarian River Basin Management Plans. Available at: <https://www.kvvm.hu/en/river-basin-management-plans>
- Hungary. (2021). The Fundamental Law of Hungary: English translation of the consolidated version incorporating the First to Ninth Amendments, as in force on 23 December 2020. Ministry of Justice. Retrieved from: <https://www.parlament.hu/documents/125505/138409/Fundamental+law/73811993-c377-428d-9808-ee03d6fb8178>



- Jewitt, G. (2002). Can integrated water resources management sustain the provision of ecosystem goods and services?. *Physics and Chemistry of the Earth, Parts A/B/C*, 27(11-22), 887-895.
- KAPONYI, E. K. (2013). SOME LEGAL ASPECTS OF CENTER AND PERIPHERY IN THE EUROPEAN UNION. In *Le clivage centre-périphérie dans une approche interdisciplinaire: actes du colloque de clôture du programme Centre-périphérie*, Paris, 1-3 décembre 2011 (p. 329). *Cahiers de la Nouvelle Europe*.
- Kristensen, P., Whalley, C., Zal, F. N. N., & Christiansen, T. (2018). European waters assessment of status and pressures 2018. EEA Report, (7/2018).
- Lee, J., Lee, S., An, K., Hwang, S., & Kim, N. (2020). An Estimated Structural Equation Model to Assess the Effects of Land Use on Water Quality and Benthic Macroinvertebrates in Streams of the Nam-Han River System, South Korea. *International Journal of Environmental Research and Public Health*, 17. <https://doi.org/10.3390/ijerph17062116>.
- Miranda, G., & Reynard, E. (2020). Integrated Water Resources Management in Federations: The Examples of Brazil and Switzerland. *Water*. <https://doi.org/10.3390/w12071914>.
- Muxika, I., Borja, Á., & Bald, J. (2007). Using historical data, expert judgement and multivariate analysis in assessing reference conditions and benthic ecological status, according to the European Water Framework Directive. *Marine pollution bulletin*, 55 1-6, 16-29. <https://doi.org/10.1016/J.MARPOLBUL.2006.05.025>.
- Nicollier, V., Bernardes, M., & Kiperstok, A. (2022). What Governance Failures Reveal about Water Resources Management in a Municipality of Brazil. *Sustainability*. <https://doi.org/10.3390/su14042144>.
- Noori, R., Berndtsson, R., Hosseinzadeh, M., Adamowski, J., & Abyaneh, M. (2019). A critical review on the application of the National Sanitation Foundation Water Quality Index.. *Environmental pollution*, 244, 575-587 . <https://doi.org/10.1016/j.envpol.2018.10.076>.
- Phillips, G., Kelly, M., Teixeira, H., Salas, F., Free, G., Leujak, W., Lyche Solheim, A., Várbiro, G., Poikane, S. (2018). Best practice for establishing nutrient concentrations to support good ecological status, EUR 29329 EN, Publications Office of the European Union, Luxembourg. doi:10.2760/84425
- Ramos-Merchante, A., & Prenda, J. (2017). Macroinvertebrate taxa richness uncertainty and kick sampling in the establishment of Mediterranean rivers ecological status. *Ecological Indicators*, 72, 1-12.
- Shortle, J. S., Mihelcic, J. R., Zhang, Q., & Arabi, M. (2020). Nutrient control in water bodies: A systems approach. *Journal of Environmental Quality*, 49(3), 517-533.
- Smith, R. J. (2009). Use and misuse of the reduced major axis for line-fitting. *American Journal of Physical Anthropology: The Official Publication of the American Association of Physical Anthropologists*, 140(3), 476-486.
- Veiga, L., & Magrini, A. (2013). The Brazilian Water Resources Management Policy: Fifteen Years of Success and Challenges. *Water Resources Management*, 27, 2287-2302. <https://doi.org/10.1007/s11269-013-0288-1>.



- Wang, D., Hubacek, K., Shan, Y., Gerbens-Leenes, W., & Liu, J. (2021). A review of water stress and water footprint accounting. *Water*, 13(2), 201.
- Wang, L., Robertson, D. M., & Garrison, P. J. (2007). Linkages between nutrients and assemblages of macroinvertebrates and fish in wadeable streams: implication to nutrient criteria development. *Environmental management*, 39, 194-212.
- WWAP. The United Nations World Water Development Report 2017: Wastewater, the untapped resource. United Nations World Water Assessment Programme (WWAP). Paris, United Nations Educational, Scientific and Cultural Organization. 2017.