Interreg
Danube Region

Co-funded by
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D-CLEAN

Report on current situation on wastewater and stormwater management in small settlements of the Danube River Basin

D.1.1.1

November, 2025

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Content

Introduction

This deliverable provides a comprehensive insight into the existing infrastructures, technologies and practices in wastewater and stormwater management in small settlements of the Danube River Basin and reviews current national policies and management plans.

Analysis of regional status quo

The first specific objective of the D-CLEAN project—*Improving Water Quality in the Danube River Basin: Nature-Based Solutions for Sustainable Wastewater and Stormwater Management in Small Settlements*—was to assess the current status, needs and challenges of wastewater and stormwater management in the Danube River Basin (DRB). This analysis serves as the foundation for identifying and prioritizing sustainable solutions tailored to the unique conditions of small settlements across the region.

To propose a relevant and effective set of sustainable solutions, it was essential to gain a comprehensive understanding of the **existing infrastructure, legislative frameworks, management practices, and technical challenges** related to wastewater and stormwater collection, treatment, and disposal in small settlements.

Activity 1.1. therefore, focused on a detailed analysis of the regional status quo. This included a thorough analysis of existing infrastructure, technologies and practises, identification of strengths and weaknesses of current systems and a comprehensive review of national policies and management plans.

To ensure a robust and inclusive analysis, a **comprehensive questionnaire** was developed and distributed among **project partners**. Each partner provided detailed input for their respective countries: Austria, Croatia, Hungary, Romania, Serbia, Slovakia, and Slovenia. To extend the scope beyond the project consortium, **additional DRB countries** with more than 1% territorial share of the basin were identified. These included: Germany, Bulgaria, Moldova, Ukraine, Bosnia and Herzegovina, and Czechia. Experts from these countries were identified and invited to participate in the questionnaire and contribute national data. No contact was identified in Moldova. We received data from all project countries (Austria, Croatia, Hungary, Romania, Serbia, Slovakia, and Slovenia) and from Bosnia and Herzegovina, Czechia and Germany. Ukraine expressed interest to participate but no data was provided while no response was received from Bulgaria.

In total, **information was gathered from 10 out of 13 countries** with significant DRB territory, covering approximately **80% of the basin area** (Figure 1, Table 1). This broad participation ensures that the analysis reflects a diverse range of geographical, institutional, and technical contexts across the DRB.

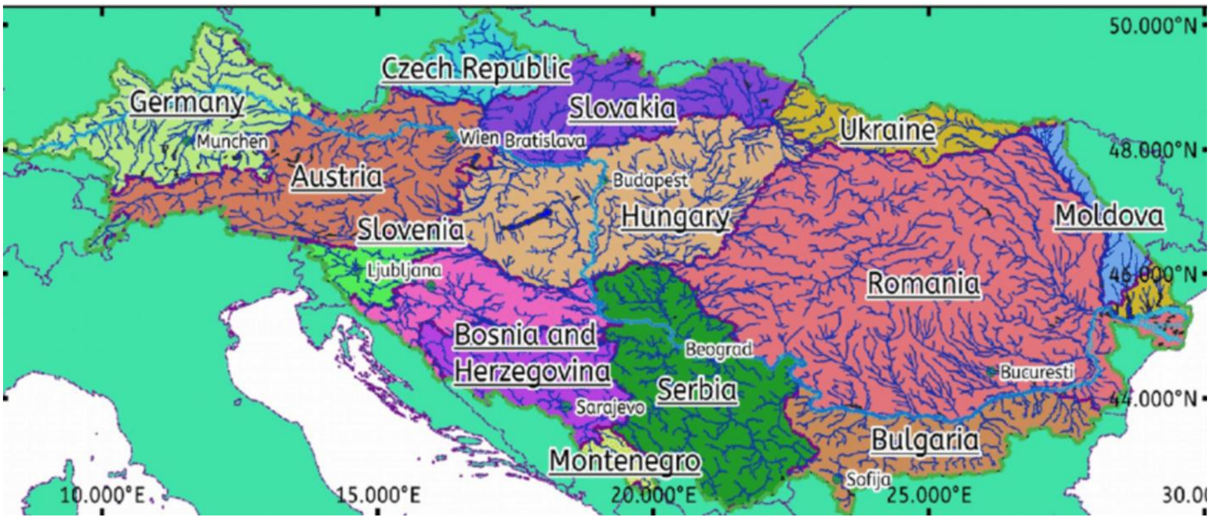


Figure 1: Geographical overview highlighting countries within the Danube River Basin (source: Morlot, 2018).

Table 1: Countries with more than 1 % share of the DRB invited to participate in the status quo analysis. Countries that provided data are marked with blue (adapted from [ICPDR, Countries of the Danube River Basin](#)).

	Country	Coverage in DRB (km²)	Share of DRB (%)	Percentage of land territory within the DRB (%)	Population within the DRB (Mio)
1	Austria	80,593	10.03	96.1	8.4
2	Bosnia and Herzegovina	38,289	4.77	74.9	3.2
3	Bulgaria	47,235	5.88	42.6	3.6
4	Croatia	35,111	4.37	62.1	2.9
5	Czech Republic	21,681	2.70	27.5	2.7
6	Germany	56,250	7.00	15.7	10.1
7	Hungary	93,000	11.58	100	9.8
8	Moldova	12,505	1.56	36.9	1.1
9	Romania	232,193	28.91	97.4	19.5
10	Serbia	81,974	10.21	92.6	7.0
11	Slovakia	47,084	5.86	96.0	5.2
12	Slovenia	16,420	2.04	81.0	1.8
13	Ukraine	30,626	3.81	5.1	3.03
	Sum	**792,961**	**98.72**		**78.3**
	Sum (acquired data)	**646,345**	**80**		**61**

Structure of the questionnaire

The questionnaire (Annex I) was composed of 8 chapters as follows:

A. General information

The chapter gathered contact information of the person who filled in the questionnaire in case of the need for further explanations

B. Settlement structure of the country

The chapter included five questions regarding definition of settlements and agglomerations and numbers of settlements in the country according to the size with corresponding number of inhabitants.

C. Wastewater collection and treatment

The chapter included two questions; i.e., how data on wastewater treatment plants is collected in the country and regarding the number of inhabitants connected to individual treatment systems. The chapter then directed the interviewee to fill in the excel spreadsheet – a database of existing wastewater treatment plants (WWTPs) in the DRB of each country specifying its design capacity, year of implementation, technology applied, location, treatment step (secondary/tertiary), amount of wastewater treated and treatment efficiency.

D. Discharge limits

The chapter first asked for the information if there is national legislation on discharge limits for wastewater treatment plans smaller than 2000 PE. Next, it was necessary to fill in a table with discharge limits for prescribed parameters according to the size of a treatment plant.

E. Monitoring protocols

The chapter included a table asking for information regarding the frequency, responsibility and monitored parameters for discharge according to the size of WWTP.

F. Management plans

The chapter included six questions on national and municipal wastewater management plans, deadlines for wastewater collection and treatment for settlements between 1000 and 2000 PE and settlements with less than 1000 PE. Next, the information on sewer systems was collected (combined or separated).

G. Stormwater management

The chapter included six questions gathering information on current practices in stormwater management in small settlement, the relevant national regulations, problems that small settlements are facing due to stormwater, stakeholder awareness, rainwater harvesting and spatial planning.

H. Strengths, weaknesses and challenges

The chapter included two tables to mark advantages / disadvantages of decentralized systems and nature-based solutions for various aspects followed by three questions on the main technical challenges and obstacles for wastewater collection and treatment in small settlements and climate change effects. At the end of the chapter the interviewees were asked to provide successful examples of wastewater and stormwater management in small settlements in their countries. These best management practices are presented in a separate chapter of this Deliverable.

Data processing

The completed questionnaires were collected and systematically compiled into a unified Excel spreadsheet. Each response—whether in tabular or narrative format—was consolidated to present a comprehensive overview of results across all participating countries.

This centralized dataset enabled a comparative analysis of wastewater and stormwater management practices in small settlements throughout the Danube River Basin. The data were reviewed and interpreted in alignment with the structure of the questionnaire, ensuring consistency and clarity in reporting.

The findings from this analysis are presented in the following chapters of this deliverable, organized thematically according to the questionnaire sections.

A. General information

There is considerable diversity among the participating countries and institutions. While some responses may reflect the institutional perspectives of the experts, the dataset as a whole provides a solid foundation for understanding regional trends in wastewater and stormwater management.

Participating countries and institutions

As mentioned in the introduction 10 countries out of 13 with more than 1% share of DRB have provided data on wastewater and stormwater management in small settlements. We could not gather data from Bulgaria, Moldova and Ukraine. The countries included in the survey have different historic, cultural and economic background which results in significant differences in water management. Germany, Austria, Czechia, Slovakia, Hungary, Slovenia, Croatia and Romania are **EU countries**, while Serbia and Bosnia and Herzegovina are **EU candidate country**.

The questionnaires were completed by project partners and invited experts representing a range of institutional backgrounds, the majority of which were public (Table 2). Specifically, three experts were affiliated with **regional or national authorities**, two with **sectoral agencies**, and two with **higher education institutions**. Additionally, one expert came from a small or medium-sized enterprise (**SME**), and two from a non-governmental organization (**NGO**). The institutional affiliation of each expert may have influenced responses to questions closely related to their professional focus—such as the perceived strengths and weaknesses of decentralized systems and nature-based solutions, or challenges and awareness surrounding stormwater management. However, other questions were more factual or technical in nature, where the expert's background and institutional context likely had minimal impact on the objectivity of the responses.

Table 2: List of affiliated institutions of the experts participating in the regional status quo analysis.

	Name	Type	Legal status	Project partner
1	BOKU	Higer education or research organisations	Public	Y
2	Međimurske vode	Sectoral Agency	Public	Y
3	Kotivizig	Regional Public Authority	Public	Y
4	Romanian waters	National Public Authority	Public	Y
5	RRA Srem	Sectoral Agency	Public	Y
6	Water Research Institute	Higher education or research organisations	Public	N
7	LIMNOS	SME	Private	Y
8	Bavarian Environmental Agency	Regional Public Authority	Public	N
9	Aquasan network BiH	NGO	Private	N
10	Charles University Prague	Higer education or research organisations	Public	N

Sanitation services in DRB

Western countries like Germany and Austria, with long-standing stable democracies and strong economies, have historically invested in comprehensive wastewater infrastructure, including in rural areas which is clearly demonstrated in the following chapters. In contrast, many Central and Eastern European countries—such as Slovakia, Czechia, Hungary, Romania, and the countries of the former Yugoslavia (Slovenia, Croatia, Serbia, Bosnia and Herzegovina)—underwent socialist rule during the 20th century, followed by complex transitions to market economies and democratic governance. These transitions often resulted in **uneven infrastructure development**. Economic disparities, particularly in Romania, BiH, and Serbia, have led to limited funding and institutional capacity for wastewater management. Moreover, **EU membership has played a critical role in driving improvements** through Urban Waste Water Treatment Directive (UWWTD) 91/271/EEC and its recast 2024/3019 and funding mechanisms, benefiting countries like Slovenia and Croatia more than non-EU members.

Overall, **historical legacies, political stability, and economic strength continue to influence the pace and quality of wastewater infrastructure development** across the basin. **The access to water and sanitation services has improved** in the Danube River Basin in the last 10 years, with non-EU countries lagging behind (Figure 2). Meeting the UWWTD remains a challenge in many countries while Austria reached almost 100% share of population connected to wastewater collection and treatment system. In BiH, Albania and Montenegro this share is around 60% and below 30% in Serbia and North Macedonia. In all countries wastewater collection and treatment in rural areas is well behind urban sewer connections (Havens and Gabrić, 2025).

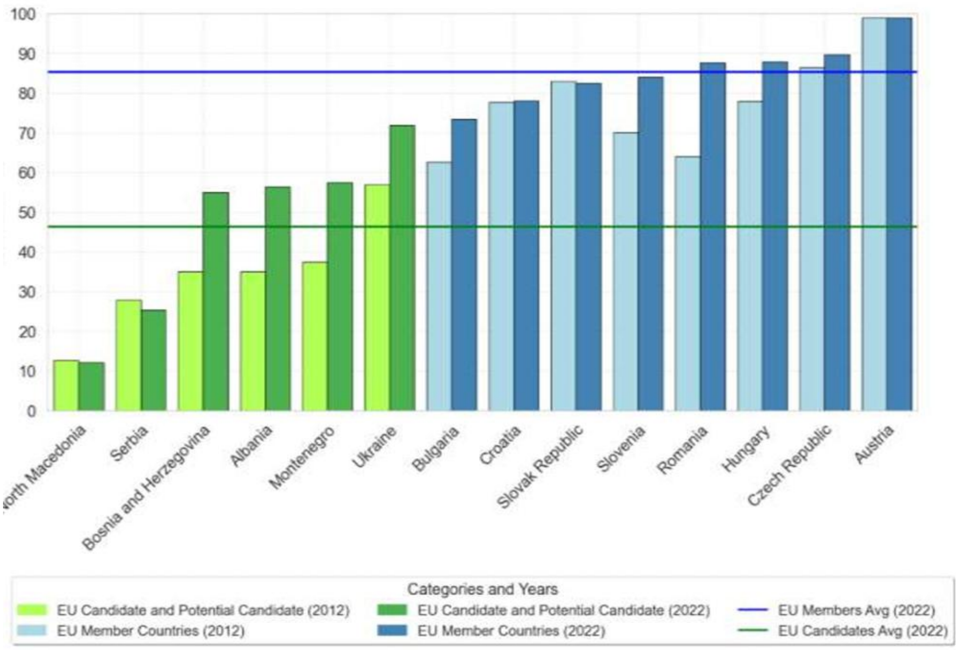


Figure 2: Share of population using safely managed sanitation services 2012 vs 2022 (Havens and Gabrić, 2025).

B. Settlement structure

There is a high number of small settlements in the Danube River Basin. It is estimated that 17.4 million people live in 60,000 settlements with less than 2,000 inhabitants and about 10.9 million in 55,000 settlements with less than 1,000 inhabitants, respectively.

Settlement and agglomeration definition

Table 3 presents a comparison between the definition of *settlement/municipalities* and *agglomeration* in the UWWTD and those used in the DRB countries, based on the questionnaire responses. In actually all participating countries **settlements/municipalities are officially defined** by national legislation as **local self-governing authorities**. The terminology used to describe settlements varies by country and is typically based on population size. In some of the countries, the large settlements (i.e., cities) are counted as municipalities (e.g., Austria) in others they are not included in the number of municipalities (e.g., Croatia).

Regarding **agglomeration definitions**, two main approaches are observed in alignment with the UWWTD:

- **Delineation-based approach**: countries such as Romania, Slovakia, and Slovenia apply a detailed delineation method, using slightly different criteria to define what constitutes a “sufficiently concentrated” population.
- **Simplified catchment-based approach**: in Austria and Croatia, agglomerations are defined more broadly as the catchment area of a WWTP.

Hungary and Serbia did not report any specifics regarding the delineation of agglomeration.

This variation in definitions reflects differing national interpretations of agglomeration and has implications for planning, reporting, and implementing wastewater infrastructure in small settlements.

Table 3: Definition of settlement/municipality and agglomeration in the UWWTD (2024) and countries in the DRB (i.e., results from the questionnaire).

	Settlement/municipality	Agglomeration
UWWTD (2004)	n/a	Article §2(4) ‘agglomeration’ means an area where the population expressed in population equivalent, combined or not with economic activities, is sufficiently concentrated for urban wastewater to be collected and conducted to one or more urban wastewater treatment plants or to one or more final discharge points. Whereby, when delineating their agglomerations, Member States should take into account the indicative reference threshold of 10 to 25 PE per hectare, above which the population, possibly combined with economic activities, located in a specific area is considered sufficiently concentrated (point 6 of the introduction to the UWWTD).
Austria	The municipality as a local authority at the municipal level is generally referred to as "Gemeinde" in Austria. A village ("Ortschaft") is a designation independent of municipalities for one or more settlements, such as villages, hamlets or other closed settlement areas, which is relevant for postal purposes. It encompasses the actual settlement area and can be defined independently of municipal boundaries, although there are often overlaps.	An agglomeration is defined as the catchment area of WWTP. The size of the agglomeration is the organic design capacity of the plant. Plants with design capacity ≥ 1,000 PE are referred to urban wastewater treatment plant (UWWTP). WWTPs in agglomeration < 1,000 PE are considered as small UWWTPs and WWTPs ≤ 50 PE as small WWTPs or individual systems (BMLUK, 2021).

Bosnia and Herzegovina	A settlement is a part of the area of a local government unit that has built housing facilities, basic communal infrastructure and other facilities necessary to meet the needs of residents living in its area.	Agglomeration means an area where population and/or economic activities are sufficiently concentrated that urban wastewater can be collected and conveyed to a wastewater treatment plant or to the final discharge point.
Czechia		In Czech practice, the boundaries of agglomerations are traditionally not determined by municipal boundaries, but by continuously built-up/buildable areas where collection is cost-effective.
Croatia	In Croatia, a municipality ("općina") is a unit of local self-government, alongside cities ("grad"). They are part of the second level of administrative subdivisions, below counties ("županije"). Municipalities are typically found in more rural or suburban areas and often encompass multiple settlements ("naselja"). (Wikipedia)	The area of one agglomeration is served with one collection system and one WWTP.
Germany	Settlements are divided into towns and communities.	Independent of settlements, the individual wastewater treatment plants are defined according to PE. Particularly in rural areas, small/individual sewage treatment plants with design capacity < 50 PE are used and referred Kleinkläranlagen (KKA).
Hungary	Settlements are self-governing areas of Hungary, elected and governed by the representatives of the local community.	Agglomerations are defined according to 379/2015. (XII.8). Main economic aspects: at least 120 people or 52 houses must be connected to each 1 km of drainage system.
Romania	An urban locality is a locality where most of the labour resources are employed in non-agricultural activities with a diversified level of endowment and equipment, exerting a constant and significant socioeconomic influence on the surrounding area. A rural locality (village) is a locality where most of the workforce is concentrated in agriculture, forestry, fishing, offering a specific and viable way of life for its inhabitants, and which, through modernization policies, will preserve its rural specificity in the future.	Agglomerations are defined according to the requirements of the UWWTD. The criteria for "sufficiently concentrated" are: • 19 people connected per 100 m or 7 houses per 100 m of pipeline, which can be considered equivalent to an interval of 10–25 PE/ha; • a distance criterion of 250 m (used as an approximation) is applied to determine whether two neighbouring settlements should be included in the same agglomeration.
Serbia	The Statistical Office of the Republic of Serbia (SORS) defines settlements in census methodology as basic spatial units	The indicative reference threshold of 10–25 PE per hectare, as mentioned in Article 6 of the UWWTD, is acknowledged but not

	used for demographic and socio-economic reporting. Settlements are legally recognized by administrative-territorial regulations and are further categorized as urban (typically larger and more developed) or rural settlements (smaller, often agriculturally based).	yet systematically applied in national practice. At present, agglomerations are identified mainly on the basis of administrative boundaries and infrastructural criteria, such as existing sewer networks and discharge points. The integration of this indicative density criterion will be considered during the future harmonisation of Serbian legislation with the new Directive in the course of the EU accession process.
Slovakia	A municipality ("obec") is the basic unit of local self-government, a territorial and administrative unit comprised of residents who permanently reside there. Essentially, it's a town, village, or other community with its own local government. Municipalities are legal entities with the right to manage their own property and finances.	Agglomerations are defined according to the requirements of UWWTD. As a general rule, if the distance between two settlements is less than 500 m they are considered as one agglomeration (with few exemptions and a case-by-case approach).
Slovenia	A settlement is an area of an existing settlement that includes land developed with residential and other buildings, civil engineering structures, and associated areas necessary for their use, as well as public spaces. A settlement consists of a group of at least ten residential buildings. Settlements differ in terms of their function and role within the settlement network, as well as in size, urban planning, and architecture. Settlements are classified as towns, other urban settlements, and other settlements.	Agglomerations are defined in areas where the load density is equal to or greater than 10 PE/ha, and where the load is equal to or greater than 50 PE. The load density is calculated based on the number of permanently registered residents in each square cell of 100 m by 100 m (hereinafter referred to as a “cell”). The population load in a given area is calculated as the sum of the load of groups of contiguous cells whose load density is equal to or greater than 10 PE/ha and that are contiguous at least at one node. Agglomerations are groups of contiguous cells with a total load ≥ 50 PE. Of course, there are exemptions.

Number of and population living in small settlements

The results from the questionnaire related to small settlements are summarised in Table 4. Due to differences in how settlements and agglomerations are defined across countries (see Table 2), direct comparisons are not always possible. For instance, in **Austria** and **Slovenia**, the minimum size of an agglomeration is **50 inhabitants**, while for other countries the definition is based on the delineation of agglomerations according to the UWWTD.

Table 4: Number (#) of settlements (sett.)/agglomerations (aggl.) and their population (Pop.; in millions) in the DRB countries (i.e., results from questionnaire provided from countries of D-CLEAN partners).

	Total		< 2,000 inhabitants		< 1,000 inhabitants		Outside aggl.
	#	Pop.	#	Pop.	#	Pop.	Pop.
Austria[1]	17,010	9.1	10,900	2,018,517	10,453	1,391,537	130,522
BiH[4]	6,141	3.2	ca. 5,500	2,650,000	ca. 5,000	No data	None
Croatia[2]	6,757	3.8	896 sett. 487 aggl.	302'180	No data	No data	469,460
Czechia	6,258	10.9	5,527	2,928,358	4,723	1,809,349	No data
Germany[5]	2,000	83.6	No data	No data	No data	No data	No data
Hungary	3,199	9.6	2,378	1,650,000	1,775	780,000	No data
Romania[3]	12,816	19.0	1,619[6]	2,063,997	562[6]	297,319	0
Serbia	6,158	6.9	2,639	4,470,000	2'170	3,700,000	2,177,000
Slovakia	2,890	5.5	2,262 sett. 2,047 aggl.	1'570'504	1,619 sett. 1,539 aggl.	723,373	No data
Slovenia	6,035	2.1	5,927 sett. 1,410 aggl.	1,097,118 480,765	795 sett. 1,310 aggl.	917,290 334,926	436,902

[1] # = number of villages, 2,093 municipalities with 1'348 municipalities < 2'500 inhabitants; outside agglomeration = villages ≤ 50 inhabitants; number of and population in small villages (< 2,000 inhabitants) based on Pistocchi et al. (2022);
[2] 128 towns and 428 municipalities, which in turn are subdivided into 6757 settlements;
[3] according to the questionnaire, "*all Romanian population was allocated to agglomerations*";
[4] 4,756 sett. < 500 PE (578,458 inhabitants); according to the questionnaire, "no population outside agglomerations ";
[5] Number of settlements: 2,000 local authority districts.
[6] number of agglomerations in Romania;

Other responses showed some obvious inconsistencies:

- **Croatia** reported a total number of 6,757 settlements but only 896 settlements with less than 2,000 inhabitants. If the remaining ~5'680 settlements each had a population of 2,000 inhabitants this would imply a total population of approximately 11.7 million, which significantly exceeds Croatia's actual population of 3.8 million. Additionally, Croatia officially reported 127 towns and 428 municipalities resulting in a total number of 555 settlements, which is fewer than the 896 small settlements reported—indicating a discrepancy in classification or reporting.

- **Romania** provided criteria for defining agglomerations, including population density thresholds. However, the statement that "*all Romanian population was allocated to agglomerations*" appears to contradict the definition of agglomeration, which typically excludes areas with low population density. This raises questions about how agglomeration boundaries are interpreted.

In several countries, **data gaps** were noted, particularly regarding specific aspects of settlement classification and population distribution.

Data reported on **uninhabited settlements** vary greatly. Most countries acknowledged the existence of uninhabited settlements, though **exact numbers were generally unavailable**. Hungary was the only country to report that no uninhabited settlements exist. Uninhabited villages may include areas abandoned due to military activity, depopulation, or seasonal occupancy (e.g., summer homes). Most countries stated that uninhabited settlements are not included in the reported number of settlements. An exception is Serbia and Slovenia, where these uninhabited settlements are included in the official total.

Table 5 presents the number of small settlements and Table 6 shows the corresponding population figures. Besides the countries listed in Table 1, also Montenegro was included as more than 50 % of the Montenegro's territory is part of the DRB. Data from Serbia in Table 1 include the territory of Kosovo and thus, Kosovo is included in the Serbia data in Table 5 and Table 6, respectively.

Table 5: Estimated number of small settlements in the DRB (estimation based on Pistocchi et al., 2022).

Country	<2,000	<1,000	1,999-1,000	999-500	499-100	99-50	<50
Austria	10,472	10,043	429	641	2,702	2,209	4,492
Bulgaria	1,718	1'549	169	266	636	274	374
BiH*	1,941	1,800	141	219	706	433	441
Czechia	2,910	2,763	147	277	1,177	595	714
Croatia	3,274	3,163	111	214	1,035	772	1,142
Germany	8,115	7,568	547	849	2,655	1,406	2,658
Hungary	4,827	4,224	603	677	1,545	692	1,310
Moldova*	749	695	55	85	273	167	170
Montenegro*	256	237	19	29	93	57	58
Romania	12,369	10,913	1,456	2,040	4,524	1,696	2,654
Serbia*	5,184	4',807	377	585	1,887	1,157	1,178
Slovakia	2,669	2,275	394	550	1'032	331	362
Slovenia	3,323	3,254	69	149	809	688	1,607
Ukraine*	2,125	1,990	135	203	639	404	744
Total	**59,933**	**55,281**	**4,651**	**6,782**	**19,713**	**10,882**	**17,905**

* Non-EU Member States have not been part of the Pistocchi et al. (2022) paper

Pistocchi et al. (2022) provided estimates on the number of small settlements and their populations across EU Member States. For those within the DRB, figures were adjusted based on the share of national territory within the basin, under the assumption that the distribution of small settlements is uniform across each country. For non-EU countries, estimates were extrapolated using patterns observed in EU Member States.

Based on this methodology, it is estimated that there are about **60,000 settlements with less than 2,000 inhabitants** in the DRB of which around **55,000 have fewer than 1,000 inhabitants** (Table 5). There are about 7,000 settlements with 500 to 999 inhabitants, 20,000 with 100 to 499 inhabitants, 11,000 with 50 to 99 inhabitants, and 18,000 with less than 50 inhabitants, respectively.

The total population of the DRB is estimated at approximately 80 million. Of this, about 17.4 million people live in settlements with less than 2,000 inhabitants and about 10.9 million in settlements with less than 1,000 inhabitants (Table 6). About 4.8 million people live in settlements with 500 to 999 inhabitants, about 4.8 million in settlements with 100 to 499 inhabitants, about 800,000 in settlements with 50 to 99 inhabitants, and about 550,000 in settlements with less than 50 inhabitants, respectively.

Table 6: Estimated inhabitants living in small settlements within the DRB (estimation based on Pistocchi et al., 2022).

Country	<2,000	<1,000	1,999-1,000	999-500	499-100	99-50	<50
Austria	1,939,348	1,336,959	602,389	457,637	598,681	155,238	125,403
BiH*	574,326	376,444	197,881	154,714	168,874	30,986	21,870
Bulgaria	614,685	381,004	233,681	187,970	162,125	20,238	10,671
Czechia	732,119	530,717	201,402	194,743	271,198	42,929	21,847
Croatia	622,884	465'157	157,727	148,102	227,015	54,827	35,214
Germany	2,173,897	1,407,855	766,042	602,581	629,232	100,545	75,498
Hungary	1,833,120	959,986	873,134	489,177	384,706	49,490	36,614
Moldova*	221,684	145,304	76,380	59,718	65,184	11,960	8,442
Montenegro*	75,685	49,608	26,077	20,388	22,254	4,083	2,882
Romania	4,861,812	2,824,526	2,037,286	1,453,327	1,171,213	121,413	78,573
Serbia*	1,533,789	1,005,329	528,460	413,178	450,993	82,752	58,406
Slovakia	1,257,335	701,523	555,812	389,944	277,143	23,897	10,538
Slovenia	459,393	364,988	94,405	102,766	169,624	47,851	44,747
Ukraine*	535,586	346,471	189,115	143,323	152,658	28,865	21,624
Total	**17,435,662**	**10,895,872**	**6,539,790**	**4,817,568**	**4,750,902**	**775,075**	**552,327**

* Non EU Member States have not been part of the Pistocchi et al. (2022) paper

C. Wastewater collection and treatment

In the DRB, nearly 3,000 small WWTPs (51–1,999 PE) with a total design capacity of 1.76 million PE are reported. Despite significant efforts in some countries (e.g. AT: 30%, CZ: 29%, DE: 20%, SI: 38%) to equip small settlements, decentralised wastewater management remains a regional challenge, with approximately 85% of the load still untreated. Conventional systems are the most widespread (>67%), while the adoption of nature-based solutions remains limited.

National data collection

Under the previous UWWTD, European Member States had no reporting obligations for agglomerations below 2,000 PE. This changed with the **revised UWWTD** (2024), which came into force on 1 January 2025. The updated directive **lowers the threshold for mandatory wastewater**

treatment to 1,000 PE, aiming to address cumulative pollution from smaller but significant sources. Settlements/agglomeration below 1,000 PE as well as **individual and appropriate systems (IAS)** may still be regulated under national legislation.

To monitor implementation progress, the European Commission requires Member States to comply with the following reporting obligations given in the UWWTD:

- Article 15: Monitoring data must be collected and made available to the Commission within six months of a formal request, typically issued every two years.
- Article 16: Member States must publish biennial reports on urban wastewater and sludge disposal. These reports must also be submitted to the Commission.
- Article 17: Member States must provide updates on the status and implementation of the Directive, following the format outlined in Commission Decision 93/481/EEC. The first report should be updated every two years.

As of 2028, the revised UWWTD will phase out these written reporting requirements, transitioning to more streamlined digital reporting mechanisms.

Below we summarize how countries in the DRB collect and report data on WWTPs serving fewer than 2,000 PE, including IAS. In most cases, sanitation service providers report to the federal state level, with some exceptions regarding IAS (e.g., Serbia, Slovakia).

Austria

All WWTPs—including small plants and IAS—require permits issued on the district level, thus data are available there.

- For WWTPs ≥ 2,000 PE: data are reported biannually to the EU (BMLUK, 2004) and thus collected on a national level by the Federal Ministry.
- For (small) WWTPs ≥ 1,000 PE: reporting is aligned with the new UWWTD requirements.
- Small WWTPs > 50 PE: data are collected by and are available at the 9 federal states and aggregated by the Federal Ministry.
- IAS ≤ 50 PE: data are available at district level, expected to be accessible at federal state level.

Bosnia and Herzegovina

Data systems include Pollutant Release and Transfer Register (PRTR) for Federation of BiH and Water Information System (ISV) that exists at the Federation of BiH and Republika Srpska level. It is managed by river basin agencies, but it primarily focuses on water status and quality, not specifically on (small) WWTP performance. Data for IAS (e.g., septic tanks, package plants) are mostly collected at the local level, through inspections and reports, but a centralized and updated registers is often lacking, which presents a challenge in monitoring the actual state of the systems.

Croatia

Data are collected by public water service providers and municipalities, then submitted to Croatian Waters and the Ministry of Economy and Sustainable Development. This includes data on public drainage, purification systems, and septic tanks.

Czechia

Every WWTP operator is required to report the plant's results at several levels:

- Regular sampling and analyses submitted to water authorities.
- Operational performance uploaded to Integrated System of Reporting Obligations (ISPOP) system (https://www.ispop.cz). From there, the data is automatically forwarded to the relevant authorities (e.g., the Ministry of the Environment, the Czech Environmental Inspectorate).
- Property and operational data are submitted to the Ministry of Agriculture, which is responsible for enforcing the Water Act in terms of wastewater management. This data is then also used for statistical evaluation.

Germany

Data are maintained in the Umwelt Atlas database.

Hungary

Annual data collection is conducted by water directorates, gathering information from municipalities (on IAS) and utility operators (on WWTPs). The process is consistent for systems above and below 2,000 PE.

Romania

Data are submitted by wastewater operators and local authorities to an online platform managed by the National Administration "Romanian Waters":
https://epurare-ape-uzate-urbane.rowater.ro/en/ .

Serbia

Local public utility companies and municipalities which are responsible for providing water and sanitation services collect data on WWTP coverage, use of septic tanks and IAS, households without access to sewage network. Data are reported to regional environmental agencies and the Ministry of Environmental Protection which compiles national statistics.

Slovakia

WWTP operators must report the number of inhabitants connected to both the collection system and the WWTP. IAS are not systematically reported.

Slovenia

The Slovenian Environment Agency collects data via Operational Wastewater Monitoring Reports, submitted electronically by January 31 each year. The agency also collects data on IAS.

Characteristics of small WWTPs

Individual systems

UWWTD defines an individual system (IAS) a sanitation facility designed to collect, store, treat, or dispose of domestic wastewater from buildings or parts of buildings that are not connected to a public collecting system. Specific national regulations regarding IAS vary, but in general they include nature-based solutions (NBS), small-sized treatment systems, or temporary tanks combined with regular evacuation to central treatment plants.

Under the previous Directive, small agglomerations (< 2,000 PE) were not covered, thus it was expected that IAS would be commonly used in these areas (Bacian, 2022). With the revision (2024), IAS are now mainly expected to be applied within areas located outside agglomerations (< 1,000 PE) or in agglomerations where public sewer system not yet being constructed.

Table 7 summarises the number or percentage of inhabitants connected to IAS in the studied countries relative to the total national population. A high percentage (e.g. 41% in Serbia) indicates strong reliance on IAS rather than centralised sewer networks. However, even a relatively low percentage (e.g. 4.5% in Slovenia) can be misleading if considered in isolation. In Slovenia, adequate IAS (small WWTPs < 50 PE) serve approximately 22% of the population living outside agglomerations, indicating that only one in five households in these areas provides a level of environmental protection comparable to that achieved by public collection and treatment systems.

Table 7: Individual systems (IAS) in the countries of the DRB.

Country	Number (or percentage) of inhabitants connected to IAS.	Percentage of the wastewater load addressed by means of IAS expressed in PE (CIRCABC UWWTD National Summary Chapters, 2020)
Austria	1.1 % of design capacity and ca 2 % of the population, respectively	0.6 % of the wastewater load (~122,900 PE).
BiH	Less than 40 % of BiH's population is connected to the public sanitary system, meaning over 60 % rely on individual or decentralized systems such as septic tanks and collection pits. *	/
Croatia	469,460 PE and ~12 % of the population	21 % of the wastewater load (~983,500 PE).
Czechia	This information is not publicly available.	2.1 % of the wastewater load (~195,500 PE)
Germany (Bavaria)	~350.000 PE and ~3 % of the population	1.6 % of the wastewater load (~1,806,431 PE).
Hungary	940,225 inhabitants and ~10 % of the population	9 % of the wastewater load (~1,117,800 PE).
Romania	~20,640 PE and 0.1 % of the population	1.4 % of the wastewater load (~282,800 PE).

Serbia	Around 41 % of the Serbia's population is not connected to a public sanitary system and relies on IAS, mainly septic tanks. In rural areas, this figure rises to over 76 % of households.	/
Slovakia	In 2022 there was ~9.8 % load estimated to be produced from IAS in agglomerations larger than 2,000 PE. 31 % of inhabitants are connected to public sewers in agglomerations < 2,000 PE.	11.6% of the wastewater load (~471,100 PE).
Slovenia	96,150 PE and ~4.5 % of the population	7 % of the wastewater load (~112,300 PE).

* Septic tanks must be watertight and constructed in compliance with applicable legal provisions and technical standards.

Size distribution of small WWTPs in the DRB

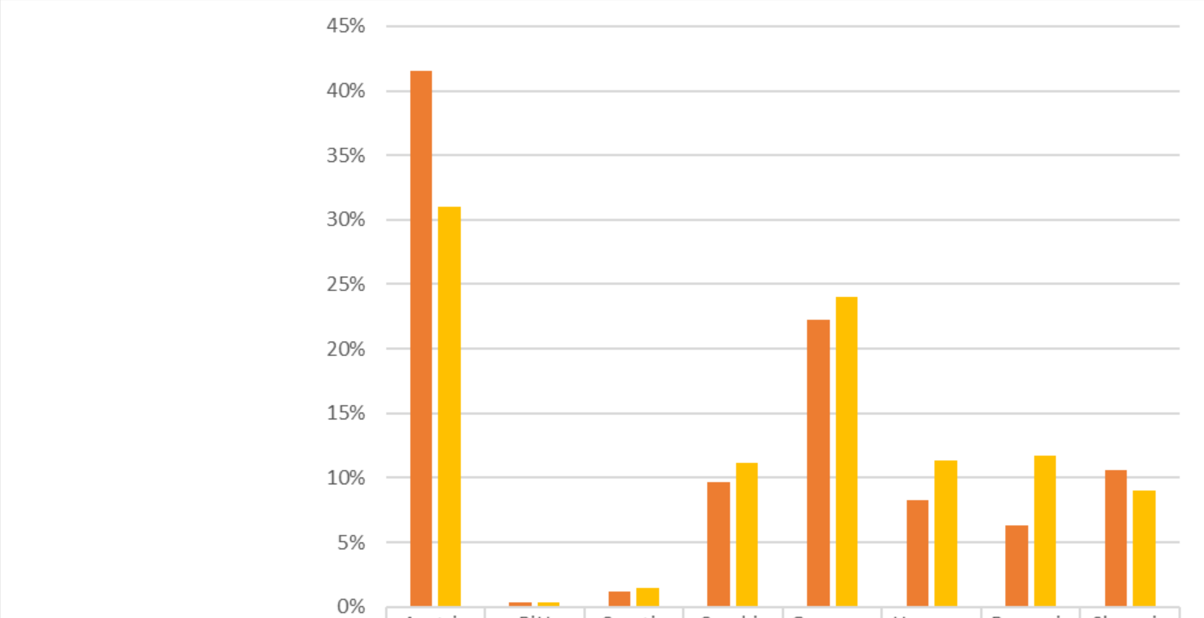
Table 8 presents the number and total design capacity of small WWTPs in the studied countries categorized by size. A total of **2,919 small WWTPs** in the 51–1,999 PE range were reported, with a combined design capacity of **1,76 million PE**. Plants in the 51–500 PE category dominate in terms of quantity (1,757 WWTPs), yet their combined design capacity (461,152 PE) is significantly lower than that of the 501–1,999 PE category. Despite having fewer plants (1,162), the latter accounts for a much larger share of the total design capacity of 1,3 million PE, highlighting their greater contribution to wastewater treatment in small settlements in the DRB.

Table 8: Number of small WWTPs by size category and their total design capacity in the studied countries.

	Number of WWTPs				Total design capacity (PE)			
	≤ 50 PE	51-500 PE	501-1,000 PE	1001-1,999 PE	≤ 50 PE	51-500 PE	501-1,000 PE	1,001-1,999 PE
Austria	*27,452	958	120	135	260,500	259,287	96,023	191,000
BiH	n.a	4	4	1	n.a.	900	3,100	1,500
Croatia	1	13	11	10	50	3,056	7,928	14,885
Czechia	9	120	98	65	353	33,929	72,271	90,711
Germany	6	350	152	147	292	82,825	118,518	221,283
Hungary	5	82	78	80	233	19,739	60,180	119,550
Romania	0	26	56	101	0	10,830	46,750	149,225
Serbia								
Slovakia								
Slovenia	*12,705	204	70	34	84,962	50,586	55,888	53,070
Total	**40,178**	**1,757**	**589**	**573**	**346,390**	**461,152**	**460,658**	**841,224**

*Data also includes private small WWTP (IAS), owned and operated by individual households.

As illustrated in Figure 3, **Austria and Germany** together account for nearly **two-thirds of all reported WWTPs** (51–1,999 PE) in the DRB and treat over half of the region's collected wastewater. Czechia, Hungary, Romania and Slovenia each contribute approximately 10 % to overall treatment in the DRB, while Croatia and BiH contribute only a marginal share.



	Austria	BiH	Croatia	Czechia	Germany	Hungary	Romania	Slovenia
Share of sWWTPs number	42%	0%	1%	10%	22%	8%	6%	11%
Share of sWWTPs design capacity	31%	0%	1%	11%	24%	11%	12%	9%

Figure 3: Distribution of reported small WWTP (51-1,999 PE) across DRB countries (individual systems are not included in the total number).

To assess the current status of wastewater treatment in settlements/agglomeration below 2,000 PE, the reported design capacities of WWTPs were compared with the estimated population living in small settlements in DRB of each country. The data presented in

Table 9 indicate that **Slovenia and Austria** show the **highest share of treated PE**, with 33–38% and 29–30%, respectively, while coverage is very low in BiH (1%), Romania (2-4%), and Croatia (3-4%) indicating significant gaps in service provision. Data from Serbia and Slovakia were not available for this comparison.

Overall, the data indicate that **adequate wastewater treatment in small settlements remains a major challenge across the DRB** (

Table 9). A substantial portion of the population in these areas is still not connected to functioning treatment systems. This highlights that small, scattered settlements have historically received less attention, as they were not high on national priority lists. The revised UWWTD (2024) which mandates treatment for agglomerations between 1,000 and 2,000 PE is expected to help close the legal, administrative, financial, and operational gaps that have hindered progress.

Table 9: Comparison of connected inhabitants in small settlements (< 2,000 PE) in DRB.

Country	Total design capacity of sWWTP in the DRB in PE (from Table 8)		Inhabitants of small settlements in the DRB (from Table 6)		% of solved PE/inh. on a DRB country level	
	51-1,000 PE	51-1,999 PE	50-1,000 inh.	50-1,999 inh.	50-1,000 inh.	50-1,999 inh.
Austria	355,310	546,310	1,211,556	1,813,945	29 %	30 %
BiH	4,000	5,500	354,574	552,455	1 %	1 %
Croatia	10,984	25,869	429,944	587,671	3 %	4 %
Czechia	106,200	196,911	508,870	710,272	21 %	28 %
Germany	201,343	422,626	1,332,358	2,098,400	15 %	20 %
Hungary	79,919	199,469	923,373	1,796,507	9 %	11 %
Romania	57,580	206,805	2,745,953	4,783,239	2 %	4 %
Serbia			946,923	1,475,383		
Slovakia			690,984	1,246,796		
Slovenia	106,474	159,544	320,241	414,646	33 %	38 %
Total / avg.	**921,810**	**1,560,623**	***7,826,869**	***12,757,135**	**12 %**	**14 %**

*Without Serbia and Slovakia.

Discharge recipients

In the DRB, small WWTPs (between 51 and 1,999 PE) typically discharge treated effluent into surface water bodies such as streams and rivers (Table 10). Discharging regulations are subject to national legislation – i.e., in Austria and Slovenia, discharging effluent into the lakes is prohibited, while Romania and Germany allow it. Another notable difference is that some countries (e.g., Slovenia) do not consider the ecological status of the receiving water body when determining the discharge location or type.

Sewer network usually ends at the lowest point of the settlement and thus, WWTPs are commonly built-in lowland areas, along riverbanks or other locations where effluent can be discharged into the receiving water body. In contrast, on-site IAS (≤50 PE) are typically installed adjacent to residential buildings. Connecting IAS to distant surface water bodies would require significant investment from private owners—sewer construction costs in South-eastern Europe range from approximately €100 to €300 per square meter—and may involve complex administrative procedures, such as securing discharge permits across neighbouring properties. Consequently, IAS systems usually discharge effluent via indirect soil infiltration (e.g., infiltration pits), ultimately reaching groundwater.

These infrastructural and regulatory factors, combined with inconsistent reporting on IAS across countries, result in significant variation in discharge locations throughout the DRB. For example, in Bosnia and Herzegovina, Croatia, and Romania, most treated effluent is discharged into rivers, while in Germany, lakes are the predominant recipients. Slovenia stands out due to its high number of IAS systems, with 83 % of small WWTPs discharging into groundwater. However, public small WWTPs in Slovenia primarily discharge into rivers (81%).

Table 10: Wastewater recipients of small wastewater treatment plants (< 2,000 PE) across the DRB (n.a. - data not available).

Country	Nr of small WWTPs	Recipient of discharge (% of total small WWTPs)			
		Groundwater	River	Lake	Transitional waters
Austria	28,665	n.a.	n.a.	n.a.	n.a.
BiH	9		89%	11%	
Croatia	35	3%	97%		
Czechia	292	n.a.	n.a.	n.a.	n.a.
Germany	655	1%	9%	84%	1%
Hungary	245	n.a.	n.a.	n.a.	n.a.
Romania	183		97%	3%	
Serbia	0	n.a.	n.a.	n.a.	n.a.
Slovakia	n.a.	n.a.	n.a.	n.a.	n.a.
Slovenia	13,013	83%	17%		

Wastewater treatment technologies

In the DRB, small WWTPs are implemented using a variety of technology types to address local treatment needs. Based on our analysis, the main WW treatment technologies (Figure 2) in the DRB are:

- **Suspended growth treatment systems (58 %):** These systems rely on biological processes where microorganisms are suspended in the wastewater to break down pollutants. Commonly reported technologies in the DRB include conventional activated sludge systems, sequencing batch reactors (SBRs), and compact "package plants," which often incorporate variations of activated sludge treatment.
- **Nature-based solutions (29 %):** NBS harness natural processes to treat wastewater while delivering additional ecological and social benefits. The most widely applied NBS in the DRB is the constructed wetland. Other reported systems include lagoon systems, waste stabilization ponds, and poplar-based treatment systems.
- **Attached growth systems (9 %):** These systems use fixed media surfaces where microorganisms can attach and form biofilms to treat wastewater. Technologies reported

in the DRB include biofilters, rotating biological contactors (bio-disks), and other biofilm-based systems.

- **Hybrid systems (< 1 %):** These integrate multiple wastewater technologies to enhance and optimize wastewater treatment. Reported hybrid systems include conventional activated sludge or sequencing batch reactors combined with treatment wetland, electrophysical processes coupled with natural treatment, and combined biological treatment systems.
- **Other systems (4 %):** This category includes unclassified or unidentified wastewater treatment technologies.

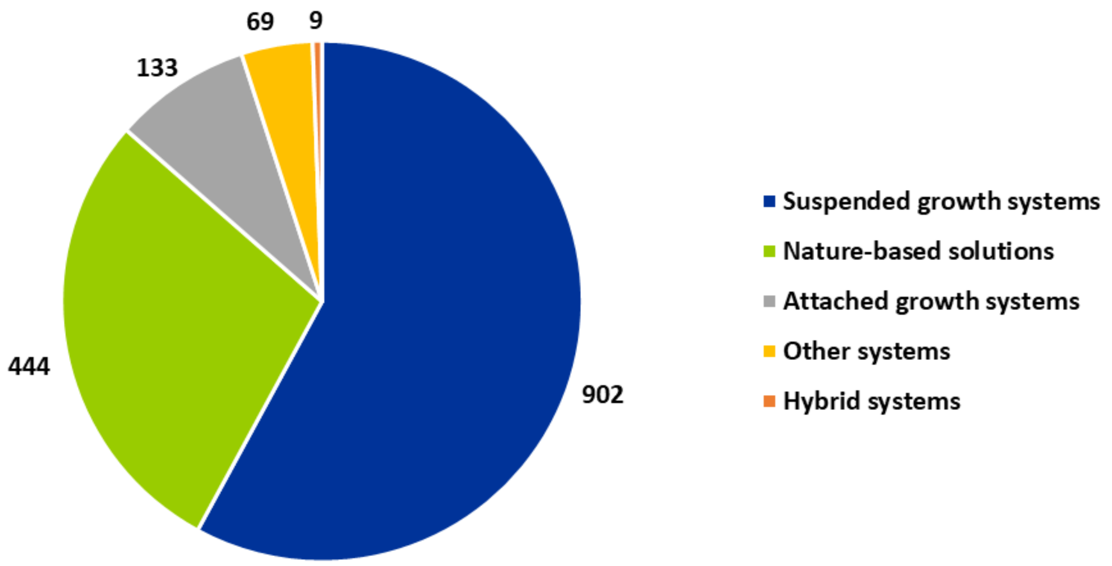


Figure 4: Number of reported suspended growth, nature-based solutions, attached growth, hybrid and other systems of small wastewater treatment plants (< 2,000 PE) in the DRB.

Table 11 summarizes the distribution of wastewater treatment technologies of small WWTP in the DRB. The highest share of suspended growth systems is found in Czechia (32 %), followed by Slovenia (25 %), Hungary (23 %), and Germany (18 %). By far, the largest share of NBS is in Germany (90%) due to the presence of 365 waste stabilization ponds. Slovenia and Hungary follow with a share of 3.8% each. Attached growth systems are most common in Germany (60 %), followed by Slovenia (26 %) and Hungary (9.8 %).

Figure 3 illustrates the types of WW treatment technologies used in small WWTPs across individual countries in the DRB. The comparison highlights a strong reliance on conventional WW treatment technologies in most DRB countries that provided data.

Bosnia and Herzegovina is at the early stages of implementing small WWTP (<2,000 PE), which is reflected in the low number (9 in total) of reported systems. The country has primarily focused on NBS, which account for 67 % of all reported systems, while suspended growth systems make up the remaining 33 %. No attached growth systems or other categories have been reported.

Croatia stands out for its relatively diverse range of wastewater treatment technologies, with suspended growth systems (31 %), attached growth systems (14 %), NBS (11 %), and a large share categorized as "other" (43 %).

Czechia has so far implemented almost exclusively suspended growth systems, which account for 99 % of reported small WWTPs. NBS and attached growth systems are nearly absent, representing only 0.7% and 0.3%, respectively.

Germany emphasises the implementation of NBS, which account for 61 % of reported small WWTP. Suspended growth systems represent 25 % and attached growth systems account for 12 %. Hybrid systems are present at very small share (0.9 %), while "other" technologies make up 0.9 %.

Hungary primarily relies on suspended growth systems (86 %), with smaller shares of nature-based solutions (6.9 %) and attached growth systems (5.3 %). Hybrid systems (1.2 %) and »other« systems (0.8 %) account for only minor shares.

Slovenia shows a significant reliance on suspended growth systems (71 %), with smaller shares of attached growth systems (11 %) and NBS (5.3%). A notable portion (13 %) of small WWTP is classified under the "other" category.

Table 11: Distribution of reported wastewater treatment technologies of small wastewater treatment plants (< 2,000 PE) in the DRB, by country according to the results from the questionnaire.

Treatment technology	small WWTP (Nr)	Austria	BiH	Croatia	Czechia	Germany	Hungary	Romania	Serbia	Slovakia	Slovenia
Suspended growth systems	**902**		0.3 %	1.2 %	32 %	18 %	23 %				25 %
Nature-based solutions	**444**		1.4 %	0.9 %	0.5 %	90 %	3.8 %				3.8 %
Attached growth systems	**133**			3.8 %	0.8 %	60 %	9.8 %				26 %
Other systems	**69**			22 %		13 %	2.9 %				62 %
Hybrid systems	**9**					67 %	33 %				

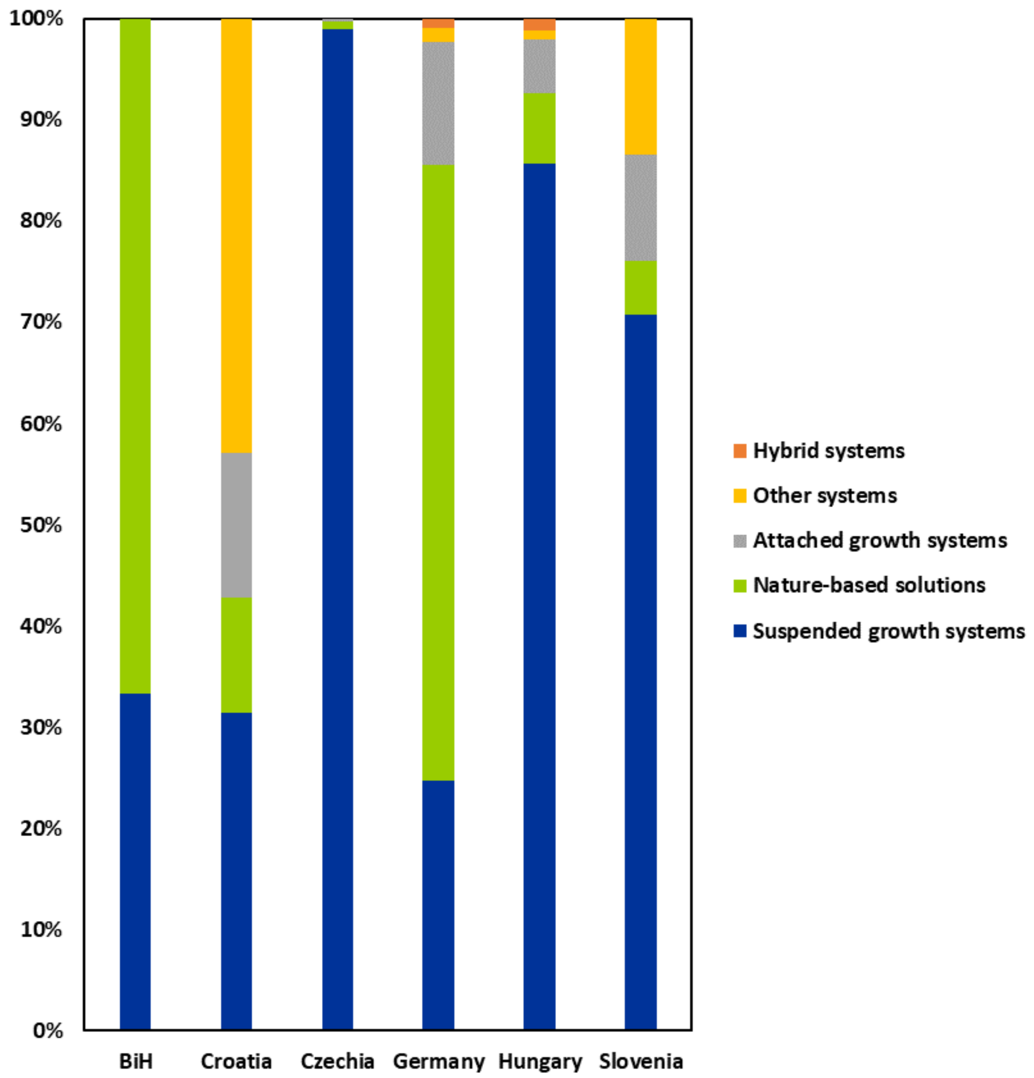


Figure 5: Reported wastewater treatment technologies for small wastewater treatment plants (< 2,000 PE) across DRB countries.

Efficiency

The efficiency results of small WWTPs (< 2,000 PE) are based on annual monitoring reports from 2023 or 2024 in Croatia, Germany, Hungary, and Slovenia. Table 13 presents a comparison of the average removal efficiencies for BOD, COD, P, and N across different wastewater treatment technologies (suspended growth systems, treatment wetlands, and attached growth systems), providing insight into treatment performance within the region.

All treatment technologies achieved COD removal efficiencies exceeding 85%. The highest average COD removal was observed in suspended growth systems (88 %), followed by attached growth systems (86 %) and treatment wetlands (85 %).

Table 12: Comparison of reported removal efficiencies in small wastewater treatment plants (<2,000 PE) in selected countries of the DRB. Standard deviation and number of wastewater treatment plants in given in brackets.

	Removal efficiency (%)			
	COD	BOD	TP	TN
Suspended growth systems	88% (SD=19, n=717)	92% (SD=12, n=624)	66% (SD=23, n=375)	70% (SD=22, n=312)
Treatment wetlands	85% (SD=19, n=29)	91% (SD=8, n=19)	52% (SD=23, n=12)	55% (SD=28, n=12)
Attached growth systems	86% (SD=17, n=46)	88% (SD=20, n=38)	53% (SD=24, n=13)	61% (SD=24, n=14)

BOD removal efficiencies were within the expected long-term ranges reported in Table 12. Among the technologies, suspended growth systems achieved the highest average BOD removal (92 %), followed by treatment wetlands (91 %) and attached growth systems (88 %).

Nutrient removal performance was also highest in suspended growth systems (TP: 66 %; TN: 70 %), followed by attached growth systems (TP: 53 %; TN: 61 %). Treatment wetlands achieved nutrient removal efficiencies above 50% (TP: 52 %; TN: 55 %), exceeding the typical performance ranges presented in Table 13.

All analysed wastewater treatment technologies showed effective removal of organic matter, while suspended growth systems show highest nutrient removal.

Table 13: Comparison of different common domestic wastewater treatment systems in terms of ranges of expected removal efficiencies of major constituents (adapted from Wallace et al., 2026).

Category	Treatment chain	Expected ranges of long-term removal efficiencies from the overall treatment system (from raw sewage to final effluent)					
		BOD (%)	TSS (%)	TKN (%)	TN (%)	TP (%)	*E. coli* (LRV)
Extensive (wetlands)	Septic tank (ST) + HF wetland	80-95	90-97	20-35	30-50	10-30	1.0-2.5
	Septic tank (ST) + VF wetland (sand)	85-98	90-98	85-98	20-40	10-30	2.5-4.0
	Septic tank (ST) + VF wetland (gravel)	75-85	80-90	60-70	10-30	10-30	1.0-2.0
	French VF wetland	83-95	85-95	60-95	15-40	10-40	1.0-3.0
Intensified (wetlands)	Septic tank (ST) + aerated HF wetland	90-98	90-98	85-95	40-50	10-30	2.5-4.0
	Septic tank (ST) + aerated VF wetland	90-98	90-98	85-95	20-50	10-30	1.5-2.5
	Septic tank (ST) + fill-and-drain wetland	90-95	90-95	70-85	60-80	10-30	1.0-2.0
Extensive (ponds)	Facultative pond (FP)	75-85	70-80	20-30	20-40	10-30	1.0-2.5
	Stabilization ponds + maturation ponds (MP)	80-85	73-83	50-65	50-65	20-50	3.0-6.0
Intensive (anaerobic)	UASB reactor without post-treatment	60-75	65-80	0-5	0-5	0-5	0.5-1.0
	Septic tank (ST) + anaerobic filter (AnF)	60-80	70-80	0-10	0-10	0-10	0.5-1.0
Intensive (aerobic)	Trickling filter (TF)	80-90	85-95	20-40	20-40	10-30	0.5-1.5
	Activated sludge (AS)	85-95	85-95	60-85	20-40	20-50	1.0-2.0
	Activated sludge (AS) with BNR	85-95	88-98	80-95	75-90	75-88	1.0-2.0

removal efficiencies refer to the *overall treatment system* and are calculated based on raw sewage and final effluent concentrations; LRV = log reduction values.

D. Discharge limits

While all Danube region countries regulate discharge from small wastewater treatment plants, the scope, stringency, and parameters vary widely. These differences reflect national priorities, environmental conditions, and legal frameworks.

National legislation

All participating countries report having national legislation that regulates discharge limits for small wastewater treatment plants, though the scope and specificity vary. **Austria, Slovenia, Serbia, Slovakia, Czechia, and Germany** have clear legal frameworks that explicitly include small plants, often with tailored limits based on plant capacity or receiving water body. Czechia, Germany, Slovakia and Slovenia have legislation that defines discharge limits also for individual treatment systems < 50 PE, while in Austria and Serbia there are legislative limits starting from systems above 50 PE; however, in Austria in general also for individual systems ≤ 50 PE required effluent concentrations are the same as for 51 < PE < 500. **Romania and Hungary** apply discharge limits independently of plant size, focusing instead on the type of recipient. Similarly, Austria also has specific regulations for remote locations and Slovenia mandates monitoring of microbial pathogens (e.g. *E. coli*) at discharges to bathing waters for treatment plants above 500 PE. **Croatia and Czechia** base their regulations on broader water laws and government decrees, which include provisions for small systems. **Bosnia and Herzegovina** does not distinguish discharge limits *specifically for <2000 PE plants in its legislation, but applies general discharge standards to all systems, with variations depending on the entity (Federation of Bosnia and Herzegovina, Republika Srpska, Brčko District) and the nature of the receiving environment.

Discharge limits for small wastewater treatment plants

According to the UWWTD minimum discharge limits are defined for COD, TOC, BOD, TSS for treatment plants with a capacity of ≥1000 PE. All countries in this study regulate **COD and BOD_5,** with reported limits ranging from 50–200 mg/L for COD and 15–80 mg/L for BOD_5 (Table 14). For reference, the UWWTD sets maximum values of 125 mg/L for COD and 25 mg/L for BOD_5. In Croatia, Romania, Bosnia and Herzegovina, and Serbia, the UWWTD limits are directly transposed into national legislation. While the directive allows Member States to monitor either COD or TOC, all countries in our study opted for COD, except Austria, which monitors both COD and TOC. Additionally, Austria also measures settleable substances.

Table 14: Discharge limits for small wastewater treatment plants (< 2,000 PE) in participating Danube region countries. Reported ranges reflect differences in treatment plant capacity and the sensitivity or type of receiving water bodies.

Country	COD	BOD	TOC	TSS	Sett. Sub.	TN	NH_4-N	NO_3-N	NO_2-N	TP	PO_4-P	*E. coli*	Enterococci
	mg/L	mg/L	mg/L	mg/L	mL/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	CFU/100 mL	CFU/100 mL
Austria	75-90	20-25	25-30		0.3-9.5		5-10			2			
BiH	125	25		35			10	10*	1*			500-1000**	200-400**
Croatia	125	25		35		15	10	2	1	2	1		
Czechia	125-150	30-40		20-50		30	20-30					150	100
Germany	75-150	15-40		50-75		25	10			2		100	
Hungary	50-150	15-50		35-200		20-55	2-40	3-28	2-10	0.7-10		10	
Romania	125	25		60		15	3	37	2	2			
Serbia	125	50-80		75-100									
Slovakia	135-150	30-40		30-50		40	20					150	
Slovenia	150-200	30										500-1000	200-400
count	10	10	1	8		6	8	4	5	5	1	6	3
min	50	15		35		15	2	2	1	0.7		10	
max	200	80		200		55	20	28	10	10		1000	

*only in RS, **only in FBiH

TSS is regulated in all countries except Austria and Slovenia, with discharge limits ranging from 35 to 200 mg/L. The UWWTD limit for TSS is 35 mg/L, which is applied in Croatia, BiH, and Hungary (specifically for discharges into Lake Balaton). Other countries apply higher limits, especially for general recipients. It should be noted that stricter limits may apply to WWTPs >2,000 PE.

Although the UWWTD does not mandate **nitrogen and phosphorus** limits for WWTPs <2,000 PE, it encourages Member States to apply stricter standards to meet the objectives of the Water Framework Directive (2000/60/EC), Marine Strategy Framework Directive (2008/56/EC), Environmental Quality Standards Directive (2008/105/EC), and Bathing Water Directive (2006/7/EC).

In this context, nitrogen removal is required in 8 out of 10 countries. **Ammonia nitrogen** (NH_4-N) is limited in 7 countries, typically at 10 mg/L, with values ranging from 2 mg/L (e.g. Lake Balaton, Hungary) to 20 mg/L. **Total nitrogen** (TN) is limited in 6 countries, with thresholds between 15 mg/L (Croatia, BiH and Romania) and 55 mg/L (Hungary). Nitrate (NO_3-N) and nitrite (NO_2-N) are also regulated in BiH, Croatia, Hungary, and Romania. Slovenia and Serbia do not impose nitrogen limits for small WWTPs.

Phosphorus discharge is regulated in 5 countries: Austria, Croatia, Germany, Hungary, and Romania with all focusing on total phosphorus (TP). Croatia additionally limits orthophosphate (PO_4-P). The most stringent TP limit is 0.7 mg/L (Hungary, Lake Balaton), while other countries typically apply a 2 mg/L threshold.

Microbiological parameters such as *E. coli* and/or intestinal enterococci are regulated in BiH (only for discharge in surface water used for swimming and recreation), Czechia, Hungary, Germany, and Slovakia, and also in Slovenia when discharging into bathing waters.

Finally, Romania also regulates additional parameters such as **phenols, synthetic detergents, and sulphides/hydrogen sulphide**, reflecting a broader scope of environmental protection.

The analysis reveals significant variation in discharge limits and regulatory approaches for small wastewater treatment plants across the Danube region. While EU member and candidate countries generally align with the UWWTD, national adaptations reflect local environmental priorities and technical capacities. Parameters such as COD, BOD_5, and TSS are widely regulated, but nutrient and microbiological standards vary considerably. These differences underscore the need for harmonized yet context-sensitive strategies to improve wastewater management in small settlements and protect water quality throughout the basin.

E. Monitoring

Monitoring of small WWTPs in the Danube basin is highly heterogeneous, shaped by national regulations, plant size, and local conditions. While some countries apply structured and frequent monitoring others rely on flexible, reactive, or site-specific approaches.

General observations

Monitoring requirements for small WWTPs vary significantly in terms of frequency, parameters analysed and financial responsibility. While some countries have clearly defined national regulations, others rely on site-specific decisions or general environmental laws. Additionally, most countries apply tiered monitoring obligations based on plant capacity; however, WWTP size classifications differ.

Austria, Croatia, Germany, and **Slovakia** demonstrate structured monitoring frameworks, with frequencies ranging from once to twelve times per year. Monitoring is typically conducted by the plant operator, often in collaboration with accredited laboratories or specialized service providers. Austria and Germany require both external (third-party) and internal (self-monitoring) assessment ensuring comprehensive oversight. Croatia allows a limited number of samples to exceed the limits which provides a certain flexibility for the small systems; the permissible number is defined according to the total annual samples.

Country specific models:

- **Slovenia** has a unique model where visual inspections are conducted every three years for the smallest plants (< 50 PE) while effluent sampling is required for larger systems ranging from twice every two years to three times annually. Financing responsibilities are split - private owners typically cover costs for systems <50 PE, while public utilities manage larger installations.
- **Hungary** applies a reactive monitoring scheme. For private systems (<50 PE), monitoring is only required upon request by authorities, particularly in sensitive areas. WWTPs between 50 and 2,000 PE are subject to biannual monitoring, which may increase if discharge limits are exceeded. In case of private treatment plants (< 50 PE) the costs of monitoring are covered by the owner.
- **Romania** and **BiH** distinguish between operator-led monitoring and regulatory control by water authorities. Romania lacks specific legal requirements for WWTPs <2,000 PE but enforces monitoring to ensure operational reliability. In BiH, monitoring practices differ by entity: in the Federation of BiH, operators conduct biannual sampling, while in Republika Srpska, water authorities perform quarterly external monitoring.
- **Serbia** currently lacks detailed regulations for small WWTPs. Monitoring frequency, sampling responsibilities, analyses, and financial mechanisms remain undefined. Future obligations are expected to align with broader water management plans.
- **Czechia** emphasizes site-specific monitoring plans tailored to local hydrological conditions, catchment characteristics, and protection zones. Monitoring frequencies range from 4, 6 or 12 times per year, using composite sampling protocols. This flexible site-specific approach may serve as a model for other countries with diverse geographic and hydrological conditions.

Financing responsibilities

Operators are most commonly responsible for monitoring costs. In Romania costs are shared between operators, owners and public utilities, depending on the type of monitoring. Slovenia and Hungary apply mixed models where private owners finance monitoring of small systems and public utilities cover larger installations. Similar situation is in BiH, where WWTPs in private ownership (serving households, industry, or small businesses), the monitoring costs are covered by the owners. For public WWTPs, which are managed by public utility companies, monitoring is financed through PUC funds.

Monitoring by WWTP size

Smallest plants (< 50 PE) are often privately owned; however certain monitoring is required in all countries except Serbia and in Hungary only in sensitive areas. Austria, Croatia and Slovakia mandate one monitoring per year. BiH, Czechia, Germany, and Romania require two or more assessments annually, while in Slovenia there is only visual inspection every 3 years (Table 15).

Regarding small WWTPs (<2000 PE), monitoring frequency increases with plant size. Systems between 1000 and 2000 PE are subject to more frequent assessments—ranging from twice per year in Hungary, to six times annually in Austria and Slovakia, and monthly in Germany. Austria also differentiates monitoring frequency based on the specific parameter being analysed, reflecting a more refined approach to environmental risk management.

Table 15: Different size classification of small WWTPs and monitoring frequency.

	10 < PE < 49	< 50 PE	50 ≤ PE < 200	50 < PE < 500	50 < PE < 1,000	200 ≤ PE < 1,000	1,000 < PE < 2,000	501 < PE < 5,000
Austria		1 per year		1 per year				6 per year
BiH-FBiH		2 per year			2 per year		2 per year	
BiH-RS		4 per year			4 per year		4 per year	
Croatia	1 per year				2 per year		4 per year	
Czechia				4, 6 or 12 per year*				
Germany		2 per year			quarterly		monthly	
Hungary		Only if the authority requires it.			2 per year**		2 per year**	
Romania		2-4 per year			2-4 per year		2-4 per year	
Serbia								
Slovakia		1 per year		4 per year			6 per year	
Slovenia		Visual inspection every 3 years	2 every 2 years			2 per year	3 per year	

*Individually defined according to the catchment and protection zones
** If the monitoring results show worse than the discharge limit, then the next year need more monitoring.

F. Management plans

There is significant heterogeneity in planning approaches, coverage, and updating cycles, particularly due to the new requirements of Directive (EU) 2024/3019. The planning for wastewater collection and treatment in small settlements (1,000–2,000 PE) is still at a very early or uneven stage across the region. Local wastewater management planning across the region is fragmented.

National management plans

National operational programmes are part of the reporting requirements (Article 17 of the former UWWTD, with the obligation now continued under Article 23 of the revised UWWTD (2024)). By 1 January 2028, Member States shall establish a national implementation programme in accordance with the revised UWWTD (2024). These national operational programmes are not only the basis for regular reporting to the European Commission but also serve as key planning tools.

The national management plans must include (Articles 3-8 in the Directive):

- An assessment of the level of implementation of collection and treatment obligations.
- Identification and planning of investments needed for each agglomeration, cost estimates, financing strategies, and priorities based on environmental/public health risk, etc.

Municipalities/operators must also provide information to the public, especially in agglomerations above certain thresholds (e.g., 1,000 or 10,000 PE), including:

- Data on compliance with treatment/collection obligations (e.g., are treatment plants achieving what is required).
- Volumes of wastewater collected/treated, cost, performance, etc.

Based on the results from the questionnaires for wastewater management plans in DRB, several conclusions can be drawn regarding the state of planning in the region (Table 16). Most reported countries (Bosnia and Herzegovina, Croatia, Hungary, Romania, Serbia, Slovakia, Slovenia) have national or regional wastewater management plans. Some countries rely mainly on legislation rather than dedicated plans (Germany and Czechia manage wastewater largely through national and regional legal frameworks rather than formal national plans).

Table 16: Overview of national management plans wastewater collection and treatment in the DRB countries.

Country	National management plans
Austria	The UWWTD (1991) is fully implemented in the Austrian Water Act and its specific ordinances.
BiH	The Water Management Strategy is part of the Environmental Protection Strategy (2022–2032). Basin-specific Water Management Plans 2022-2027 are available (Sava River Basin, Adriatic Sea Water Area); plans for period 2028–2033 are currently in preparation. In Republic of Srpska, an Integrated Management Strategy of Waters (2015–2024) is in place, covering Sava and Trebišnjica River Basins for period 2017–2021. A national agglomeration master plan to support UWWTD implementation is currently under development.
Croatia	A Water Management Strategy was adopted in 2010 and Implementation Plan for Water Utility Directives was prepared in the same year. The plan defines deadlines for full compliance by end of 2023 for most agglomerations > 2,000 PE. Updates are ongoing. A multi-year investment program for wastewater collection and treatment for the period from 2021 to 2030 has been prepared.
Czechia	The development of water infrastructure, including wastewater collection and treatment, is generally governed by the Water Act (254/2001 Coll). The planning process is the responsibility of the 14 self-governing regions, while supervision and oversight are carried out by the Ministry of Environment and the Ministry of Agriculture, which are responsible for ensuring compliance with national regulations and EU water directives.
Germany	Wastewater treatment is implemented through national and regional legislation rather than dedicated national management plans. Key legal frameworks include the Wasserhaushaltsgesetz (WHG, Federal Water Act) and, at the state level, laws such as the

	Bayerisches Wassergesetz (BayWG). These laws regulate wastewater collection, treatment, discharge, and environmental protection, ensuring compliance with EU directives. https://www.gesetze-im-internet.de/whg_2009/ https://www.gesetze-bayern.de/Content/Document/BayWG
Hungary	Adopted wastewater management plan pursuant to Government Decree No. 25/2002. As the last planning period covered 2002–2015, the plan is now due for revision and updating.
Romania	An Accelerated National Plan for Water and Wastewater in agglomerations > 2,000 PE was adopted in 2022 (Government Memo No. 34356), followed by the 2024-2030 National Plan for Investment and Development in the Water and Wastewater Sector. Currently no national plan exists for agglomerations < 2,000 PE; however, planning will commence following the transposition of Directive (EU) 2024/3019.
Serbia	Wastewater management is included in the Water Management Strategy until 2034, as well as in the accompanying action plans.
Slovakia	A national plan for water and wastewater management is in place for the 2021–2027 period. Further details are available on the Ministry of Environment website. https://minzp.sk/voda/verejne-vodovody-verejne-kanalizacie/
Slovenia	The Operational Program of Municipal Wastewater Disposal and Treatment is in place. The last version was published in 2020 and is applicable until 2027.

Some countries have recent or ongoing updates to align with EU directives (Bosnia and Herzegovina). Planning documents are often prepared by different institutions, for different territorial units (e.g. river basins, entities, or administrative levels), and for different timeframes, resulting in a fragmented planning landscape.

While all reported countries have established regulatory frameworks or management plans for wastewater in larger agglomerations (> 2,000 PE), the situation is notably different for smaller settlements (< 2,000 PE). In most countries, planning and regulatory coverage for these smaller agglomerations remains limited or absent. Specifically, Bosnia and Herzegovina, Croatia, Hungary, and Romania currently lack dedicated national management plans for settlements below 2,000 PE. However, Romania has indicated that it will initiate the development of such plans following the transposition of Directive (EU) 2024/3019, which mandates more inclusive and integrated wastewater management planning across all settlement sizes. In Austria and Germany all agglomerations > 1,000 PE are connected to wastewater treatment.

Countries with legal frameworks instead of operational plans (Germany, Czech Republic) rely on decentralized implementation and oversight, which may be less visible in national plan compilations but still ensures compliance. In Croatia, Bosnia and Herzegovina, and Serbia, wastewater management planning is not fully consolidated into a single, unified national plan.

Directive 2024/3019 will require many countries to develop planning for smaller agglomerations. Major adaptation will be the definition of the small agglomeration below 2,000 PE (to min. 1,000 PE). In the table, we can see how countries plan to proceed.

Table 17: National deadlines for wastewater collection and treatment for settlements (1,000<PE<2000).

Country	Schedule for Wastewater Management in Small Settlements (1000 < PE < 2000)
Austria	All agglomerations > 1,000 PE have a wastewater treatment plant already.
BiH	No specific national deadline is set for agglomerations of 1,000–2,000 PE. Deadlines for larger agglomerations are linked to EU accession, with staged obligations (6–18 years after accession) under the national regulation.
Croatia	Current planning in Croatia covers only agglomerations larger than 2,000 PE. The national deadline for compliance with Directive (EU) 2024/3019 for agglomerations between 1,000 and 2,000 PE has not yet been set; however, the general EU deadline of 31 December 2035 is implied
Czechia	There is no specific national strategy or document defining deadlines; however, according to available sources, the responsible ministries plan to follow the deadlines set out in the Directive.
Germany	Nearly 100% of the population is connected to wastewater treatment plants.
Hungary	At present, there is no national deadline for wastewater collection and treatment in settlements/agglomerations with between 1,000 and 2,000 PE. The deadline is 31. December 2035. according to the EU Directive 2024/3019. The EU directive. The revision of Hungarian legislation is in progress.
Romania	In accordance with Article 3 of Directive (EU) 2024/3019, Romania may derogate from the standard deadline for connecting all sources of domestic wastewater to collecting systems for a maximum period of 14 years, provided that on 1 January 2025 less than 25 % of the urban wastewater load of agglomerations between 1,000 and 2,000 PE is collected in collecting systems.
Serbia	December 31, 2035 (as per EU Directive 2024/3019)
Slovakia	For agglomerations of 1,000–2,000 PE, the deadlines are stipulated directly in Directive (EU) 2024/3019. Slovakia does not have the flexibility to set national deadlines and will make use of all time exemptions provided for under the Directive.
Slovenia	For agglomerations 50 ≤ PE < 2,000 the deadline is 31. December 2027, only for agglomerations 500 ≤ PE < 2,000 an interim deadline of 31 December 2025 applies if the discharge is into a sensitive area, into water within the catchment area of a sensitive area, or into water within a water protection zone.

The analysis of national schedules and planning approaches shows that most countries have not yet set clear or uniform national deadlines for wastewater collection and treatment in small agglomerations. Instead, many rely directly on the deadlines stipulated in Directive (EU) 2024/3019, or are still in the process of adapting their national frameworks.

Some countries have established explicit national deadlines (Slovakia, Slovenia), others are in early stages of planning (Croatia). Bosnia and Herzegovina, Czechia and Hungary have no defined national deadlines for this size class.

Bosnia and Herzegovina as an accession country, links its deadlines to EU membership date rather than fixed calendar deadlines, with staged obligations over 6–18 years after accession depending on agglomeration size.

Local management plans

Local wastewater management planning across the region is fragmented and uneven (Table 18); there is no uniform approach to local wastewater management planning. Some countries have robust, legally anchored municipal planning systems (Austria, Germany, Hungary and Czechia), where municipalities are legally required to prepare wastewater management plans which are regularly updated.

Table 18: Availability and scope of local management plans.

Country	Local management plans; availability and scope
Austria	Municipalities must prepare plans specifying which villages will connect to central WWTPs and where alternative solutions are needed.
BiH	Some municipalities and cantons have wastewater master plans. Examples include the city of Bihać (2008), a 20-year plan for rural areas in Una-Sana Canton (2019), and Priority Investment and Long-Term Investment Plans for six municipalities around Modrac Lake Basin in Tuzla Canton (2015).
Croatia	Municipalities do not have their own plans; wastewater management is regulated centrally by legal entity Croatian Waters, which issues permits for wastewater requiring special treatment before discharge or connection to public drainage systems.
Czechia	All Czech municipalities develop Water Supply and Sewerage Development Plans (PRVK), strategic documents covering water supply and wastewater treatment, including needs forecasts, infrastructure proposals, and investment costs. Plans are prepared regionally, updated regularly, submitted to the regional office, and must be followed by municipalities.
Germany	Yes
Hungary	The municipalities have their own wastewater management plan, which is included in the municipal environmental programme.
Romania	Generally, there are no wastewater management plans for agglomerations < 2000 PE.
Serbia	Municipal wastewater master plans vary across Serbia, depending on administrative capacity and funding. Larger municipalities can implement comprehensive plans, often supported by international assistance, such as the West Morava River Basin plan and WBIF-funded projects in medium-sized municipalities (e.g., Jagodina, Kikinda, Pirot).
Slovakia	Municipal wastewater planning information is limited. Under Act No. 200/2022, municipalities must include water infrastructure in their urban development plans, sometimes via local economic and social development programs. Self-governing regions are responsible for developing regional plans for public water supply and sewerage systems (2021–2027), which are then translated into municipal-level plans.
Slovenia	Yes; Slovenia relies on municipal plans within a nationally coordinated framework.

Majority of reported countries has at least some extend of local planning of wastewater collection and treatment. This is a common practice in Austria, Czechia, Germany, Hungary and Slovenia and is reported to be demanded also in Slovakia. Croatia and Romania rely on centralised frameworks and water authorities.

Different project-based approaches (uneven local planning) can be found in Serbia, Bosnia and Herzegovina. Plans exist, they are often prepared for specific regions or municipalities (e.g., Bihać, Tuzla Canton), rather than through a uniform obligation. Generally, municipalities with stronger administrative and financial capacity (Bosnia and Herzegovina, Serbia, Austria) are better able to develop comprehensive local plans, whereas smaller or rural municipalities often depend on national authorities or international donors.

This variability will strongly influence the pace and effectiveness of implementing Directive (EU) 2024/3019 regarding small agglomerations. Even larger gaps are reported for settlements below 1000 PE.

Table 19: Existence of national regulation for wastewater collection and treatment for settlement with less than 1,000 PE.

Country	Existence of national regulation for settlement < 1,000 PE
Austria	For WWTPs < 1,000 PE, permits are issued case-by-case under AEVkA (1996, 2006) depending on location and receiving waters. Permits are time-limited (e.g., 15 years) and can be renewed if the plant meets legal standards. Operation and maintenance requirements include self-monitoring, external monitoring, and operator training, with some federal states adjusting monitoring frequency based on training completion.
BiH	While cantonal and local plans (e.g., Una-Sana Canton) address wastewater in settlements below 1,000 inhabitants, no formal national or entity-level regulations specifically target this category; applicable rules are implemented through regional strategies.
Croatia	There are currently no national regulations for agglomerations of less than 1,000 PE
Czechia	No specific national regulation or plan exists for settlements below 1,000 PE. Wastewater treatment obligations apply to all producers, with state enforcement, while municipalities decide on compliance via individual or centralized systems, often supported by subsidies.
Germany	Nearly 100 % of the population is connected to wastewater treatment plants.
Hungary	No national regulation exists for wastewater collection and treatment in settlements below 1,000 PE.
Romania	No national regulation or plan is currently in force for wastewater collection and treatment in settlements below 1,000 PE.
Serbia	Settlements below 1,000 PE are not covered by national plans; local authorities are encouraged to implement decentralized or NBS or small-scale treatment systems.
Slovakia	No national regulation exists for wastewater collection and treatment in settlements below 2,000 PE, except in specially protected areas for drinking water, where treatment or connection is required. The new UWWTD will be transposed into national law by mid-2027.
Slovenia	For settlements with 50–500 PE, the national deadline for wastewater collection and treatment is 31 December 2027.

Settlements < 1,000 PE are currently under-regulated. Wastewater collection and treatment in these areas relies on local initiatives or regional frameworks, and will require new national regulations and plans to comply with the upcoming UWWTD requirements. Small agglomerations are most dependent on local capacity, funding, and technical support. Implementation is currently highly heterogeneous, ranging from formal municipal plans (Austria, Slovenia, and Czechia) to ad hoc or project-based approaches (Serbia, Bosnia and Herzegovina). In some countries (e.g., Bosnia and Herzegovina) cantonal or regional strategies provide the main framework for small settlements, if national regulations are absent.

Under this context, a reliance on local or decentralized solutions are indicated. Where no national framework exists, municipalities or local authorities often implement decentralized or nature-based solutions (e.g., constructed wetlands, small-scale treatment systems, for e.g. in Austria, Czechia, Germany, Serbia and Slovenia).

Applied sewer system types

In small settlements, separate sewer systems dominate in new developments, while combined sewers are mainly found in older village centres or larger towns (Table 20). Generally, countries with older infrastructure (Austria, Czechia, Bosnia) show higher shares of combined systems. Countries with active national/regional planning and recent construction (Slovakia, Slovenia, Romania) favour separate systems.

Table 20: Main types of sewer systems in small settlements and in new developments.

Country	Usual sewer system in settlements < 2,000 PE	New developments
Austria	Typically, a combination of old combined sewers in village centers and separate sewers in newer areas.	Separate sewers.
BiH	Historically, combined sewers dominated, but in the last 15–20 years, new systems are mostly separate.	Separate sewer system.
Croatia	Public drainage system managed by utility companies, while stormwater is managed by municipalities and cities.	Connection to existing mixed sewers or separate collection of wastewater and stormwater infiltration on site.
Czechia	There are 6,397 registered sewer systems; additionally, 5,339 networks are combined, 4,907 are separate, and 447 are dedicated stormwater systems.	Separate sewer system.
Germany	Combined system	Mainly separate sewer system.
Hungary	Separate sewer systems; combined sewers exist only in larger towns where separate systems are not feasible.	Separate sewer system (if enough space).
Romania	Separate sewer systems are predominant (75%), with combined systems in 22% and mixed systems in 3% of cases.	Separate sewer system.
Serbia	Individual systems; where sewerage exists, combined systems are common.	Separate sewer systems.
Slovakia	Predominantly separate (80–90%), with combined sewers mostly in larger towns.	Separate sewer systems.
Slovenia	Mainly separate (50%), followed by stormwater (30%) and combined sewers (17%), reflecting recent construction trends.	Separate sewer systems.

In most countries (Hungary, Romania, Slovakia, Slovenia, recent Bosnia developments), separate sewer systems prevail in settlements < 2,000 PE. Combined sewers are typically limited to older parts of villages or towns that were sewered decades ago (Austria, historical Bosnia, older municipalities in Slovakia, older districts in Czechia).

Across the region, all new developments are constructed with separate sanitary and stormwater systems, except when connecting to existing mixed sewers (e.g., Croatia). Stormwater is sometimes handled via open ditches, absorption wells, or dedicated stormwater pipes, depending on local conditions.

G. Stormwater management

Stormwater management is generally underdeveloped and varies widely across the region. Pluvial flooding, erosion, and limited infrastructure are recurring challenges. Awareness and stakeholder involvement are often reactive rather than proactive. Rainwater harvesting is mostly informal. While spatial planning increasingly addresses stormwater, implementation gaps persist.

Governance and system typologies

Stormwater governance across the DRB mixes combined and separate systems, with a steady drift toward separation in smaller agglomerations. Slovakia uses pricing to keep roof water out of sewers and—like Slovenia, Germany, and Croatia—continues extending separate connections where new drainage exists. Austria's decentralized, municipality-led model keeps combined systems common but explicitly encourages routing clean rainwater to natural drainage before sewer entry. Serbia, BiH, and many Hungarian villages pragmatically rely on infiltration, roadside ditches, and natural conveyance shaped by terrain and budgets, while Romania and Czechia maintain traditions of conveying runoff to streams or centralized sewers—raising CSO risks where systems are combined. Overall, countries are converging on a 'keep-clean-water-clean' approach with more property-level retention and infiltration, even as legacy configurations and local capacity drive heterogeneous outcomes.

Challenges

Across the region, small settlements face similar challenges in managing stormwater. Pluvial flooding, erosion, and combined sewer overflows are common, particularly during intense rainfall events exacerbated by climate change:

- **Pluvial flooding and system overloads**. Across the region, intense, short-duration rainfall increasingly overwhelms local capacity. Hungary reports pluvial floods and erosion in small settlements; Serbia cites lack of infrastructure leading to uncontrolled overflows; Slovenia notes that even with separation works underway, stormwater inflows still flood pumping stations and complicate sewer and WWTP operations. Germany acknowledges that sewers are simply not sized for today's most extreme cloudbursts, leading to surface flooding. BiH highlights multiple manifestations: flooding from undersized or poorly maintained systems, landslides from rapid groundwater rise, and devastating torrential flows—exemplified by floods in October 2024 in several municipalities. These cases underscore the urgency of retention, conveyance upgrades, and emergency overland flow planning.
- **Combined sewer overflows (CSOs)**. Romania and Czechia describe CSOs as a persistent issue where stormwater is mixed with sanitary sewage, causing untreated discharges during storms. While combined systems are entrenched in older urban areas, small settlements benefit from building separate networks from the outset, provided there are resources for maintenance and for treating polluted runoff sources.
- **Infrastructure and land constraints.** Slovenia notes clogged or under-designed roadside ditches and limited municipal land to expand them due to agricultural areas—an illustrative example of how right-of-way constraints can bottleneck drainage improvements. Many small communities across the region report insufficient or outdated assets, and maintenance shortfalls that compound flood risk.

Beyond these region-wide patterns, Austria cites mapping gaps for storm sewers, scarce operation and management and CSO monitoring, and more frequent pluvial flooding; Croatia reports flooding, soil erosion, and surcharge of storm drains in settlement areas; and Slovakia flags overflows during strong rains—each underscoring the need for routine maintenance, verified asset data, and added detention.

National regulation

The regulatory landscape for stormwater management varies significantly across the region. Most countries regulate stormwater through general water laws or construction codes, with few having specific provisions tailored to small settlements.

Austria's national framework for stormwater management is defined by §3(3) of the Ordinance on Wastewater Emissions into Watercourses and Public Sewer Systems (AAEV, 1996). It requires treatment of combined-sewer pollutants at central WWTPs during precipitation events, design and operation of hydraulic relief structures based on the concept of critical rainfall while maintaining ecological functionality, and preferential routing of uncontaminated or slightly contaminated rainwater from residential areas to natural surface or subsurface drainage before entering the sewer system. Technical implementation is guided by ÖWAV-Regelblätter: 11 (2009) for sewer systems, 19 (2007) for combined sewer overflows, and 45 (2015) for infiltration-based surface drainage.

Germany classifies stormwater collected from paved/built areas as wastewater under §54 of the Federal Water Act (WHG); discharges to surface waters or to soil infiltration require a water law permit. Treatment levels scale with contamination risk (e.g., roads, car parks), guided by sectoral rules such as DWA-A 138-1. In low-risk cases, some federal states exempt small, clean areas from permit requirements. This end-to-end approach (classification, permit, treatment, and technical guidance) exemplifies a comprehensive model for environmental protection and hydraulic safety.

Romanian law bans subsurface injection and land spreading of wastewater, effectively steering stormwater toward engineered collection and surface discharge, with technical norms defining how stormwater flows are calculated. Moreover, stormwater from roads and large parking areas must be collected and treated before discharge. This strict orientation can minimize groundwater contamination risks but raises the bar for small settlements that lack capital for treatment assets.

Slovakia regulates sewer performance and CSO discharges but leaves treatment of polluted rainwater largely to best available techniques (BAT) and permitting authority judgment.

Czechia integrates stormwater into a suite of spatial-planning tools, strategic adaptation policies, and building-scale obligations (e.g., retention tanks for new builds), yet acknowledges the lack of a fully unified implementation toolkit, pushing responsibility down to municipalities. These frameworks promote context-sensitive design but can lead to uneven outcomes without technical assistance and funding for small local governments.

In **Serbia** there is no stormwater-specific statute for small settlements; general construction and water laws apply, leaving practices to local adaptation and permitting.

Some countries also apply sector-specific rules. **Croatia** requires oil/grease separation for stormwater from roads and parking areas. **Hungary** mandates drainage ditches along roads and oil traps for car parks above a specified size threshold. **Slovenia**'s national decrees define when and how stormwater must be treated—including stricter rules for heavily trafficked public roads and prohibitions on direct discharge to standing waters—while in villages routine practice may still be direct discharge to streams unless special protections apply. **BiH** sets limit values for total suspended solids and mineral oils, requiring separators and control shafts for polluted runoff. Collectively, these sectoral requirements target clear pollutant pathways (traffic, parking), yet their enforcement and long-term maintenance remain variable in smaller communities.

Core infrastructure practices

In Slovakia, mixed systems are complemented by property-level storage and reuse promoted through campaigns and incentives, reinforcing infiltration and retention at source. Austria pairs combined conveyance with source control: clean roof and yard runoff is encouraged to infiltrate or drain overland ahead of the sewer, with CSO design and central treatment covering wet-weather events.

Infiltration and percolation. Infiltration is widespread where soils and groundwater conditions allow: Croatia uses soakaways, Germany deploys infiltration from separate systems and localized collection areas, while Serbia and BiH frequently rely on natural infiltration into lawns or green strips. Infiltration reduces hydraulic loads on treatment plants and streams—especially valuable where separate sewage networks are still being built—but it must be carefully sited and pre-treated to avoid contaminant transport to aquifers.

Ditches, channels, and retention. Many countries lean on open channels and roadside ditches to convey or slow stormwater. Croatia often routes roof runoff to absorption wells, canals, ditches, and retention lagoons; Hungary commonly uses ditches and receiving channels; Slovenia's roads are drained via ditches that discharge to streams or infiltration wells. Retention basins and lagoons, where present, add detention storage that can be combined with pollutant separators (oil/grease) for transport corridors and parking areas.

Separate drainage for specific land uses. Industrial yards, parking lots, and highways appear across the region as "hot spots" for first-flush pollutants. The mitigation portfolio includes oil/grease separators (Croatia, BiH), stormwater treatment prior to discharge (Germany, Romania, Slovenia), and controlled release from retention basins (Slovenia). These targeted interventions deliver high environmental value per euro spent by prioritizing the most contaminated flows.

Awareness, capacity, and uptake of NBS

Austria mirrors this mixed picture: attention often spikes after floods, while integral stormwater management and NBS uptake remain uneven in small towns; rainwater use is mostly private (e.g., garden irrigation), and systematic planning integration appears chiefly in research pilots.

Public and stakeholder awareness varies widely. Several countries point to information gaps. Hungary observes that stakeholders are “not sufficiently informed,” and Serbia reports low awareness among residents. Czechia notes residents have “almost no information,” though mayors are often well-informed because they operate municipal infrastructure directly. In contrast, Germany provides extensive public guidance and holds information events through water management authorities.

Mixed acceptance of NBS. Although NBS (e.g., infiltration swales, rain gardens, green roofs) are implicitly embedded in several national practices, their uptake is uneven. Slovakia runs campaigns and funding schemes to promote garden reservoirs and on-site reuse; projects by public agencies and private actors (e.g., malls, factories) demonstrate benefits. Slovenia remarks that while stakeholders are generally informed, NBS adoption remains limited, especially in rural areas where communities perceive existing green areas as “enough,” highlighting the need for targeted communication on functional performance (storage volumes, infiltration rates), not just aesthetics.

Consultative planning processes. Romania emphasizes structured public information and consultation in environmental impact assessment and river basin planning processes—engaging residents, mayors, utilities, and NGOs. This institutionalized dialogue can build support for investments and operating practices that reduce CSOs and flood risk.

Rainwater Harvesting

Rainwater harvesting is present but uneven (Table 21). The most structured uses are either household-scale (e.g., Slovenia, Romania) or system-scale reservoirs (e.g., Croatia's Butoniga). Others show pilot-level adoption or ad-hoc practices.

Table 21: Status of rainwater harvesting and use in small settlements across DRB.

Country	Rainwater harvesting and reuse
Austria	Limited – mainly private garden irrigation; some research pilots.
BiH	Limited – mostly household scale; broader adoption uncommon.
Croatia	Yes – rain/stormwater collected in reservoirs; e.g., Butoniga lake in Istria and Vransko lake are used as a drinking-water source after treatment.
Czechia	Limited – most rainwater still drains via sewer to recipients; reuse not common, though old fire reservoirs are being repurposed as water features.
Germany	Partially – residents/industry use (e.g., garden/toilet) depending on local conditions.
Hungary	Yes (some municipalities) – stormwater reservoirs with infiltration are used.
Romania	Yes (especially rural) – household irrigation and other home uses.
Serbia	Rare – in some rural households for irrigation or toilet flushing.
Slovakia	Yes (growing) – garden/public-space watering; subsidy campaigns for rainwater retention.
Slovenia	Yes – roof water commonly used for garden irrigation as a household supplementary source.

Stormwater in spatial planning

Spatial planning acts as the main tool or mechanism to integrate SW management into development decisions (Table 22). Countries with clear legal hooks (Croatia, Romania, Germany, Czechia) show more consistent integration. Where integration is partial or contingent (Slovenia, Slovakia, Serbia), uptake varies with local capacity, prior studies, or funding.

Table 22: Integration of stormwater management into spatial planning in small settlements.

Country	Stormwater management inclusion into spatial planning
Austria	Not systematic – considered mostly in research/pilot contexts.
BiH	Yes (legal obligation) – required in spatial/urban/regulatory documents, but implementation often weak or delayed.
Croatia	Yes – explicitly included in spatial planning.
Czechia	Yes – embedded through zoning plans, regulatory plans, studies, and planning agreements with developers.
Germany	Yes – integrated into planning/approval processes with stakeholder information duties.
Hungary	Yes – considered when designating new development sites.
Romania	Yes (legal obligation) – required under spatial planning law and county master plans.
Serbia	Partially – increasingly reflected in newer spatial plans/green-infrastructure concepts, but not yet fully integrated.
Slovakia	Partially – addressed in the Urban Planning Act (No. 200/2022); some permitting/fee incentives steer rainwater outside sewers.
Slovenia	Partially – NBS for SW appear in detailed plans mainly where a prior SW study exists; not yet systematic.

H. Strengths and weaknesses

Decentralized systems and NBS are generally viewed as advantageous for rural areas in the DRB, especially in terms of stakeholder involvement, water cycle balance, and resource recovery. However, successful implementation depends on overcoming financing challenges, institutional fragmentation, lack of technical capacity, and climate resilience.

Decentralized and centralized approach

Experts were invited to evaluate the advantages and disadvantages of decentralized wastewater systems using a standardized scoring system (from –2 = very disadvantageous to +2 = very advantageous). The evaluation covered a range of aspects including investment, management and control, design, financing, stakeholder involvement, NBS implementation, effect on water cycle, resource recovery and other (free space to fill in other potential aspects to evaluate decentralized approach). These aspects (Table 23) were introduced during the in-person kick-off meeting in Vienna (10–11 June 2025), and the exercise was carried out in a workshop format. The results were visualized in a heatmap, highlighting both regional trends and country-specific perspectives (Table 24).

Table 23: Comparison of centralized and decentralized systems according to different aspects (Masi et al., 2020).

	CENTRALIZED SYSTEMS	DECENTRALIZED/ON-SITE SYSTEMS
Investment	Condensed Necessity to build the whole system in one part	Dispersed and divided Possibility to implement separate parts, part by part
Management and control	Standard practises, good control and overview on big systems	Non-conventional; poorly defined monitoring and high dependence on the manager capabilities
Design	Existing standards and legislations; long term experience; in many cases legislation stimulates centralized systems	Existing but not complete coverage with standards; legislation needs improvement and is not stimulant to such systems
Financing	Mainly public	Mainly private
Stakeholders involvement	Not involved or hardly involved in implementation and management	Direct involvement in implementation and management
NBS implementation	Less feasible	Favourable
Effect on water cycle	Unbalanced with respect to the regional water cycle Increased surface runoff, decreased infiltration and retention	Better balance of local water circle through direct water reuse and reduced surface runoff Local water retention and infiltration
Resource recovery	Poor due to difficult source control	Good potential for resources recovery if source control is applied

Overall, decentralized systems were **positively perceived**, particularly in terms of their compatibility with NBS, improved local water cycle balance, enhanced stakeholder involvement, and flexible design. Investment was also viewed favourably in many cases, especially due to the modular and phased implementation potential of decentralized systems. Countries such as BiH, Czechia, and Romania rated decentralized systems highly across most categories, indicating strong potential for their application in rural areas. This is especially relevant in BiH and Romania, where wastewater infrastructure is limited in small settlements. Romania also emphasized advantageous operation and maintenance, lower energy consumption and beneficial reduction of pollution.

Conversely, decentralized systems were viewed **less favourably** in Hungary, and to a lesser extent in Slovakia and Slovenia. Key concerns included difficulties in management and control, limited financing options and resource recovery. These challenges are often linked to the fragmented nature of decentralized systems, which require oversight of numerous small-scale units, often employing diverse technologies. A lack of skilled personnel for operation and maintenance further complicates effective management. In such context, deployment of robust and reliable technologies is essential to ensure reliability and reduce the need for frequent inspection.

While decentralized systems typically require lower capital investment due to shorter sewer networks and localized treatment, **financing** remains a major barrier. Namely individual systems are often privately funded, and municipal co-financing which would ease the implementation is frequently hindered by limited access to public funding or EU support. This financial gap can slow down or prevent the implementation of decentralized solutions, particularly in economically weaker municipalities.

Expert opinions on resource recovery were mixed. On one hand, decentralized systems offer proximity to agricultural land, enabling efficient reuse of treated water for irrigation without the need for long-distance transport of reclaimed water from the point of origin to the point of reuse. Additionally, rural municipal wastewater is typically free from industrial contaminants and stormwater runoff, resulting in lower concentrations of heavy metals and toxic substances. On the other hand, small-scale treatment plants are generally not required to provide advanced (quaternary) treatment, which means micropollutants such as pharmaceuticals and personal care products may remain in the effluent. This raises concerns about environmental accumulation and potential transfer through the food chain.

Table 24: Advantages and disadvantages of decentralized wastewater collection and treatment in rural areas of DRB (Germany did not participate).

	Investment	**Management and control**	**Design**	**Financing**	**Stakeholder inv.**	**Effect on water cycle**	**Resource recovery**	**Other: O&M**	**Other: energy cons.**	**Other: reduction of pollution**
Austria	1	1	0		2	1	0			
BiH	2	1	1	2	1	1	1	2		
Croatia	1	1	2	0	1	1	1			
Czechia	1	2	2	-1	2	2	0			
Hungary	-1	-2	0	-1	1	2	-1			
Romania	2	1	1	1	1	1	2	1	1	2
Serbia	0	-1	1	1	1	1	1			
Slovakia	1	-1	1		0	1	1			
Slovenia	2	-1	2	-1	1	2	-2			

Nature based solutions

A parallel assessment was conducted to evaluate the perceived advantages and disadvantages of nature-based solutions for wastewater treatment. The results, also presented in a heatmap format, show that NBS are generally viewed as beneficial, particularly in terms of their positive impact on the water cycle, stakeholder engagement, financing, and resource recovery (Table 25).

Table 25: Advantages and disadvantages of nature-based solutions for wastewater treatment in rural areas of DRB (Germany did not participate).

	Investment	Management and control	Design	Financing	Stakeholder inv.	Effect on water cycle	Resource recovery	Other: O&M	Other: energy cons.	Other: reduction of pollution	Other: Land acquisition
Austria	1	2	0		2	1	0				
BiH	1	1	2	1	1	1	1	2			-1
Croatia	1	0	1	2	0	1	1				
Czechia	-1	2	2	-1	1	2	2				
Hungary	1	-1	-1	1	0	1	-1				
Romania	2	1	2	2	2	2	2	2	2	1	
Serbia	1	1	1	1	1	1	1				
Slovakia	1	-1	0		1	2	1				
Slovenia	0	0	0	2	0	1	1				

Romania, Austria, BiH, and Serbia rated NBS highly across most categories. Romania, in particular, highlighted the operational and environmental benefits of NBS, including simplified operation and maintenance, energy consumption and pollution reduction. Czechia expressed concerns regarding investment and financing but still acknowledged the overall benefits of NBS.

However, Hungary and Slovakia raised concerns about management and control, which may reflect a lack of technical knowledge or experience with NBS among water utility staff. In Hungary, NBS were generally not perceived as advantageous, with scepticism regarding management and control, design and resource recovery. Slovenia showed limited support for NBS, recognizing advantages primarily in financing and operational costs. E.g., When comparing treatment wetlands to conventional activated sludge systems, the most significant difference lies in operational costs, which are substantially lower for wetlands. Additionally, treatment wetlands provide valuable ecosystem services such as biodiversity support and landscape integration. Simple NBS designs—such as gravity-fed wetlands—require no mechanical or electrical components, making them especially suitable for rural areas. However, when higher treatment performance is needed, NBS can be intensified with more complex designs, approaching the technical sophistication of conventional systems.

Challenges and obstacles

Experts were consulted to identify the key technical challenges and obstacles in wastewater and stormwater management in small settlements. The responses revealed a complex interplay of **technical, financial, institutional, and social barriers** with notable variations across countries. While the nature of these challenges varies by country, several common themes emerged, highlighting the need for **tailored, multi-dimensional strategies**.

Technical challenges

Countries such as **Croatia, Slovenia,** and **Slovakia** highlighted the difficulties of constructing wastewater infrastructure in scattered settlements, hilly terrain, and areas with limited access. These geographical constraints complicate both the design and implementation of sewerage networks and WWTPs. Interestingly, **Austria**, despite its Alpine topography, does not perceive terrain as a limiting factor. The successful deployment of numerous small WWTPs in Austria demonstrates that **technical solutions exist to overcome such challenges**, provided there is adequate planning and investment.

Slovakia also pointed out **land ownership issues** which can lead to delay or obstruct WWTP construction.

In **Hungary** and **Czechia,** concerns center around **inefficiency of small-scale treatment plants**, especially in low-density areas, and the **high costs associated with phosphorus removal and sludge treatment**. **Romania** and **BiH** emphasise the **lack of trained personnel, technical knowledge, and experience with NBS**. **Serbia** added that **inadequate planning, poor maintenance and lack of unified standards and technical guidance** further hinder progress. Romania also faces challenges in meeting **stringent nutrient removal requirements** in sensitive areas.

Austria again offers a contrasting perspective, stating that **technical challenges are not the primary barrier**. Instead, success depends on **proper operation and maintenance**, suggesting that existing technologies are sufficient when managed effectively.

Financial constrains

Across the region, **financial limitations** are the most frequently cited obstacle. Countries like **Croatia, Hungary, Slovenia, and Romania** report that **municipal budgets are insufficient**, and **EU or national funding is either unavailable or not prioritized** for small agglomerations. Germany adds that smaller systems generate higher per capita costs, making them less economically viable.

Institutional and legal barriers

Institutional fragmentation is another major barrier, especially in Serbia and Slovenia, where responsibilities are dispersed across multiple municipalities and agencies, leading to **coordination issues**. Romania and BiH also note the **lack of clear strategies and legal frameworks**, which hinders effective planning and implementation.

There is a widespread **lack of institutional and professional capacity** to support the implementation and operation of small WWTPs. Czechia expressed concerns about the **lengthy planning and permitting processes**, while **strong lobbying by companies promoting conventional systems** often undermines the adoption of NBS.

Awareness and transparency

Austria and BiH highlighted **lack of awareness**—both public and institutional—regarding importance of wastewater treatment in small settlements. Raising awareness is crucial, as these settlements represent a significant share of the population and pollution load in the Danube River Basin and across Europe.

Slovenia pointed out the **lack of transparency in monitoring treatment efficiency** for different technologies. Monitoring results are not publicly available and may be skewed due to pre-announced inspections. Furthermore, **public procurement process often prioritizes the lowest price**, discouraging innovative and sustainable solutions.

Social factors

Migration from rural areas, affordability concerns, and resistance to NBS—particularly in Czechia—further complicate implementation efforts. These social dynamics must be considered when designing inclusive and sustainable sanitation strategies.

Recommendations for improvement

The responses suggest that technical solutions alone are not enough. To improve wastewater and stormwater management in small settlements, countries must:

- **Secure diversified funding sources**, including EU support and national subsidies.
- **Strengthen institutional capacity**, especially at the municipal level.
- **Simplify legal and administrative procedures**, including procurement and permitting.
- **Invest in training and knowledge exchange**, particularly for NBS and small-scale systems.

- **Promote public awareness and affordability**, ensuring inclusive access to sanitation services.

The challenges are deeply interconnected—financial, institutional, and technical barriers reinforce each other. Addressing them requires a coordinated, multi-sectoral approach that considers the unique conditions of small settlements.

Impact of climate change

Experts across the Danube basin countries report clear and growing impacts of climate change on wastewater and stormwater systems in small settlements. These impacts are primarily related to extreme weather events, infrastructure stress, and changing precipitation patterns.

- **Heavy Rainfall and Flash Floods**
  More frequent and intense rainfall, leading to urban flash floods, sewer system overloads, and damage to infrastructure is reported especially from BiH, Czechia, Germany and Serbia. In Czechia, the shift toward fewer but more intense rain events is particularly problematic for combined sewer systems and WWTPs.
- **Drought and Water Retention**
  BiH, Germany, and Hungary note extended dry periods, which reduce soil infiltration capacity and groundwater recharge, while increasing surface runoff risks. Hungary mentions efforts to retain rainwater as a climate adaptation strategy.
- **Infrastructure Overload and Pollution Risks**
  BiH, Croatia, Czechia and Romania highlight that most of existing systems are not dimensioned to handle climate extremes. This leads to frequent discharges of untreated or partially treated wastewater, especially in settlements with improvised or outdated infrastructure.
- **Data and Monitoring Gaps**
  Romania points out the lack of limited monitoring data on stormwater impacts, which limits the ability to plan and respond to climate change effectively.
- **Increased Demand for Solutions**
  Austria acknowledges that climate change is driving demand for better wastewater and stormwater solutions, particularly in small municipalities.
- **Adaptation Concepts**
  Germany references the sponge city concept as a promising approach to mitigate climate impacts by enhancing urban water retention and infiltration.

The responses clearly indicate that climate change is no longer a future concern—it is a present reality affecting small settlements across the Danube basin. The most pressing issues are infrastructure overload, pollution risks, and inadequate system design for extreme weather conditions.

What stands out is the challenge of managing both excess water (from floods) and water scarcity (from droughts), along with combined sewers and their overflows within the same region. This paradox requires flexible, resilient infrastructure and integrated planning that considers both ends of the climate spectrum as well as water quality.

Moreover, the lack of data and monitoring, especially in smaller agglomerations, hampers effective adaptation. Countries like Romania and BiH emphasize the need for better data collection, technical capacity, and investment in climate-resilient infrastructure.

The mention of NBS and sponge city concepts suggests that innovative, decentralized, and multifunctional approaches may offer viable paths forward—especially when combined with community engagement and institutional support.

I. Best practice examples

Key lessons highlight the importance of training and cooperative models, integration of nature-based solutions into local planning, and low-cost, sustainable systems such as constructed wetlands, which offer reliable treatment and additional environmental benefits for small communities.

There are several best practice examples for wastewater and stormwater treatment in the DRB that can be highlighted. There are several approaches to water management that are technically effective, environmentally sustainable, and socially accepted.

The following types of best practices have been identified:

- Decentralized treatment systems (Slovenia, Serbia, Czechia)
- Sustainable organizational models for small WWTPs and individual systems (Austria)
- Pilot cases of stormwater management (Austria, Croatia, Hungary, Bosnia and Herzegovina)

Austria: Organizational models for small wastewater treatment plants

In Austria, small WWTPs of any technology are managed in several ways. Often, the owner of the small WWTP carries out operation and maintenance. This is the most common model, and training courses for small WWTP operators have been started to improve the performance of a WWTP. If owners and operators are trained and understand why operation, monitoring, and maintenance are important, the likelihood that the plant is operated well increases.

Another approach is the use of wastewater cooperatives. These are public-law bodies where the users of the services share ownership and responsibility for the small WWTP. This model is quite popular in Austria and encourages community involvement and shared responsibility.

Small WWTPs can also be operated by municipal utilities. In this case, the utility responsible for the central WWTP of a town manages smaller plants in remote settlements in the same or neighbouring municipalities. This ensures professional operation, monitoring, and maintenance even in less accessible areas.

Key lessons from Austria include the importance of training and capacity building for small WWTPs, the benefits of community-based cooperative models, and the advantages of integrating small plants with municipal utilities for reliable operation.

Austria: stormwater management best practices

In Austria, stormwater management best practices focus on decentralized, nature-based, and participatory approaches. Several research and implementation projects demonstrate effective strategies. Decentralized systems, such as rain gardens (Figure 6), have been implemented in rural communities, showing how local, small-scale solutions can reduce runoff and enhance infiltration.

Figure 6: Raingarden for surface runoff retention and treatment (source: Referenzprojekte - Zenebio GmbH)

The resilientRAIN project investigates the steps needed to develop innovative NBS for decentralized rainwater management, using a holistic approach to support technological and planning development. As existing sewer systems are increasingly overloaded, decentralized measures such as green roofs, vegetated infiltration areas, raingardens, and retention ponds are crucial. These NBS can locally retain, store, evaporate, and release rainwater slowly, preventing the overload of technical systems and contributing to the natural water balance.

In Villach, a collaborative guideline on stormwater management was prepared by BOKU University, the city administration, and housing associations, emphasizing citizen engagement and sustainability. Heavy rainfall events push existing sewer systems to their capacity limits, while extended periods of drought and heat place a significant burden on people as well as urban flora and fauna. The use of blue-green infrastructure has already proven to be an effective adaptation measure in many places. In the demo area "Kanaltaler Siedlung," cooperative measures are to be implemented and tested involving all relevant stakeholders and taking into account technical/hydrological, social, organizational/legal, microclimatic/ecological, and economic aspects. Based on these experiences, the project will conclude with a guideline that provides both the city of Villach and other municipalities with a template and orientation for integrative and cooperative stormwater management.

The COOL-INN project in Innsbruck exemplifies integrative planning for blue infrastructure. The project evaluated suitable locations for pilot implementations, and assessed impacts on urban ecology and the surrounding community. Collaboration among the water utility, scientific partners, the city, and citizens led to a holistic and sustainable stormwater concept. Similarly, the Ko-Transform project in Gleisdorf focused on building consensus for urban water and green space management to adapt to climate change. Participatory methods were used to understand stakeholder perceptions and attitudes. The project highlighted co-determination and co-responsibility, providing guidance for consensus-building in other communities. Urban open spaces are suitable for climate-sensitive urban development through the use of blue-green-brown infrastructure and urban green areas, which contribute to improving temperature conditions, flexible settlement water management, air quality, and biodiversity.

These examples show that Austrian stormwater management best practices combine technological innovation, NBS and stakeholder participation to create resilient, sustainable, and socially accepted systems.

Croatia: stormwater management in a small settlement

In Međimurje County, where the water supply and sewerage network is managed by the public utility Međimurje Waters, a good example of stormwater management can be found in the village Dunjkovec, which has around 1500 inhabitants (Figure 7) and the village of Novo Selo Rok which has around 1,300 inhabitants (Figure 8).

A stormwater drainage system has been constructed that channels rainwater throughout the settlement using pipelines and open channels. The collected water is directed into planned lagoons with sub-lagoons for seepage, allowing for controlled retention and infiltration of stormwater.

Figure 7: Lagoon for rainwater retention in Dunjkovec, Croatia.

Figure 8: Lagoon for rainwater retention in Novo Selo Rok, Croatia.

Bosnia and Herzegovina: Wastewater and stormwater management for the protection of drinking water sources and flood protection of WWTP

In Bosnia and Herzegovina, separate sewage systems have been designed, constructed, and managed in several settlements to improve wastewater and stormwater management. There is also a successful implementation of constructed wetlands in settlements Ljubijankići and Polje (the city of Cazin), where particular attention was given to wastewater and stormwater drainage and the protection of the wastewater treatment facility from floodwaters, ensuring the long-term functionality and resilience of the system. Additionally, separate sewage systems were developed in the settlements of Gata (Bihać) and Stari Grad Bužim, focusing on improved design to enhance local sanitation infrastructure and better manage stormwater.

The implementation of a constructed wetland for wastewater treatment in the settlement of Ljubijankići, located within the Pivnica water protection zone (supplies 10.000 inhabitants of this municipality, serves as a good case example of decentralized wastewater management in BiH.

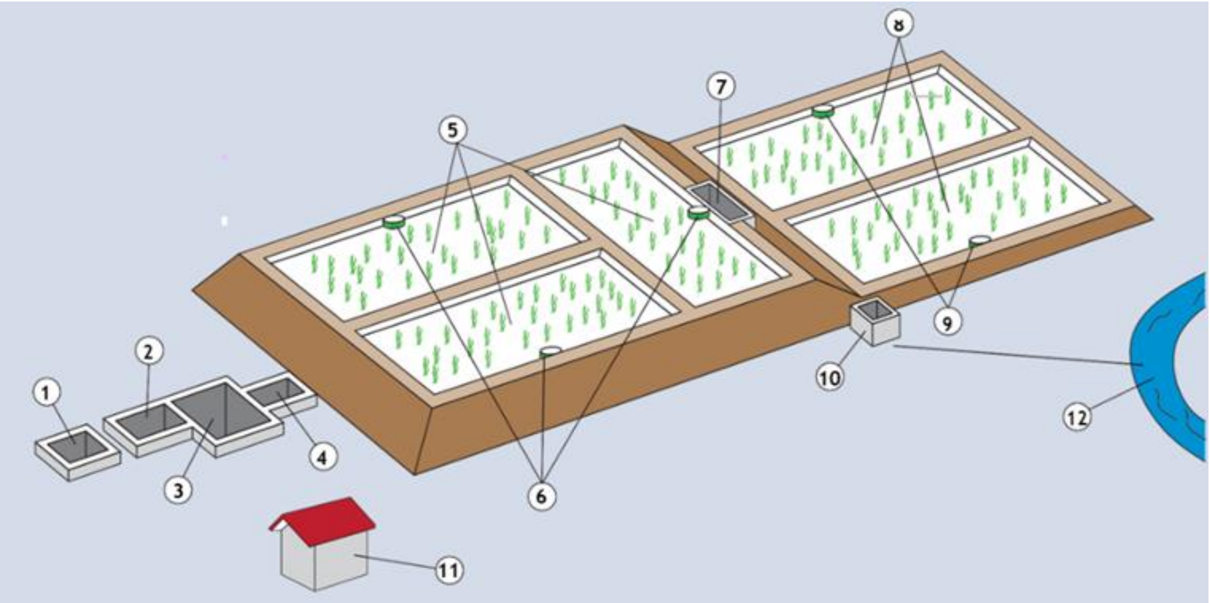
The project, which integrates nature-based solutions (NBS) into the local sanitation infrastructure, highlights the effectiveness of constructed wetlands for treating wastewater in rural areas, providing a sustainable solution that aligns with local environmental conditions and public needs.

Ljubijankići constructed wetland system applies a vertical filtration process with two-stage treatment design, consisting of a gravel filter bed planted with reed (Figure 9 and 10). This system is designed to treat sanitary wastewater generated from households and businesses within the settlement. The treatment process utilizes natural filtration mechanisms, where the wastewater is sprayed over the filter surface (in the first treatment stage) flushed to the second treatment stage, allowing it to flow vertically through the filter media, undergoing biological and mechanical treatment before being released into the environment.

Figure 9. Constructed wetland in Ljubijankići, Cazin, BiH.

The system has proven to be both environmentally effective and cost-efficient, capable of handling up to 600 PE. The vertical filtration process ensures high removal rates for organic matter and nutrients, significantly improving water quality and reducing environmental impacts.

The constructed wetland system implemented in Ljubijankići achieved several important goals. It enabled the collection and treatment of wastewater, preventing its infiltration into the sanitary protection zone of the Pivnica water source. In addition, the separate sewage system provided effective drainage of storm water which helped to prevent flooding of the surrounding area and nearby residential buildings. From the very beginning, local residents and businesses from the Ljubijankići community were actively involved in the project. Through continuous outreach and awareness-raising about new technologies, their support was secured, which contributed to the smooth and successful implementation of the entire project.



Legend:

1. Inlet chamber with overflow 140x140x120cm;
2. Chamber with manual screen, small settling and solid waste container 260x160x160 cm;
3. Pumping station 260x300x360cm;
4. Control chamber for exchange of 1st stage treatment filters,
5. Vertical filters – 1st treatment stage 3x2400x1000 cm;
6. Inspection manholes for 1st stage filters - Ø1000;
7. Collection chamber for 1st stage treatment filters with mechanism for batch loading of 2nd stage filters and control chamber for exchange of 2nd stage filters 355x420x210cm;
8. Vertical filters – 2nd treatment stage 2x2400x1000 cm;
9. Inspection manholes for 2nd stage filters - Ø1000;
10. Collection chamber for 2nd treatment stage - 150x150x120cm;
11. Tool House;
12. Recipient (stream Pivnica).

Figure 10. Scheme of the constructed wetland to treat municipal wastewater from Ljubijankići, BiH.

Hungary: Municipalities as integrators and coordinators in adaptation to climate change

The LIFE MICACC project ("Municipalities as integrators and coordinators in adaptation to climate change") was implemented between 2017 and 2023. with the goal of enhancing climate resilience in vulnerable Hungarian municipalities. The project focused on reducing climate-related risks—particularly those associated with water scarcity and excess—through the integration of NBS into local planning.

A key innovation of the project was the development of a decentralized system for stormwater retention and reuse. In small settlements, stormwater is managed using natural small water retention measures. For example, runoff is diverted into small lakes, then into secondary basins where it infiltrates into the soil. A drainage canal equipped with three small wooden sluice gates helps regulate water levels during periods of excessive rainfall. Instead of being drained away, surplus water is retained and redirected to flood nearby pastures, thereby improving local water retention and contributing to groundwater recharge.

Several pilot sites were established to demonstrate decentralized stormwater and wastewater management, e.g.:

- Püspökszilágy (population 735): This village faced recurring droughts and flash floods due to the Szilágyi Stream. The project introduced leaky wooden dams to slow water flow and retain runoff. These simple yet effective structures have already proven their value during multiple heavy storms, mitigating flood risks while enhancing local water availability.

Figure 11: Example of natural water retention measures to mitigate water stress in rural areas (Source: https://vizmegtartomegoldasok.bm.hu/en/nwrm/5_pilot).

• Ruzsa (population 2,336): The main challenges here included the absence of natural surface water and a declining groundwater table. Previously, approximately 150 m³ of treated water from the sewage treatment plant and 10–20 m³/day of process water from the drinking water purification facility were discharged into canals and lost. The project demonstrated how these water sources could be retained and reused locally.

Figure 12: Example of natural water retention measures in Ruzsa village (Source: https://vizmegtartomegoldasok.bm.hu/en/nwrm/5_pilot).

The Hungarian best practice revealed the benefits of integration of nature-based water management into local planning. The pilots demonstrated a simple, low-cost solutions adapted to small settlements.

Serbia: constructed wetland for wastewater treatment

In the village of Gložan in Vojvodina, Serbia, a constructed wetland for wastewater treatment has been in operation since 2004, serving a local population of around 2,275 residents (Figure 13). The wetland system consists of three sequential treatment fields covering a total area of approximately 9,400 m². It uses a horizontal subsurface flow design, where wastewater passes through layers of gravel and soil planted with common reed (*Phragmites australis*), a species naturally present at the site.

Figure 13: Constructed wetland for the village of Gložan, Serbia.

The system achieves high treatment performance. It removes 93–96% of suspended solids and reduces Biochemical Oxygen Demand (BOD_5) by 79–84%, indicating effective decomposition of organic matter. Nutrient removal rates are also significant: 47.3% of nitrates, 47.5% of ammonium, 78.3% of nitrites, and 29.1% of total phosphorus are eliminated. The reeds also accumulate nutrients in their tissues, with nitrogen concentrations reaching up to 42.7 g/kg in leaves and phosphorus up to 2.1 g/kg in inflorescences.

Beyond treatment performance, the Gložan constructed wetland provides additional environmental benefits. Over a five-year monitoring period, 53 vascular plant taxa were recorded within the system, highlighting its contribution to local biodiversity and habitat creation.

Slovenia: constructed wetland and a sludge drying reed bed

In the Municipality of Krško, a constructed wetland system was implemented for the Raka agglomeration, serving around 400 population equivalents (PE) (Figure 14). The system was chosen for its low operating costs and its fully passive treatment process, which requires no electricity or chemical additives.

Wastewater is treated biologically, beginning with a sedimentation tank, followed by four vertical subsurface flow beds, which effectively remove total suspended solids (TSS), biochemical oxygen demand (BOD), and chemical oxygen demand (COD). This setup ensures the system meets secondary treatment standards.

Figure 14: Constructed wetland for Raka village, Slovenia.

Sludge from the sedimentation tank is periodically pumped onto adjacent reed drying beds, where it naturally dehydrates, mineralizes, and stabilizes. Over a 10-year period, approximately 120 m³ of humus-like material is expected to accumulate, which can then be reused or disposed of in line with regulations. Once emptied, the reed beds are ready for the next cycle of use.

The constructed wetlands in Raka and Gložan serve as excellent examples of NBS for wastewater treatment, with Raka also showcasing effective sludge management. These systems highlight key advantages for small communities, offering sustainable wastewater treatment that combines operational simplicity, environmental benefits, and low long-term costs.

Conclusion

The current state of wastewater and stormwater management in small settlements across the DRB reflects a complex interplay of historical, institutional, technical, and socio-economic factors. While significant progress has been made in some EU Member States—particularly Austria, Germany, Slovenia, and Czechia—many small settlements in Central and South-eastern Europe still face substantial challenges. These include limited infrastructure coverage, fragmented planning, insufficient funding, and lack of technical capacity, especially in rural and economically weaker regions.

The challenges are deeply interconnected and create a complex landscape that demands a coordinated, multi-sectoral approach. Solutions must be context-sensitive, addressing the unique conditions of each settlement while leveraging regional knowledge and cooperation.

The analysis reveals that decentralized systems and NBS offer promising pathways for improving sanitation services in small settlements. However, their implementation is uneven and often hindered by regulatory gaps, financing constraints, and low stakeholder awareness. The revised Urban Wastewater Treatment Directive (Directive EU 2024/3019) introduces new obligations for agglomerations between 1,000 and 2,000 PE, which will require most DRB countries to expand their planning frameworks and invest in inclusive, climate-resilient infrastructure.

Stormwater management remains underdeveloped in many areas, with increasing risks from pluvial flooding and combined sewer overflows. Although spatial planning and rainwater harvesting are gaining traction, integration into local development remains inconsistent. Climate change is already impacting small settlements, amplifying both water scarcity and excess, and underscoring the need for adaptive, multifunctional solutions.

Moving forward, coordinated efforts are needed to strengthen institutional capacity, secure diversified funding, and promote innovative, low-cost technologies tailored to local conditions. Therefore D-CLEAN project builds on regional cooperation, stakeholder engagement, and knowledge exchange in addressing the sanitation needs of small settlements and protecting water quality across the Danube River Basin.

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UWWTD – Urban Wastewater Treatment Directive (2024): Directive (EU) 2024/3019 of the European Parliament and of the Council of 27 November 2024 concerning urban wastewater treatment (recast); https://eur-lex.europa.eu/eli/dir/2024/3019/oj/eng.

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Annex I

Interreg
Danube Region

Co-funded by
the European Union

D-CLEAN

A 1.1 Analyses of regional status quo

Questionnaire

Introduction

The first specific objective of the project D-CLEAN *Improving Water Quality in the Danube River Basin: Nature-Based Solutions for Sustainable Wastewater and Stormwater Management in Small Settlements* is to analyse the needs and challenges of wastewater and stormwater management in the Danube River Basin (DRB) in order to prioritise sustainable solutions. In order to propose a collection of the most appropriate sustainable solutions, we need to understand the current situation, legislation, needs and challenges of wastewater and stormwater collection, treatment and disposal in small settlements of the DRB countries.

Activity 1.1. therefore includes a thorough analysis of existing infrastructure, technologies and practises, identifying both the strengths and weaknesses of current systems. In addition, a comprehensive review of national policies and management plans is planned. In order to conduct the analysis, it is of utmost importance to collect input data for all project countries and beyond.

> ***This questionnaire and the accompanying excel sheet are designed to collect information on wastewater collection and treatment and stormwater management in small settlements of the Danube River Basin.***
>
> ***Please answer all questions as detailed and accurate as possible.***
>
> ***Your answers will directly contribute to the design of future project activities, policy recommendations and technical solutions tailored to the needs of small settlements in the region. We are very grateful for your time and thoughtful input.***

A. General Information

1. **Country:**

2. **Name and surname of contact person for the questionnaire:**

3. **E-mail:**

4. **Institution:**

B. Settlement structure of the country

1. **How are the settlements in your country defined?**

2. **What is the total number of settlements in your country?**

3. **Does this number include uninhabited settlements (without permanent inhabitants)? How many are they?**

4. **Do you define agglomerations according to the PE? By what method are they defined (*according to the EU Urban Waste Water Treatment Directive (2024/3019), Member States should take into account the indicative reference threshold of 10 to 25 PE per hectare*)?**

5. **Please provide the following data:**

Number of settlements/agglomerations < 2000 inhabitants/PE	
Total population in settlements/agglomerations < 2000 inhabitants/PE	
Number of settlements/agglomerations < 1000 inhabitants/PE	
Total population in settlements/agglomerations < 1000 inhabitants/PE	
Total population outside agglomerations	

C. Wastewater collection and treatment

1. **How is data on wastewater treatment plants < 2000 PE collected (including individual systems)?**

2. **Is there data on the number of inhabitants (or percentage of population) connected to individual systems? If yes, what is the number/percentage?**

3. **Please enter the data on public wastewater treatment plants < 2000 PE in the country in the provided Excel sheet.**

D. Discharge limits

1. **Is there national legislation on discharge limits for wastewater treatment plants < 2000 PE? If yes, please specify the legislation, if no, which standards are applied for discharge limits for wastewater treatment plants < 2000 PE?**

2. **Please indicate the discharge limits for treated wastewater in accordance with the current national legislation regarding the size of the agglomeration (correct the agglomeration size or add additional columns if necessary). If there are special requirements for sensitive areas, please indicate these as well.**

Parameter		Unit	Discharge limit		
			PE<50	50<PE<1000	1000<PE<2000
COD	Chemical oxygen demand	mg/L			
BOD	Biochemical oxygen demand	mg/L			
TSS	Total suspended solids	mg/L			
TN	Total nitrogen	mg/L			
NH_4-N	Ammonia nitrogen	mg/L			
NO_3-N	Nitrate nitrogen	mg/L			
NO_2-N	Nitrite nitrogen	mg/L			
TP	Total phosphorous	mg/L			
PO_4-P	Orthophosphate phosphorous	mg/L			
E. coli	*Escherichia coli*	CFU/100 mL			
Other:					

E. Monitoring protocols

1. **What are the monitoring requirements for wastewater treatment plants < 2000 PE – please indicate the frequency and responsibility for sampling and analyses as well as the financial responsibility (who pays)?**

	PE<50	50<PE<1000	1000<PE<2000
Period (frequency)			
Sampling and analyses			
Financing			

Comment:

F. Management plans

1. **Do you have a national wastewater management plan[1]? For what period was the last plan published?**

2. **What is the national deadline for wastewater collection and treatment for settlements/agglomerations <u>between 1000 and 2000</u> inhabitants/PE? *According to EU Directive 2024/3019, member states shall ensure that agglomerations between 1000 and 2000 PE comply with the requirements (i.e. provision of collecting system) by 31 December 2035; however, extensions are possible under certain circumstances.***

[1] By »management plan« we mean operational programme for implementation of wastewater collection and treatment on a national level and including all sizes of settlements and treatment plants.

3. **Is there a national regulation or plan for wastewater collection and treatment for settlements/agglomerations with <u>less than 1000</u> inhabitants/PE? Please describe how wastewater collection and treatment will be handled in these settlements and what deadlines apply.**

4. **Do the municipalities have their own wastewater management plans?**

5. **What kind of sewer system is mainly used in settlements/agglomerations < 2000 inhabitants/PE – combined or separate?**

6. **What type of sewer system (combined or separate) is used in new developments?**

G. Stormwater management

1. **How is stormwater currently managed in settlements/agglomerations < 2000 inhabitants/PE? If multiple management practices are used, please describe the most important factors for selecting the specific practice (e.g. infiltration capacity, receiving waters, ditches).**

2. **Please describe the relevant national regulations for stormwater management in settlements/agglomerations < 2000 inhabitants/PE? Does the stormwater need to be collected and treated? If yes, in which cases (e.g. parking lots, roads)?**

3. **What problems do you face in your country with stormwater management in settlements/agglomerations < 2000 inhabitants/PE (e.g. pluvial floods, erosion, combined sewer overflows)?**

4. To what extent are various stakeholders informed about stormwater management (residents, mayors, water utilities, spatial planners, etc.)?

5. Is rainwater harvested and used as an alternative water source? If so, for what purposes?

6. Is stormwater management taken into account during spatial planning?

H. Strengths, weaknesses and challenges

1. **Do you find decentralized systems advantageous or disadvantageous in the following aspects (mark grades with “x”):**

	Disadvantage		No effect	Advantage	
	-2	-1	0	1	2
Investment					
Management and control					
Design					
Financing					
Stakeholder involvement					
NBS implementation					
Effect on water cycle					
Resource recovery					
Other:					
Other:					

2. **Do you find nature-based solutions (like treatment wetlands) advantageous or disadvantageous in the following aspects (mark grades with “x”):**

	Disadvantage		No effect	Advantage	
	-2	-1	0	1	2
Investment					
Management and control					
Design					
Financing					
Stakeholder involvement					
NBS implementation					
Effect on water cycle					
Resource recovery					
Other:					
Other:					

3. **In your opinion, what are the main technical challenges in the wastewater collection and treatment in settlements/agglomerations < 2000 inhabitants/PE?**

4. **What are the main obstacles (e.g., financial, institutional, legal) to improving wastewater and stormwater management in settlements/agglomerations < 2000 inhabitants/PE? Do you have any suggestions or ideas on these can be overcome?**

5. **Can you observe impacts of climate change on stormwater and wastewater infrastructure in settlements/agglomerations < 2000 inhabitants/PE?**

6. **Do you know of any successful examples or best practises in your country for wastewater and stormwater management in settlements/agglomerations < 2000 inhabitants/PE?**

I. Please list links and references used to fill the questionnaire:

Instructions for completing the data sheet

IMPORTANT

This data sheet in intended to collect information on wastewater collection and treatment in small settlements in the Danube River Basin.

Please only provide data on wastewater treatment plants with less than 2000 PE and include individual systems if possible.

Please answer all questions as detailed and accurate as possible.

If some data is not available, please note this in a column using N.A. (not available).

Your answers will directly contribute to the design of future project activities, policy recommendations and technical solutions tailored to the needs of small settlements in the region. We are very grateful for your time and thoughtful input.

If you have any questions or need assistance in completing the questionnaire, please do not hesitate to contact us at darja.istenic@fgg.uni-lj.si

Instructions	
Column	Explanation
A	consequtive number
B	ID of the treatment plant (usually provided by national authority or water utility)
C	Name of the treatment plant (e.g. settlement or village name)
D	Name of water utility or private owner in charge for the treatment plant
E	Enter a capacity in PE for which the treatment plant was designed for
F	Year in which wastewater treatment plant was put to operaton
G	Enter a treatment technology used (e.g. SBR, MBR, CAS, treatment wetland)
H	Address of the treatment plant
I	Geographical coordinates of the treatment plant. Please provide also the information on coordination system used.
J	Geographical coordinates of the treatment plant
K	Recipient (water body, infiltration, reuse) for treated water
L	Indicate if secondary treatment is provided (YES/NO)
M	Indicate if tertiary treatment is provided (YES/NO)
N	Amount of wastewater treated per year. Please provide also the year to which the data in columns N-R are related
O	Treatment efficiency for COD (%)
P	Treatment efficiency for BOD (%)
Q	Treatment efficiency for P (%)
R	Treatment efficiency for N (%)

								Coordinate system used:					Year for the data:				
Nr	ID	Name	Water utility / owner	Designed capacity (PE)	Year of implementation	Technology	Address	Coordinates E	Coordinates N	Recipient	Secondary treatment	Terciary treatment	Amount of WW treated (m^3/year)	Efficiency COD (%)	Efficiency BOD (%)	Efficiency P (%)	Efficiency N (%)
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
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