

**UPRAVLJANJE INDUSTRIJSKIM OTPADNIM VODAMA U SRBIJI
KAO PREDUSLOV ODRŽIVOG UPRAVLJANJA VODNIM
RESURSIMA**Original scientific paper
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APSTRAKT: Upravljanje vodnim resursima, posebno u kontekstu industrijskih otpadnih voda, predstavlja jedan od najvažnijih izazova za održivu zaštitu životne sredine u Srbiji. U poslednjim godinama, sve učestalije pojave nekontrolisanog ispuštanja otpadnih voda iz velikih industrijskih postrojenja postavljaju ozbiljnu pretnju ekosistemima i javnom zdravlju. Mnogi industrijski subjekti ne poseduju adekvatne sisteme za tretman otpadnih voda, čime se dodatno pogoršava stanje vodnih resursa prilikom direktnog ispuštaja otpadnih voda. Stoga je za ostvarivanje održivog upravljanja vodnim resursima, neophodno uspostaviti efikasne sisteme za tretman otpadnih voda, kao i implementirati strože regulative koje će obezbediti odgovorno ponašanje industrije prema životnoj sredini. Stim u vezi ovaj rad ima za cilj da ukaže na značajne mehanizme i instrumente upravljanja vodnim resursima koji su potrebni kako bi se osiguralo održivo upravljanje ovim vitalnim resursima, te da predloži mere zaštite od zagađenja, čime se može doprineti očuvanju kvaliteta voda i zdravlja lokalnih zajednica.

Ključne reči: održivost, vodni resursi, industrijske otpadne vode

**INDUSTRIAL WASTEWATER MANAGEMENT IN SERBIA AS A PREREQUISITE
FOR SUSTAINABLE WATER RESOURCES MANAGEMENT**

ABSTRACT: Management of water resources, especially in the context of industrial wastewater, represents one of the most important challenges for sustainable environmental protection in Serbia. In recent years, increasingly frequent occurrences of uncontrolled discharge of wastewater from large industrial plants pose a serious threat to ecosystems and public health. Many industrial entities do not have adequate wastewater treatment systems, which further worsens the condition of water resources during direct discharge of wastewater. Therefore, in order to achieve sustainable

management of water resources, it is necessary to establish efficient systems for the treatment of waste water, as well as to implement stricter regulations that will ensure the responsible behavior of the industry towards the environment. In this regard, this work aims to point out the significant mechanisms and instruments of water resource management that are needed to ensure the sustainable management of these vital resources, and to propose measures to protect against pollution, which can contribute to the preservation of water quality and the health of local communities.

Key words: sustainability, water resources, industrial wastewater

1. INTRODUCTION

Water, as a key resource and an essential condition for biosystem sustainability, is a vital factor in ecosystems and human societies. Its role is multiple, including biological, chemical and ecological functionality, which makes it a central element in the development of civilization. However, the growth of the demographic population and industrialization led to an exponential increase in the consumption of this resource, which, in combination with intensive anthropogenic activity, caused the accumulation of various polluting substances in water ecosystems. This water contamination includes a wide range of pollutants, including nutrients in excessive concentrations, pathogenic microorganisms, liquid and solid wastes, as well as chemicals of industrial origin. Such pollution causes the so-called water degradation, which results in a decrease in the quality and functionality of water ecosystems, endangering biological diversity and human health. Water pollution is considered one of the most critical environmental problems, as it leads to eutrophication, accumulation of toxins, disturbances in biochemical processes and reduction in the availability of safe water sources (Đorđević, 2019).

The trend of water pollution strongly warns of the urgent need for the implementation of integrated management systems and strategies for the preservation, rehabilitation and sustainable use of water resources. Effective measures include the improvement of purification technologies, regulation of emissions and the application of circular economy principles in order to minimize the anthropogenic impact on aquatic ecosystems and ensure the availability of clean water for future generations (Vranjanac, 2025).

In this regard, the paper presents the importance of industrial wastewater treatment and pollution protection measures, with the aim of improving water quality and sustainable management of this vital resource.

2. LEGAL FRAMEWORK FOR INDUSTRIAL WASTEWATER MANAGEMENT

As a candidate for membership in the European Union, Serbia undertook to harmonize its legal regulations and institutional capacities in the field of environmental protection with the *acquis communautaire*, i.e. the legal framework of the EU. This process includes the harmonization of national legislative acts with the *acquis*, which implies the transposition of EU directives and regulations into domestic legal systems, in order to ensure the consistent implementation of standards in environmental protection (Mitrović et al., 2025).

Furthermore, on a bilateral level, Serbia confirmed its commitment to regional cooperation with the countries of the Western Balkans and the EU on the implementation of measures to reduce environmental pollution, which was formalized by signing the Sofia Declaration in 2020. This document highlights the need for the integration of the latest European directives, including regulations for water quality monitoring, waste management, emissions from industrial plants, as well as the development of infrastructure projects for environmental rehabilitation (Malinauskaite et al., 2024).

The implementation of these measures includes the development and improvement of the system for continuous monitoring of the quality of water bodies, which includes the establishment of normative parameters for the assessment and maintenance of water quality in accordance with EU standards, as well as the construction of the necessary infrastructure to improve the environment. These steps reflect Serbia's commitment to fulfilling the *acquis* criteria and achieving sustainable development through the integration of EU environmental standards into the national legal framework and practice.

3. INDUSTRIAL WASTEWATER

Apart from being one of the main sources of pollution of water resources, the industrial sector is also among the most hazardous in terms of environmental and health safety.

In industrial production, water has various roles, starting from being a raw material in various stages of the production process, an intermediate product that participates in chemical reactions, to its role as a solvent for removing industrial waste and unwanted substances. In addition, water is used as a means for chemical, physical and biological elimination of waste materials, in the processes of purification, hydro-explosion, and industrial disinfection.

Just from the aforementioned role in the industrial sector, one can see the great need for the exploitation of this natural resource. In this connection, based on the data of the Republic Institute of Statistics of the Republic of Serbia, in 2024, in the industrial sectors, a total water consumption of 4,026 million m³ was recorded, which represents a slight increase of 0.2% compared to 2023. This trend indicates a relative stability in the total volume of water resource use in industry, but also a significant use of water in the production processes of industry (ECO-BULLETIN, 2024).

Structural analysis of water sources shows that the dominant part, i.e. 99.6% of the total water intakes, is provided from own water intakes. Within that, surface waters make up 98.7%, while underground waters participate with 0.9%. In contrast, a negligible share of 0.4% refers to water taken from the public water supply system (ECO-BULLETIN, 2024).

Observed by industrial sector, the dynamics of water consumption in 2024 compared to the previous year shows significant variations, which is shown in Table 1. In the mining sector, a marked growth of 39.4% was recorded, while in the processing industry, a decrease of 4.4% was registered. The electricity, gas and steam supply sector recorded a minimal growth of 0.1% (ECO-BULLETIN, 2024).

Table 1: Used water in the industrial sector, 2024

Republic of Serbia		(mil.m ³)
Sector	2023	2024
In total ¹⁾	4016	4026 ²⁾
B - Mining	20	28
C - Manufacturing industry	82	78
D - Supply of electricity, gas, steam and air conditioning	3914	3919

¹⁾ The area of waste collection, treatment and disposal is included

²⁾ The amount of flowing water for hydropower plants amounts to 174 930 mil. m³

The analysis of the structure of total water consumption indicates a distinct dominance of the electricity, gas and steam supply sector, which participates with 97.4%. Manufacturing industry participates with 1.9%, while mining has a share of 0.7%.

The total amount of wastewater generated from industrial production processes in 2024, based on the data of the Republic Institute of Statistics, shown in Table 2, amounted to 112 million m³. Of this, the largest share comes from the electricity, gas and steam supply sector (41.0%), followed by the processing industry (36.6%), while mining participates with 22.4% (ECO-BULLETIN, 2024).

Table 2: Wastewater in the industrial sector, 2024

Republic of Serbia		mil.m ³	
Sector	In total	Untreated	Treated
In total ^{1) 2)}	112	82	30
B - Mining	25	22	3
C - Manufacturing industry	41	15	26
D - Supply of electricity, gas, steam and air conditioning	46	45	1

¹⁾ Flowing water in hydroelectric power plants is not included.

²⁾ The area of waste collection, treatment and disposal is included.

From the aforementioned data, it can be seen that there is still a large amount of untreated water that is directly or indirectly discharged into recipients, thereby endangering the quality of water and the environment itself. In order to prevent the deterioration of water quality and the environment, emission limit values for certain groups or categories of polluting substances are determined by law and by-laws, namely for technological waste water before it is discharged into the sewers, technological and other waste water that is directly discharged into natural and artificial watercourses (Jovanović, 2016).

Due to the high content of various toxic and dangerous components, industrial wastewater especially requires specialized treatment procedures and wastewater treatments, including physical-chemical, biological and membrane processes, in order

to ensure their safe disposal or deployment in the environment, in accordance with current legal regulations and standards for environmental protection.

4. TREATMENT OF INDUSTRIAL WASTEWATER

There is no single and unique system for wastewater treatment because each wastewater has its own specific characteristics, especially when it comes to industrial wastewater. Treatment aims to remove pollution from wastewater so that it can be discharged into the recipient without harmful consequences or can be reused (Marinović et al., 2016).

There are four stages of wastewater treatment (Bryukhov & Ulrikh, 2022; Fernandes et al., 2024):

- I degree / primary treatment - refers to the mechanical treatment of wastewater to remove undissolved substances. It can be preliminary and primary. Preliminary purification removes floating solids.
- II degree / secondary purification - refers to biological purification that ensures the removal of dissolved organic matter.
- III degree / tertiary purification - removal of residual pollution, such as biogenic elements, non-biodegradable organic matter, pathogenic microflora, toxic substances
- IV degree / quaternary purification - represents the final purification to remove the remaining load and water disinfection if necessary.

Based on data from the Republic Institute of Statistics regarding wastewater treatment, a total of 30 million m³ were treated in 2024. The first degree covered the purification of 56.2% of the total amount of water treated, the second degree 22.5%, and the third stage 21.3%. The sectoral analysis shows that the highest percentage of purified water is metal production (16.8%), followed by production in the food industry (16.2%), production in the chemical industry (15.0%) and production of paper and paper products (11.0%). The remaining industrial areas together account for 41.0%. When it comes to water purification in the three previously analyzed industrial sectors, data on primary, secondary and tertiary water treatment are shown in Table 3 (ECO-BULLETIN, 2024).

Table 3: Treated water in the industrial sector, 2024.

Republic of Serbia		mil.m ³			
Sector		Treated water (treatment)			
		In total	I degree	II degree	III degree
In total ^{1) 2)}		31	17	7	7
B - Mining		3	0	3	-
C - Manufacturing industry		26	16	4	6
D - Supply of electricity, gas, steam and air conditioning		2	1	0	1

¹⁾ Cooling water is not included.

²⁾ The area of waste collection, treatment and disposal is included.

These results indicate a high concentration of water consumption in the energy sector, as well as the need for further improvement of the wastewater treatment system, especially in the context of sustainable management of water resources.

Within the scientific-research approach to the analysis of environmental protection in the Republic of Serbia, the Draft Environmental Protection Strategy identifies large industrial complexes as dominant sources of water resource pollution, with a special emphasis on industrial wastewater emissions. Among the biggest polluters are metallurgical, thermal energy and mining systems, whose activities generate significant pressure on surface and underground waters (Pavićević & Anđelković, 2022). Analysis of the existing regulatory framework indicates insufficient representation of clearly defined measures to control and reduce emissions of polluting substances from these industrial sectors.

In this regard, the analysis of the management of mineral and geological resources indicates that wastewater from the mining sector represents one of the key challenges in the field of environmental protection (Marinković et al., 2014). Deficiencies in the planning of mining activities, inadequate application of environmental impact assessment procedures, as well as limited functionality of the purification plant, due to financial and technological limitations, were identified as the causes of ineffective management.

Empirical findings confirm the aforementioned theses, whereby the territory of the city of Bor represents an illustrative example of a degraded ecological system, the so-called. "sacrifice zones" (Boyd & Keene, 2021). Intensive mining activities have led to a significant deterioration of water quality, which is manifested through increased concentrations of heavy metals and other pollutants (Đorđević & Mihajlović, 2022). Jurisprudence additionally confirms the operator's responsibility for inadequate waste water management, including the discharge of untreated water with a high content of sulfates, ammonia and heavy metals (Đorđević & Mihajlović, 2022).

A more detailed analysis of individual industrial systems further illuminates the complexity of the problem. In the Draft Environmental Protection Strategy, the industrial complex of the ironworks in Smederevo was identified as a potential polluter of water resources, given that it is characterized by a high degree of dependence on water resources, with significant amounts of water intake and discharge. Problems were observed in the management of water flows, including the lack of separate sewage systems and inadequate monitoring of water quality, as well as the lack of detailed analyzes of the presence of heavy metals and insufficiently developed monitoring (Gavrilović & Miladinović, 2009).

Similar challenges have been identified in the thermal energy sector. Additionally, the problem of thermal pollution of watercourses due to the discharge of cooling water represents a significant environmental risk, while the existing regulatory framework does not provide adequate control mechanisms.

Analysis of the application of modern technological solutions shows deviations from the standards based on the best available techniques. In some cases, outdated technologies are still used, while the implementation of infrastructure projects is often not fully aligned with regulatory requirements. In addition, an evaluation of the institutional response indicates limited effectiveness of punitive policies, with lenient sanctions and inconsistent enforcement of regulations contributing to the perpetuation of undesirable practices in the industry.

Monitoring results confirm significant deviations from prescribed water quality standards, including elevated concentrations of nutrients, suspended substances and metals in surface and underground waters. These findings point to the need to improve the water resources management system, strengthen regulatory mechanisms and more consistent application of the principles of sustainable development in the industrial sector.

5. CONCLUSION

Industrial wastewater management in Serbia represents a significant environmental and public health risk. This issue can be analyzed through multiple aspects, including legal, technical, infrastructural and socio-economic factors.

Legal regulations, such as laws on environmental protection and standards for waste water treatment, are often not sufficiently applied in practice or are imprecise, which leads to low efficiency in the implementation of obligations by industrial entities. This discrepancy between legal provisions and their implementation results in the fact that most industrial facilities do not have or do not use appropriate technologies for wastewater treatment.

From the technical aspect, infrastructure capacities are often inadequate or outdated, which makes it impossible to effectively remove pollutants, such as heavy metals, organic pollutants, and other harmful ingredients. The lack of modern treatment plants leads to the release of high concentrations of pollutants into the environment, causing biological and chemical changes in ecosystems, such as eutrophication and accumulation of toxic substances in living organisms.

Socio-economic factors, including lack of financial resources or motivation to invest in environmentally friendly technologies, also contribute to this problem. The lack of education and awareness about the importance of environmental protection further complicates the situation, because industry and local communities are often not sufficiently informed about the consequences of illegal and ineffective wastewater treatment.

If there are no systemic reforms that will include stricter legislation, modernization of infrastructure and raising environmental awareness, there is a danger of further deterioration of the environment and increased health risks for the population, including diseases caused by water and soil pollution.

From all of the above, it can be concluded that there is a big difference in the amount of water that is used in the industrial sector and that which is of adequate quality returned to the environment. It certainly affects both the quality of the water resource and the state of the healthy environment. Responsible water management is the only sure way to sustainable management of water resources.

REFERENCES

- [1] Boyd, D. R., & Keene, S. (2021). Special Rapporteur on human rights and the environment. *Human Rights Obligations Relating to the Enjoyment of a Safe, Clean, Healthy and Sustainable Environment*. globalactionplan.org.uk
- [2] Bovan, A., Stojanović, B., Dalmacija, B., Jovin-Radovanović, H. (2015). *Korišćenje i tretman komunalnih i industrijskih otpadnih voda u Republici Srbiji*. CEDEF, Pokrajinski sekretarijat za urbanizam, graditeljstvo i zaštitu životne sredine. <http://www.ekourbapv.vojvodina.gov.rs/wp-content/uploads/2019/12/KORISCENJE-I-TRETMAN-KOMUNALNIH-I-INDUSTRIJSKIH-OTPADNIH-VODA.pdf>

- [3] Bryukhov, M., & Ulrikh, D. (2022, July). Wastewater treatment: methods and prospects. In *IOP Conference Series: Earth and Environmental Science* (Vol. 1061, No. 1, p. 012049). IOP Publishing.
- [4] Dašić, T. & Đorđević, B. (2020). Upravljanje vodama u uslovima klimatskih promena. *Zbornik radova VODA 2020* (1-8). Trebinje: Srpsko društvo za zaštitu voda.
- [5] Fernandes, J., Ramísio, P. J., & Puga, H. (2024). A comprehensive review on various phases of wastewater technologies: Trends and future perspectives. *Eng*, 5(4), 2633-2661. <https://doi.org/10.3390/eng5040138>
- [6] Ferronato, N., & Torretta, V. (2019). Waste Mismanagement in Developing Countries: A Review of Global Issues Environmental research and public health. *International journal of environmental research and public health*. DOI:[10.3390/ijerph16061060](https://doi.org/10.3390/ijerph16061060)
- [7] Gavrilović, L., & Miladinović, S. (2009). Pollution of watercourses on the territory of Smederevo municipality and their protection. *Zbornik radova-Geografski fakultet Univerziteta u Beogradu*, (57), 19-34. <https://scindeks.ceon.rs/article.aspx?artid=1450-75520957019G&lang=sr>
- [8] Đorđević, M. (2019). Vode u Srbiji i njihovo zagađenje. Beograd: Univerzitet u Beogradu, Filološki fakultet, 380-388. DOI: [10.5937/vojdela1906380D](https://doi.org/10.5937/vojdela1906380D)
- [9] Đorđević, N., & Mihajlović, S. (2022). OSVRT NA SVETSKO PATENTE I DOMAĆA REŠENJA ODRŽIVOG RAZVOJA I BEZBEDNOSTI VODE. In *ŠESTA NAUČNO-STRUČNA KONFERENCIJA SA MEĐUNARODNIM UČEŠĆEM: „ODRŽIVI RAZVOJ I ZAŠTITA VODA (PRAVO, EKONOMIJA I MENADŽMENT)“ Zbornik radova, Vol.* (p. 93).
- [10] Malinauskaite, J., Delpech, B., Montorsi, L., Venturelli, M., Gernjak, W., Abily, M., ... & Jouhara, H. (2024). Wastewater reuse in the EU and Southern European countries: Policies, barriers and good practices. *Sustainability*, 16(24), 11277. <https://doi.org/10.3390/su162411277>
- [11] Markovic, S., & Ditrh, S. (2018). A Legal Protection of Waters in Republic of Serbia. *Law Theory & Prac.*, 35, 15. <https://casopis.pravni-fakultet.edu.rs/index.php/lt/article/view/57>
- [12] Marinković, V., Obradović, L., Bugarin, M., & Stojanović, G. (2014). Uticaj zagađenih otpadnih voda na kvalitet vode Borske reke i okolnih podzemnih voda. *Mining and Metallurgy Engineering Bor*, 3, 37-40. DOI: [10.5937/mmeb1403033m](https://doi.org/10.5937/mmeb1403033m)
- [13] Mitrović, A., Ratković Kovačević, N., Ilić, I., Ilić, D., & Anđelković, M. (2025). Assessment of Wastewater Treatment, Water Quality, and Climatic Stressors on Freshwater Resources in the European Union Compared to Serbia: Trends and Implications. In *Sinteza 2025-International Scientific Conference on Information Technology, Computer Science, and Data Science* (pp. 389-395). Singidunum University.
- [14] Pavićević, A., & Anđelković, M. (2022). Tehnologija i inženjerstvo u zaštiti voda. In 6. *Naučno-stručna konferencija sa međunarodnim učešćem: „održivi razvoj i zaštita voda (pravo, ekonomija i menadžment)“ Zbornik radova Vol. 2* (p. 146).
- [15] Vranjanac, Ž. (2025). State of the wastewater treatment system in southeastern Serbia by municipalities and cities. *Facta Universitatis, Series: Working and Living Environmental Protection*, 025-032. <https://doi.org/10.22190/FUWLEP250116003V>