FACTA UNIVERSITATIS
Series: **Working and Living Environmental Protection** Vol. 22, Nº 1, 2025, pp. 25 - 32
https://doi.org/10.22190/FUWLEP250116003V

Review scientific paper

STATE OF THE WASTEWATER TREATMENT SYSTEM IN SOUTHEASTERN SERBIA BY MUNICIPALITIES AND CITIES

Žarko Vranjanac

University of Niš, Innovation Center, Serbia

ORCID iD: Žarko Vranjanac https://orcid.org/0000-0002-0893-8330

Abstract. *This paper focuses on the state of wastewater treatment systems in Southeastern Serbia, specifically within the municipalities and cities of the Nišava, Toplica, Pirot, Jablanica and Pčinja districts. It provides a comprehensive overview of wastewater treatment systems in Europe and globally, offering a comparative perspective on Serbia's current status. This study conducts research and a comparative analysis using an indicator to monitor the state of wastewater treatment in the Republic of Serbia, across regions, and in cities and municipalities of Southeast Serbia, based on the most recent available data. Key results and findings are presented, followed by conclusions derived from the analysis, aiming to contribute to a deeper understanding of the challenges and opportunities in improving wastewater treatment systems in Southeastern Serbia.*

Key words: *Wastewater treatment, Indicators, Public utilities, Comparative analysis*

1. INTRODUCTION

In contemporary global conditions, approximately 700 million people lack access to sanitation systems, highlighting the urgency of addressing Sustainable Development Goal 6 – Clean Water and Sanitation. This ambitious goal aims to reduce untreated wastewater by 50% by 2050. Globally, the treatment of wastewater from urban areas has increased by approximately 2.29%, rising from 55.5% in 2020 to 57.8% in 2022 [1]. The importance of public utilities, particularly drinking water supply and wastewater management, is underscored by the fact that one in five neonatal deaths worldwide is linked to waterborne diseases [2].

In the global context of wastewater treatment, Europe leads with a treatment rate of 70.6%, followed by the global average of 57.8%. In Serbia, however, only 36.5% of generated wastewater undergoes treatment before being discharged into surface water recipients such as rivers and lakes, as shown in Fig. 1. Despite these statistics, Serbia's wastewater treatment projections remain optimistic, particularly in the context of this study, which focuses on Southeastern Serbia.

Received: January 16, 2025 / Revised March 18, 2025 / March 24, 2025
Corresponding author: Žarko Vranjanac
University of Niš, Innovation Center, Univerzitetski trg 2, 18000 Niš, Serbia
E-mail: zarevranjanac@gmail.com

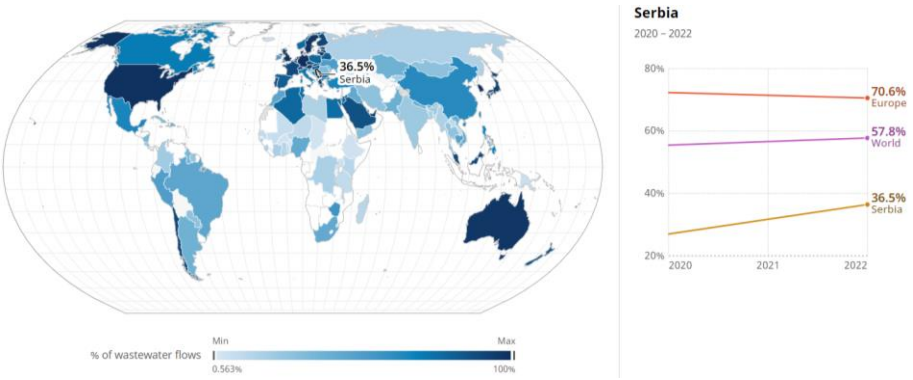

Fig. 1 Landscape of the safely treated domestic wastewater flows in Europe, the World and Serbia from 2020 to 2022 [3]

In developed EU countries, approximately 90% of urban wastewater is systematically collected and treated. Nations such as Austria, Germany, Luxembourg, and the Netherlands achieve a 100% treatment rate for their wastewater. In contrast, EU countries like Romania and Malta, as well as Balkan countries such as Albania, Serbia, North Macedonia, and Bosnia and Herzegovina, treat less than 50% of their wastewater. Examples of best practices can be observed in cities like Amsterdam (the Netherlands). Amsterdam operates state-of-the-art facilities that incorporate circular economy principles, extracting resources such as biogas and phosphates during the treatment process, with innovative projects like Buiksloterham piloting decentralized wastewater treatment through vacuum sewer systems and floating treatment plants, enabling efficient local resource recovery. Future developments, such as Strandeiland in IJburg, aim to expand these sustainable sanitation solutions by utilizing wastewater and surface water for thermal energy, further supporting the city's goal of achieving energy neutrality [4].

Addressing the challenge of wastewater treatment is critical, not only for current but also for future generations. By following these successful examples, Serbia must strive to build such facilities as part of the "Clean Serbia" project and other EU and international funding programs [5]. Beyond construction, key questions arise regarding the efficiency of wastewater treatment systems, their resilience to emergencies such as floods, and the integration of advanced technologies. This necessitates the development of specialized personnel, their training and significant investments to ensure the maintenance of these systems. The overarching goal is to protect the environment by safeguarding surface and groundwater as recipients of urban wastewater, while simultaneously ensuring the availability of clean drinking water in adequate quantity and continuity.

Serbia is currently in the process of planning to achieve compliance with the EU Urban Wastewater Treatment Directive (Directive 91/271/EEC) by 2044 [6]. This alignment underscores the country's commitment to improving its wastewater management systems and environmental standards.

This manuscript examines the current status, challenges, and future prospects of wastewater treatment in Serbia, with an emphasis on Southeastern Serbia. It identifies vital areas for improvement and proposes strategies derived from best practices in leading EU countries. The study aims to assist policymakers, engineers, and researchers in advancing sustainable

wastewater management solutions, contributing to the alignment of Serbia's systems with EU standards and enhancing the resilience and efficiency of municipal water infrastructure.

2. Wastewater Treatment In Serbia

The legal framework in Serbia recognizes the dual importance of wastewater treatment, as outlined in key legislative acts. The Law on Public Utilities defines wastewater treatment and discharge as a comprehensive process that includes the collection, conveyance, treatment, and disposal of wastewater, stormwater, and surface water from public areas. It also covers the connection of users to the street sewer network, wastewater treatment at dedicated facilities, as well as the pumping, transportation, and treatment of sewage from septic tanks [7].

Additionally, the Law on Environmental Protection imposes obligations on entities and entrepreneurs who operate or are required to construct wastewater treatment facilities. Those discharging wastewater into recipients or public sewer systems must develop an action plan to progressively achieve the limit values for pollutant emissions into water. This process must align with the Regulation on Limit Values for Pollutant Emissions into Water and Deadlines for Their Achievement, ensuring compliance with national environmental standards [8].

The Ministry of Construction, Transport and Infrastructure has been reporting on public utilities since 2016, providing insights into the state of this sector at the national level in Serbia. However, there is no evident monitoring or evaluation of performance by individual cities and municipalities, which highlights a pressing issue that will need to be addressed in the future. Relevant data include [9]:

- 62% of the population is connected to public sewer systems.
- There are 46 wastewater treatment plants (WWTPs), of which: 30 are operational, 3 are under reconstruction, 5 are in trial operation, and 8 are non-operational due to outdated treatment technology.
- Only 13–14% of the population is connected to wastewater treatment systems.
- 15% of wastewater is properly treated.

To provide a more comprehensive and detailed overview of the state of wastewater treatment in Serbia, Fig. 2 presents the Wastewater Balance in Serbia from 2016 to 2022, measured in millions of cubic meters annually. Fig. 2 illustrates the wastewater balance in Serbia, highlighting key trends in wastewater management. The primary recipient of wastewater in most cases is the public sewer system, while septic tanks account for more than half as much. This suggests a significant reliance on centralized infrastructure for wastewater disposal. The largest contributor to wastewater generation is households, with industry producing more than half as much.

The complexity of the situation becomes evident when considering that primary wastewater treatment, which involves basic filtration through a coarse screen, is just the first step. The secondary treatment, which is a more advanced and effective process, is only applied to approximately one-sixth of the wastewater that is discharged into the public sewer system. This indicates that while wastewater treatment is a critical issue, there are significant gaps in the level of treatment provided, particularly for the majority of wastewater that passes through primary treatment only. The situation underscores the need for enhanced infrastructure and more efficient treatment technologies to ensure the protection of the environment and public health.

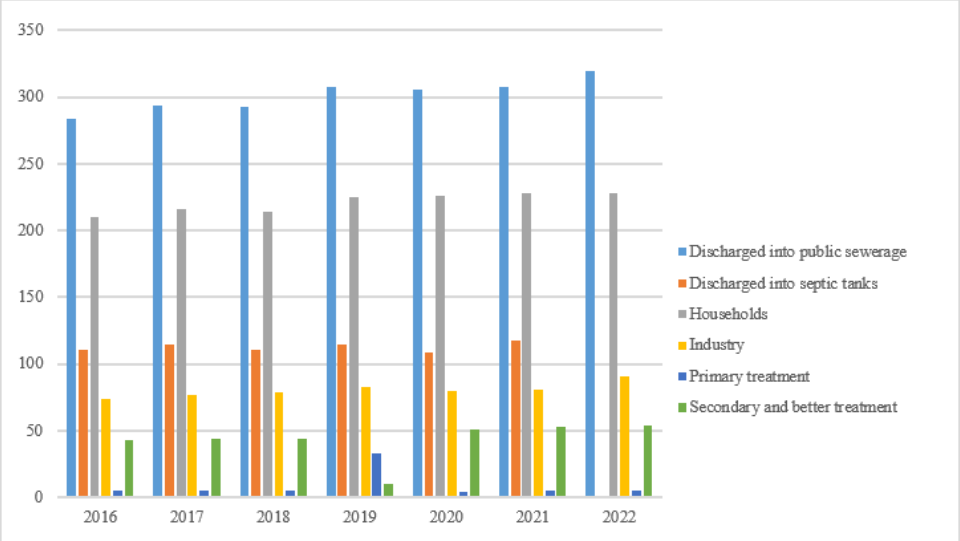

Fig. 2 The Wastewater Balance in Serbia from 2016 to 2022 in millions of m^3 [9]

Primary wastewater treatment in Serbia involves basic filtration processes, such as passing through coarse screens and settling larger particles, which removes solid waste and debris from the water. Secondary treatment relies on biological processes, typically using activated sludge, to break down organic matter and reduce pollutants in the water. Tertiary treatment is the highest level of treatment, employing advanced techniques like chemical treatment and filtration to further reduce pollutants and ensure the water meets stricter environmental standards.

The distribution of wastewater treatment across the regions of Serbia is as follows [10]:

- the Šumadija and Western Serbia region accounts for 49.52%,
- the Vojvodina region for 21.65%,
- the Southern and Eastern Serbia region for 4.6% and
- the Belgrade region has no systemic wastewater treatment solution, with 0%.

3. Wastewater Treatment In Southeastern Serbia

Considering that the Southeastern region of Serbia is underdeveloped in terms of wastewater treatment, with only 4.6% of wastewater being treated before being discharged into recipients, it is crucial to investigate the distribution and extent of treatment across districts, cities and municipalities [10]. This will help define strategies for improving environmental protection measures and municipal services, which are vital for public welfare. In this context, data reveals that the highest percentage of wastewater treatment in this region occurs in the Pčinja District, with 13.81%, followed by the Pirot District with slightly less at 12.38%. The Zaječar District has nearly half the level of wastewater treatment at 6.17%, while the Bor District records a mere 1.4% [10].

Notably, in the Nišava and Jablanica Districts, there are no recorded data on wastewater treatment. This is partly because Leskovac only began operating its wastewater treatment

plant in Bogojevac in 2024, while Niš is still in the early stages of constructing its wastewater treatment facility.

To provide a clearer picture of the state of wastewater treatment in this region across cities and municipalities, Fig. 3 illustrates the percentage of wastewater treated in Southeastern Serbia from 2016 to 2022.

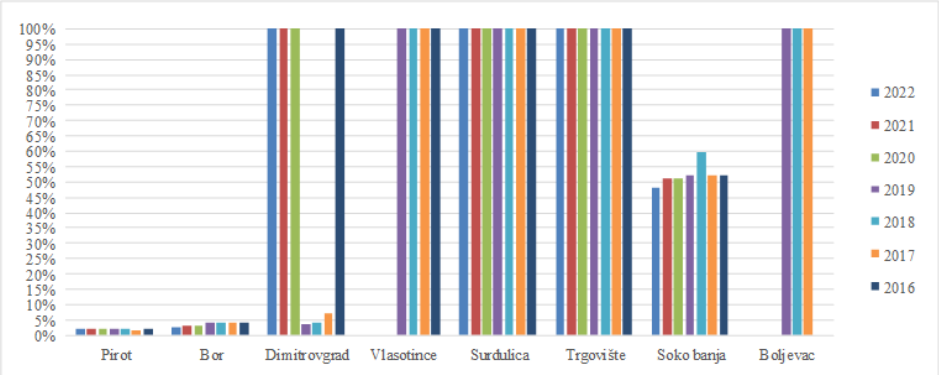

Fig. 3 The Percentage of Wastewater Treated in Southeastern Serbia from 2016 to 2022 by Cities and Municipalities [10]

The data highlights significant disparities in wastewater treatment coverage, reflecting both the availability of treatment facilities and the practical challenges faced by these regions. Bor, Pirot, Dimitrovgrad, Vlasotince, Surdulica, and Sokobanja have mechanical and biological wastewater treatment, while Boljevac and Trgovište have only mechanical wastewater treatment [11]. The graph reveals that wastewater treatment in Bor and Pirot is below 3%, while in smaller municipalities, the percentage ranges between 50% and 100%. The wastewater treatment percentage in Pirot remains consistently below 3% across all observed years, showing minimal improvements or operational changes. This highlights the lack of functional wastewater treatment infrastructure in the municipality, leading to significant environmental risks from untreated discharges. Bor similarly exhibits treatment percentages below 3%, reflecting a critical gap in wastewater management. Given the industrial nature of Bor, this raises concerns about the environmental impact of untreated industrial and municipal wastewater being released into natural water bodies.

Trgovište stands out as a leader in wastewater treatment, maintaining a consistent 100% treatment rate throughout the entire analyzed period (2016–2022). This reflects the presence of an efficient and fully operational treatment system, demonstrating the municipality's strong commitment to environmental protection and sustainable wastewater management. Similar to Trgovište, Surdulica has maintained a 100% treatment rate across all years in the analyzed period. This consistency highlights the importance of well-maintained treatment infrastructure and effective local governance in achieving such results.

Dimitrovgrad started the analyzed period with 100% wastewater treatment in 2016. However, the municipality faced challenges from 2017 to 2019, with significantly lower treatment percentages during this time. In recent years (2020–2022), Dimitrovgrad has returned to a 100% treatment rate, showcasing a recovery in its wastewater management system.

Considering that a project for a new wastewater collector was developed in 2018 but its implementation remains pending, the system experienced a significant drop in treatment percentages between 2017 and 2019 due to infrastructural challenges—such as the inability to relocate an international high-voltage line and an oversized design capacity relative to current needs. Nevertheless, mechanical and biological treatment processes continue to operate, ensuring that wastewater is treated while preparations for the new project are underway.

Vlasotince achieved a 100% treatment rate from 2016 to 2019, indicating a fully functional wastewater treatment facility during this period. Unfortunately, since 2020, the treatment plant has been out of operation and there are no recorded data on wastewater treatment for the municipality. This reflects a significant setback in wastewater management, emphasizing the need for urgent infrastructure repairs or upgrades.

Boljevac experienced a similar situation to Vlasotince. The municipality had a fully operational treatment facility, achieving 100% wastewater treatment in earlier years, but the facility has since ceased functioning. As a result, there are no recent data on wastewater treatment in Boljevac, indicating a decline in environmental management efforts.

Sokobanja demonstrates partial wastewater treatment coverage, with percentages ranging between 50% and 60% in recent years. This reflects moderate progress but indicates the need for further investment in treatment facilities and operational capacity to achieve higher coverage.

The data illustrates significant disparities in wastewater treatment across Southeastern Serbia. While municipalities like Trgovište and Surdulica have consistently achieved 100% treatment rates, others like Dimitrovgrad have faced fluctuations, and areas such as Vlasotince and Boljevac have experienced a complete halt in wastewater treatment operations in recent years. Larger municipalities like Pirot and Bor continue to struggle with minimal treatment rates, below 3%, reflecting a critical lack of infrastructure and operational capacity.

The environmental and public health implications of untreated wastewater are severe, necessitating urgent action. Municipalities with non-operational facilities, such as Vlasotince and Boljevac, require immediate attention to restore their wastewater treatment systems. Additionally, partial treatment coverage in areas like Sokobanja highlights the need for increased investment in infrastructure and staff training.

Efforts to improve wastewater treatment must focus on consistent monitoring, maintenance of existing facilities and the development of new infrastructure in underserved regions. These actions are essential to achieving sustainable environmental protection and improving public health across Southeastern Serbia, particularly in major cities such as Niš, which is in the initial phase of constructing a wastewater treatment plant, and Leskovac, where a plant in Bogojevac was commissioned in 2024, as well as other large cities in the region that lack recorded data on wastewater treatment [12, 13].

4. CONCLUSION

The state of wastewater treatment systems in Southeastern Serbia reveals significant disparities and challenges, underscoring the vital importance of this public utility for environmental protection and sustainable urban development. Wastewater treatment is not merely a technical issue but a cornerstone of public health, environmental conservation, and regional socio-economic growth. Southeastern Serbia, despite its limited infrastructure

and underdeveloped systems, demonstrates the potential for improvement through targeted investments, strategic planning and international cooperation.

The findings indicate that only a small fraction of the population in the region is connected to functional wastewater treatment systems, with substantial variations between municipalities. While municipalities like Trgovište and Surdulica exemplify best practices with 100% treatment rates, larger urban centers like Niš and Leskovac lag behind due to delays in infrastructure development. The construction of new facilities, such as the wastewater treatment plant in Leskovac and the ongoing project in Niš, marks a step forward but highlights the need for sustained efforts.

This study emphasizes the dual significance of wastewater treatment: it protects water resources and ecosystems while fostering sustainable urban and rural development. Properly treated wastewater reduces pollution, safeguards biodiversity, and ensures the availability of clean water for future generations. Furthermore, it aligns with Serbia's commitments under the EU Urban Wastewater Treatment Directive and the Sustainable Development Goals, particularly Goal 6 (Clean Water and Sanitation).

To bridge the existing gaps, it is crucial to prioritize the development of modern wastewater treatment facilities, adopt advanced technologies and strengthen institutional capacities. Investments in personnel training and public awareness are equally important to ensure the long-term efficiency and sustainability of these systems. By following examples of best practices from developed European countries and leveraging international funding opportunities, Southeastern Serbia can transform its wastewater treatment systems into a model of environmental stewardship and sustainable development.

In conclusion, addressing the challenges of wastewater treatment in Southeastern Serbia is not just a technical necessity, but a moral and strategic imperative. It is a pathway to achieving environmental justice, improving public health and fostering resilience in the face of future challenges, thereby contributing to the overall well-being and prosperity of the region.

Acknowledgement: *This research was financially supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (Contract No. 451-03-136/2025-03/ 200371).*

REFERENCES

1. WHO, UNICEF, 2017, *Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines*, Geneva, Switzerland.
2. UNICEF, WHO, 2015, *Progress on Sanitation and Drinking Water – 2015 Update and MDG Assessment,* Geneva, Switzerland.
3. https://data.who.int/indicators/i/6EFF579/A37BDD6 (last access: 26.12.2024)
4. EEA, 2022, *Beyond water quality: sewage treatment in a circular economy*, Report 05/2022, Copenhagen, Denmark.
5. https://cistasrbija.rs (last access: 27.12.2024)
6. EU Urban Wastewater Treatment Directive, Directive 91/271/EEC.
7. Law on Environmental Protection, Official Gazette of the Republic of Serbia, No. 135/2004, 36/2009, 36/2009 - amended, 72/2009 - amended, 43/2011 - Decision of the Constitutional Court, 14/2016, 76/2018, 95/2018 - amended, 95/2018 - amended, and 94/2024 – amended.
8. Law on Public Utilities, Official Gazette of the Republic of Serbia, No. 88/2011, 104/2016, 95/2018, and 94/2024.
9. The Ministry of Construction, Transport, and Infrastructure, 2024, *Report on the performance of public utilities in the territory of the Republic of Serbia*, Belgrade, Serbia.

10. Gavrilović, D., 2017-2023, *Municipalities and regions of the Republic of Serbia*, Statistical Office of the Republic of Serbia, Belgrade, Serbia.
11. Ministry of Environmental Protection - Environmental Protection Agency, 2024, *Report on the State of the Environment in the Republic of Serbia*, Belgrade, Serbia.
12. Vranjanac, Ž., Vasović, D., 2017, *Importance of oxygen regime indicators—Case study of the Nišava river in Serbia*, Facta Universitatis, Series: Working and Living Environmental Protection, 14(2), pp. 181-186.
13. Vasović, D., Stanković, S., Vranjanac, Ž., 2018, *Working conditions at the water treatment plants: Activities, hazards, and protective measures*, Safety Engineering, 8(1), pp. 27-32.