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CONTENT

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Domestic wastewater treatment in the rural areas of the Republic of Serbia

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Abstract *Wastewater collection and treatment have a wide range of impacts on the environment and the economy, both locally and globally. The lack of a sewage system outside of central urban areas and the insufficient number of constructed and operative wastewater treatment plants are leading problems concerning the management and treatment of municipal, domestic, and industrial wastewater in the Republic of Serbia. In the Republic of Serbia, about 418 million m³ of wastewater was discharged in 2019, from which 308 million m³ was wastewater from municipalities with a public sewage system. Currently, only about 64 % of the population has a connection to the public sewage system and Serbia treats approximately 48 million m³ of wastewater. The highest number of people, about 44% of the population, lives in rural settlements and discharges wastewater from their households into septic tanks.*

For small communities in the rural settlements, on-site treatment technologies using natural systems are a highly efficient, adequate, and inexpensive treatment. This paper provides an overview of the situation in the wastewater sector in the Republic of Serbia and discusses on-site treatment technologies and/or the possibility of reuse of household wastewater in rural settlements that aren't connected to the sewage system in the Republic of Serbia.

Keywords *Domestic wastewater, rural settlements, decentralized treatment, Republic of Serbia*

1. INTRODUCTION

According to the Our World in Data, in 2017, 4.1 billion people were living in urban areas, and 3.40 were living in rural areas [1]. That means that globally, more people live in urban areas than in rural areas, with 55 % of the world's population was living in urban areas in 2018 [2]. The percentage of people living in rural areas will steadily decrease as people migrate from rural areas into cities, but currently, the percentage of people living in rural areas is still huge. The way of life in rural areas is quite different than in urban areas. Rural areas are not densely populated nor developed as urban areas. In rural areas usually, there are no sewers, no system for the collection of wastewater nor wastewater treatment systems [3]. Today, the large amounts of untreated wastewater from rural areas are discharged into the ground, and-rural lakes, rivers and groundwater are becoming major sources of environmental pollution and potential health hazards for the local population [4]. Domestic wastewaters have a significant impact on sources of environmental pollution. Domestic wastewater characteristics in rural areas are different from the characteristics of wastewater from urban cities. The content of organic matter and nutrients is higher, and the content of heavy metals and other inorganic pollutants is lower [3]. Affordable and effective

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domestic wastewater treatment is a critical issue in public health and disease prevention around the world, particularly so in developing countries that often lack the financial and technical resources necessary for proper treatment facilities [5]. Also, in many countries, it is required from small communities to treat wastewater discharges to increasing standards of lesser environmental impacts but must achieve that goal at locally sustainable costs [6]. For the treatment of domestic wastewater in rural areas in many countries, decentralized system is used. Decentralized wastewater treatment systems are designed to operate at a small scale. Decentralized wastewater treatment systems can reduce the effects of wastewater disposal on the environment and public health, but may also increase the ultimate reuse of wastewater, depending on community type, technical options, and local settings [7].
According to available data, in 2019, in the Republic of Serbia approximately 44 % of the population reside in rural areas [8], and over 35 % of them are not served by sewage systems, including the wastewater treatment plants [9]. The percentage of the rural population connected to the public sewage system is about 9% [10] and they mainly discharge their wastewater into septic tanks, threatening groundwater, which accounts for 73% of Serbia's drinking water supply [11].

2. RURAL SETTLEMENTS IN THE REPUBLIC OF SERBIA

The Republic of Serbia covers an area of 88,361 km^2, and it is populated by 7 186 862 inhabitants, according to the latest data [12]. Administratively, the territory of the country consists of two autonomous provinces Kosovo and Metohija and Vojvodina and 174 local self-government units-[13].
The classification of urban and rural areas presents an essential topic in scientific research. In the Republic of Serbia, official national statistics use legal criteria to determine the type of settlement [12]. Following these criteria, settlements are defined as urban according to the decision of the local authorities. Settlements that are not covered by this criterion are classified in the category of "other", and automatically considered rural [14]. Fig. 1 presents statistical classification at the settlement level in the Republic of Serbia.

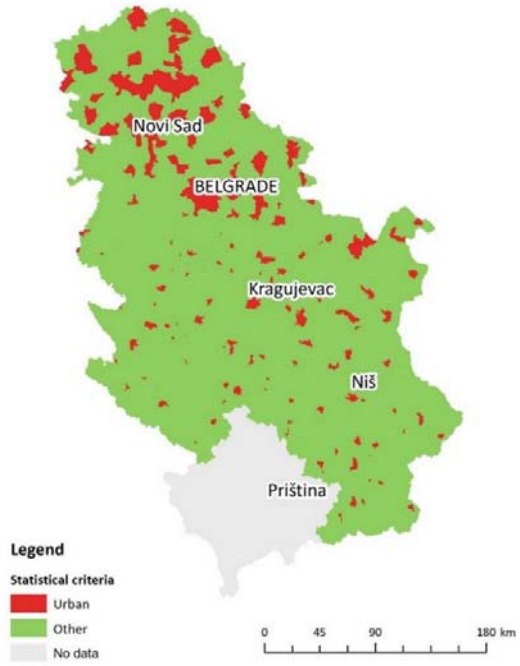


Fig. 1. Statistical classification at the settlement level [12]

The total population in the Republic of Serbia was 6 944 975 in 2019. About 3 907 243 (56.26 %) was classified as an urban population, and 3 037 732 (43.74 %) as a rural population [15]. According to the latest census, in 2011, there were 167 urban settlements in Serbia, and 4542 settlements were classified as "other". In 2011 about 59.44 % of inhabitants lived in urban settlements, while 40.6 % lived in other settlements. Also, 90.69% of settlements in Serbia have fewer than 2000 inhabitants, and 25% of the population of Serbia lives in these settlements [13]. According to the size, settlements with less than 500 inhabitants dominate, followed by settlements with 500-999 inhabitants, Table 1 [16].

Table 1. Number of settlements according to population size [16]

	Urban settlements Number		Rural settlements Number	
	Total	**%**	**Total**	**%**
> 500	5	2.99	2950	64.95
500 – 999	3	1.80	845	18.60
1000 – 1999	8	4.79	460	10.11

Depending on the level of urbanization, the connection to the public sewerage network is diverse in different parts of Serbia. Fig. 2 shows the number of households connected to the public sewage system.

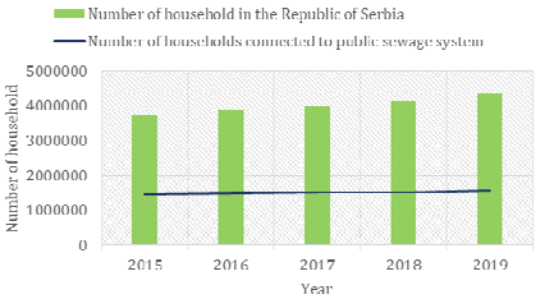


Fig. 2. Number of households connected to public sewage system [12]

Of the total number of inhabitants in Serbia, a relatively large number of both urban and rural inhabitants are not connected to the public sewage system, and mostly they use septic tanks for the discharge of wastewater from the households [17]. The urban/rural coverage with a sewage system is 87.5 and 22.2%, respectively [17]. Fig. 3 shows wastewater discharged from the municipality with/without public sewage systems.

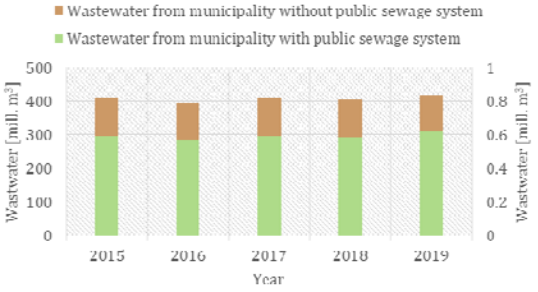


Fig. 3. Wastewater discharged from the municipality with/without public sewage systems [12]

In 2019, the total amount of wastewater from settlements was higher by 3.5% than in the reference period in 2018. The amount of wastewater discharged into the public sewer was increased by 5.3% compared to the same period in 2018. The amount of discharged wastewater into septic tanks is lower by 1.2% compared to 2018 [18]. When it comes to the discharge of wastewater into the sewage system in 2019 compared to 2018, households recorded an increase of 5.5%, the industrial sector increase of 5.4%, and other users an increase of 3.9 %, Fig. 4.

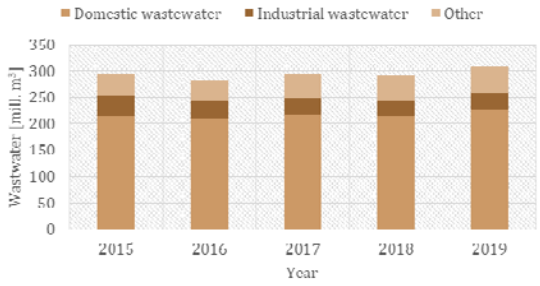


Fig. 4. Discharged wastewater from settlements according to type [18]

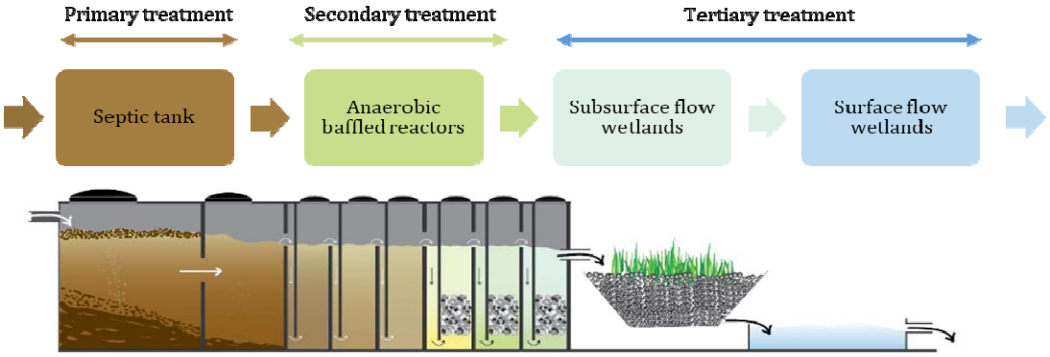
The previous figure shows that a large amount of discharged wastewater comes from households as domestic wastewater. Currently, there are no data for domestic wastewater of small settlements (rural areas). With a large proportion of Serbia's population remaining in small settlements (communities of < 2000 inhabitants), it can be estimated that the amount of domestic wastewater is significant. Also, rural coverage with a sewage system is only 22.2%, which means that there are possibilities for planning and constructing different domestic wastewater treatment plants for small settlements that are not connected to the sewerage network. Solving these problems would have a significant impact on wastewater management in the Republic of Serbia. Pressure on surface and ground waters from non-point sources of pollution remains relatively low, but it is noted that septic tanks in small communities do represent an issue of concern for Local government units [19]. Also, to align with EU environmental standards, 320 wastewater treatment facilities should be constructed in Serbia [10] and solving the wastewater treatment in rural areas could contribute to wastewater management goals.

3. DECENTRALIZED SYSTEMS

Decentralized wastewater treatment consists of a variety of approaches for collection, treatment, and dispersal/reuse of wastewater for individual households, institutional or industrial facilities, entire communities, etc.

Nowadays, decentralized systems can be designed for a specific site, thus overcoming the problems associated with site conditions [20]. Therefore, these systems can easily be applied and used in rural areas. Treatment options range from simple and cost-effective, passive treatments with soil dispersion, usually referred to as septic or on-site systems, to complex and mechanized or biological approaches providing advanced treatment by collecting and treating waste from buildings and discharging to either soil or surface waters [21]. Fig. 5 presents the operational diagram of a typical decentralized wastewater treatment system with methods of treatment.

The concept of decentralized wastewater treatment has been implemented in various developed and developing countries of the world.



	Section 1	Section 2	Section 3	Section 4	Section 5
	Primary treatment	Secondary treatment		Tertiary treatment	Post-treatment
Methods	- Septic Tank - Cesspools - Holding Tanks - Ecological Sanitation	- Waste Stabilization Ponds - Media Fillers - Membrane Biological Reactors - Anaerobic Digestion - Terra Preta Sanitation		- Constructed wetland - Sand filters - Peat filters - Vermifilters - Wastewater stabilization ponds	- Polishing pond/ Surface flow wetland
	Sedimentation tank stabilizing settled sludge by anaerobic digestion	Baffled reactors - Anaerobic degradation of suspended and dissolved solids	Anaerobic filter - Water passes through filter media	Open shallow basin filled with gravel/pebbles to support growth of plant/reeds with shallow roots	Open shallow basin for removal of stabilized or inactive suspended substances

Fig. 5. Operational diagram of a typical decentralized wastewater treatment system [21-24]

Many authors described the application of decentralized systems in small communities /rural areas in different countries.

Guo et al. [25] carried out the study between 2009 and 2011 in rural areas in China. Aim of the study was to assess problems involved with decentralized treatment in villages. They found out that decentralized treatment is the most popular wastewater treatment method in villages, and that the most common primary treatment technology used in rural areas is the septic tank. The use of septic tanks in rural areas of the Republic of Serbia is the primary technology for the treatment of domestic wastewater. There are no available data about decentralized systems in the Republic of Serbia.

Istenic et al. [26] provided the first international survey data from Central and East European countries focused on small, decentralized rural treatment systems including nature-based systems (such as treatment wetlands). There are some countries with long-term good experience with this type of process, Table 2.

Table 2. Statistics data of nature-based wastewater treatment plants (WWTP) in some countries [26]

Country	Inhabitants connected to nature-based WWTPs (10^3)	Total numbers of nature-based WWTPs (-)	Total number of treatment wetlands (-)
Bulgaria	0	5	5
Czech. Rep.	120	740	690
Estonia	9	197	14
Hungary	5	32	10
Latvia	55	10	10
Lithuania	No data	No data	No data
Poland	50	1000	500
Romania	0	6	6
Slovakia	0	10	5
Slovenia	5	80	80
Ukraine	343	1570	65
Total	537	3650	1385

Brunner et al. [27] examined the affordability of decentralized wastewater treatment systems for future users in rural areas, based on their experience in planning the decentralized wastewater treatment systems for slums of two rural towns in India. Planning on these decentralized wastewater treatment systems may generalize and apply to other developing countries seeking socially acceptable low-cost solutions with reasonable pollution reduction for resolving the sanitation crisis. Datta et al. [28] analysed constructed wetlands for the treatment of rural wastewater in semi-arid tropic villages. Constructed wetlands provide improved wastewater management and increased water efficiency. This study was conducted in Telangana in Kothapally village. The treated wastewater was stored in a farm pond and was utilized for irrigation in the nearby agricultural fields, and this perennial source of water helped nearby farmers to cultivate two additional crops. The study demonstrated that villagers manage to use a constructed wetland to treat the wastewater generated from their households. They reused water for irrigation. Also, many authors proposed applying multi-criteria decision analysis for selecting appropriate decentralized treatment technology. Younes [29] used the Median Ranked Set sample and Analytic Hierarchy Process to improve the decision-making process in choosing the proper decentralized system for wastewater treatment in rural areas. According to the study, the best-decentralized option for wastewater treatment in rural areas, based on a cluster level, is using activated sludge as a wastewater treatment technology. The modified septic tank is the best treatment option for wastewater treatment on a household level. The introduced integrated model may offer a promising tool to improve the decision-making process. Also, it would help the environmental planners in terms of uncertainty reduction and subjectivity of human judgments.

Decentralized systems allow flexibility in wastewater treatment management. Also, it is possible to combine processes to meet treatment goals and address environmental requirements. Decentralized systems provide an opportunity to reuse wastewater in agriculture without contaminating surface water bodies and groundwater.

4. DISCUSSION

Decentralized systems are applied in areas where centralized systems do not exist, and the individual houses are scattered over a large area. There is a high level of knowledge regarding the implementation and performance of decentralized wastewater systems at the expert and scientific levels. However, the transfer into practice is insufficient, and there are low awareness and recognition of these systems at the institutional and administrative levels. Moreover, there is also a lack of good examples of decentralized systems in the Republic of Serbia. Domestic wastewater treatment technology in rural areas changes according to social conditions and takes the most suitable form for a society (inhabitants) that uses the technology. When the technology of treatment used in one country is conveyed to another country, it is necessary to examine its adaptability from various aspects. Choosing the most appropriate option for the domestic wastewater treatment in rural areas requires a thorough analysis of all factors such as simplicity of design and construction, operation and maintenance, cost, environmental impact, cultural acceptability, simplicity of design and construction, operation and maintenance, local conditions. Septic tanks are usually wastewater

treatment solutions in the rural areas of the Republic of Serbia. This solution allowed domestic wastewater to be used for obtaining agricultural fertilizer, but now this solution is not enough because of stricter environmental standards.

When choosing the decentralized systems in rural areas, the following aspects must be assessed:

- Location of rural settlements or households.
- The number of inhabitants.
- The flow and the amount of the domestic wastewater for chosen rural settlements or households - usually is estimated based on well-known formulas. The flow and the amount of the wastewater are comparable to results of the Statistical Office of the Republic of Serbia for wastewater of urban inhabitants and industry. That results could indicate the significance of wastewater pollution in those rural settlements or households.
- Characteristics of domestic wastewater.
- Type of decentralized system for wastewater treatment - conducting environmental impact assessment studies.
- Treatment efficiency.
- Reuse of treated domestic wastewater.
- Financial demands for construction of decentralized wastewater treatment.
- The operation process, maintenance, health, hygiene, and other aspects.

Choosing the proper decentralized system is a multi-criteria decision-making problem that requires extensive operational, financial, environmental, social, and technical evaluations. The environmental decision-making process is complex and has a high uncertainty degree. Objective determination and constructing an appropriate hierarchical structure are essential for the process because of conflict of interests among local units and inhabitants of small settlements. Rural residents generally have limited finances, so it is difficult to raise the capital required to invest in and construct decentralized systems. In addition to increasing government investment, to secure enough social funds to address this problem it is significant to establish a long-term financial security system.

5. CONCLUSION

Currently, emission-quality standards for the urban wastewater treatment plant also are applied for rural wastewater. Achieving these standards is challenging, and unrealistic because of the typical economic situation in rural areas. Therefore, characteristics of rural areas must be taken into account when new sewage, drainage, and water quality standards are developed.

Applying of decentralized wastewater treatment system is considered a powerful solution for the domestic wastewater problem of rural areas. Decentralized systems help communities achieve the goals of sustainability: good for the environment, good for the economy and the people. Treated wastewater could be reused in agriculture, into households for toilet flushing, for landscaping, and surface storage ponds, environmental and recreation, groundwater recharge. In Serbia, about 44% of the population lives in rural settlements and discharges wastewater from their households into septic tanks. Further research is needed to study and gather information for the selection of appropriate sites and the installation of decentralized systems in rural areas in the Republic of Serbia.

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