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Mapping the Danube: Analysis of the Regional Status Quo

in Wastewater and Stormwater Management in the Danube River Basin

1st webinar

Online, 22 October 2025

Presenters

Darja Istenič[1], Günter Langergraber[2], Alenka Mubi Zalaznik[3]

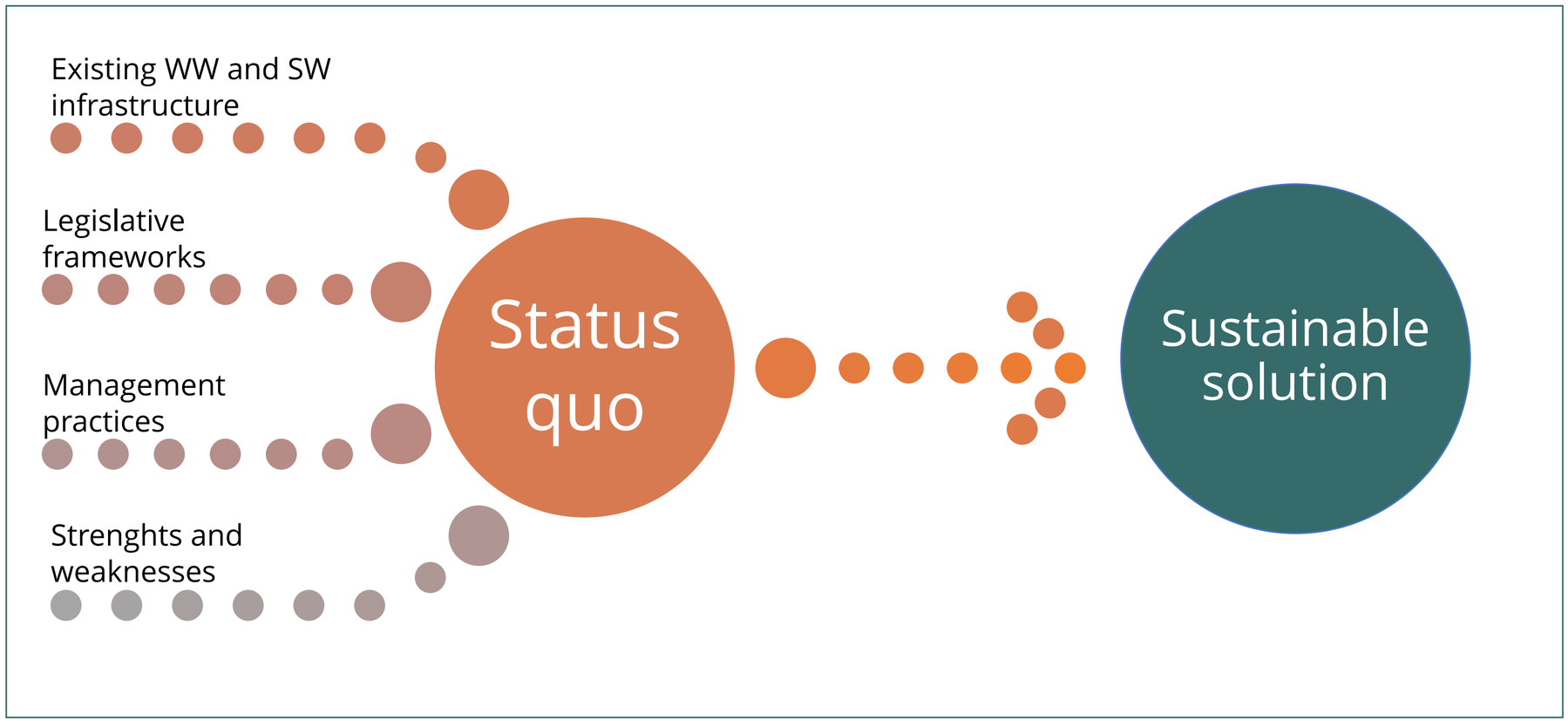
[1]University of Ljubljana, Faculty of Civil and Geodetic Engineering, Slovenia

[2]BOKU University, Institute of Sanitary Engineering and Water Pollution Control, Austria

[3]LIMNOS Company for Applied Ecology, Slovenia

Why we need status quo analysis?

small settlements of DRB



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How we did it?

- Comprehensive quesionnaire
  - General information
    - *Contact, affiliation*
  - Settlement structure
    - *Number of settlements / agglomerations according to the size*
  - Wastewater collection and treatment
    - *Database of existing wastewater treatment plants in the DRB of each country (design capacity, technology, location etc.)*
  - Discharge limits
    - *Legislative discharge limits*
  - Monitoring protocols
    - *Frequency and responsibility of monitoring*
  - Management plans
    - *National and local plans, deadlines*
  - Stormwater management
    - *National regulation, practices and challenges*
  - Strengths and weaknesses
    - *Of decentralized solutions and nature-based solutions*
  - Best practices

Project partner countries

1. Austria
2. Croatia
3. Hungary
4. Romania
5. Serbia
6. Slovakia
7. Slovenia

Questionnaire

Other countries (>1% DRB share)

1. Bosnia and Herzegovina
2. Bulgaria
3. Czechia
4. Germany
5. Moldova
6. Ukraine

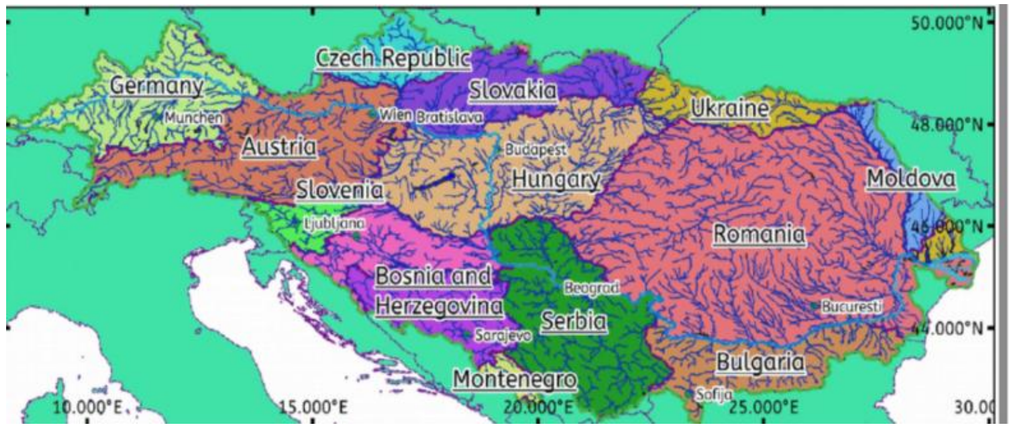

Figure: Geographical overview highlighting countries within the Danube River Basin (source: Morlot, 2018).

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Feedback

	Country	Coverage in DRB (km^2)	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**

General insights into sanitation services in DRB

- Uneven infrastructure development
  - Historical background, political stability, economic strength
- EU membership has played a critical role in driving improvements
  - UWWTD (91/271/EEC) and its recast (2024/3019)
- Water and sanitation services have improved in last 10 years
  - Non-EU countries lagging behind

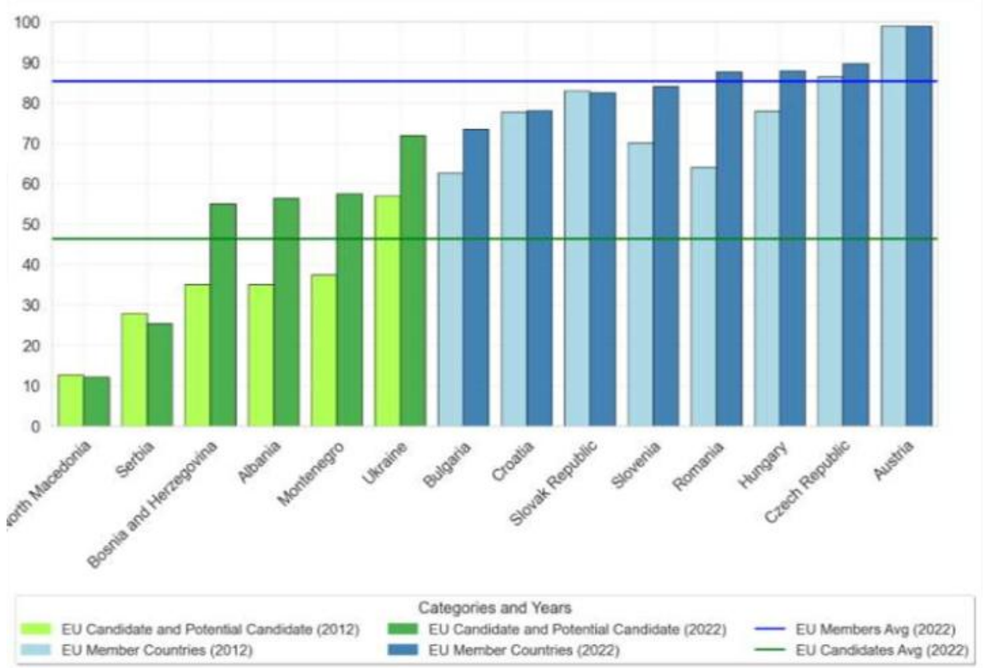


Figure: Share of population using safely managed sanitation services 2012 vs 2022 (Havens and Gabrić, 2025).*

**Use of improved sanitation facilities that are not shared with other households, and where excreta are safely disposed of in situ or transported and treated off-site.*

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.

Definition of settlements

Austria	Croatia	Slovenia
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.	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").	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***.
▪ 2,093 municipalities (“Gemeinden”) incl. 15 towns (“Städte”) ▪ 17,010 settlements (“Ortschaften”)	▪ 128 towns and 428 municipalities ("općina") ▪ subdivided into 6,757 settlements ("naselja“)	▪ 6,035 settlements
below 2,500 people: ▪ 1,348 municipalities	below 2,000 people: ▪ 896 settlements	below 2,500 people: ▪ 5,927 settlements

Definition of agglomeration

EU UWWTD (2024), Article §2(4) :

→ '**agglomeration**': area where the population expressed in population equivalent … is sufficiently concentrated for urban wastewater to be collected and conducted to one or more urban WWTPs …

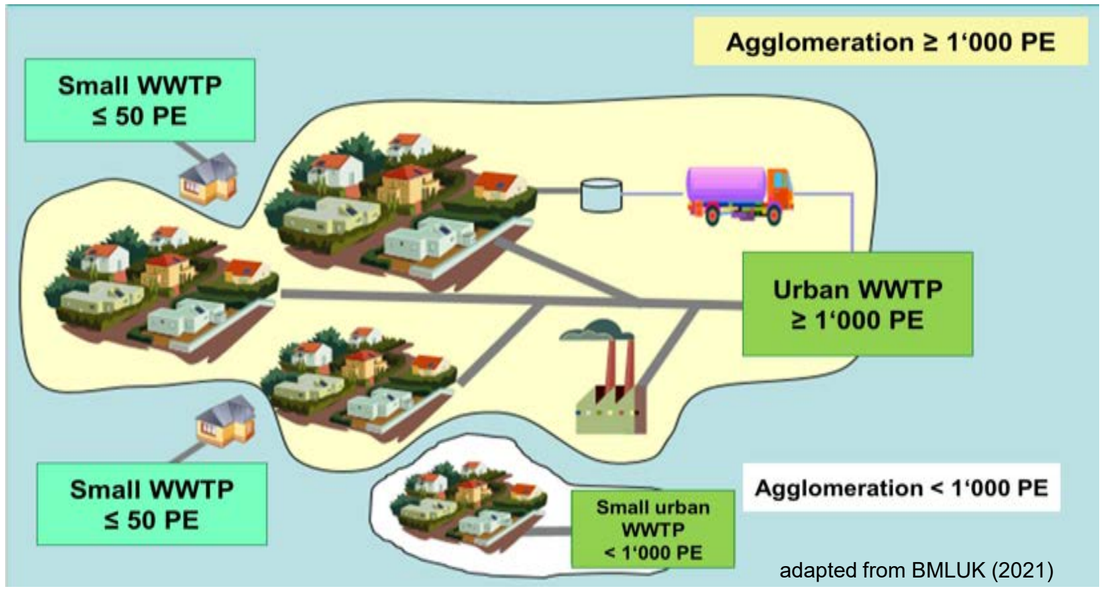
→ indicative reference threshold of 10 to 25 PE per hectare

Austria:

→ AT has chosen the approach that an agglomeration is the catchment area of an UWWTP with a size (= design capacity) ≥ 1'000 PE

→ *small UWWTPs:* 1'000 ≥ PE > 50

→ Individual systems: ≤ 50 PE



adapted from BMLUK (2021)

BMLUK (2021) Überarbeitung der Kommunalen Abwasserrichtlinie (91/271/EWG) - Österreichische Zahlen, Daten und Fakten zu ausgewählten Überarbeitungsoptionen [*Austrian data, facts and figures on selected policy options*] https://www.bmluk.gv.at/service/publikationen/wasser/ueberarbeitung-der-kommunalen-abwasserrichtlinie.html.

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

Country	<2000	<1000	1999-1000	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**

Pistocchi, A., Parravicini, V., Langergraber, G., Masi, F. (2022): How many small agglomerations do exist in the European Union, and how should we treat their wastewater? *Water Air Soil Pollut* 233, 431; https://doi.org/10.1007/s11270-022-05880-7.

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.

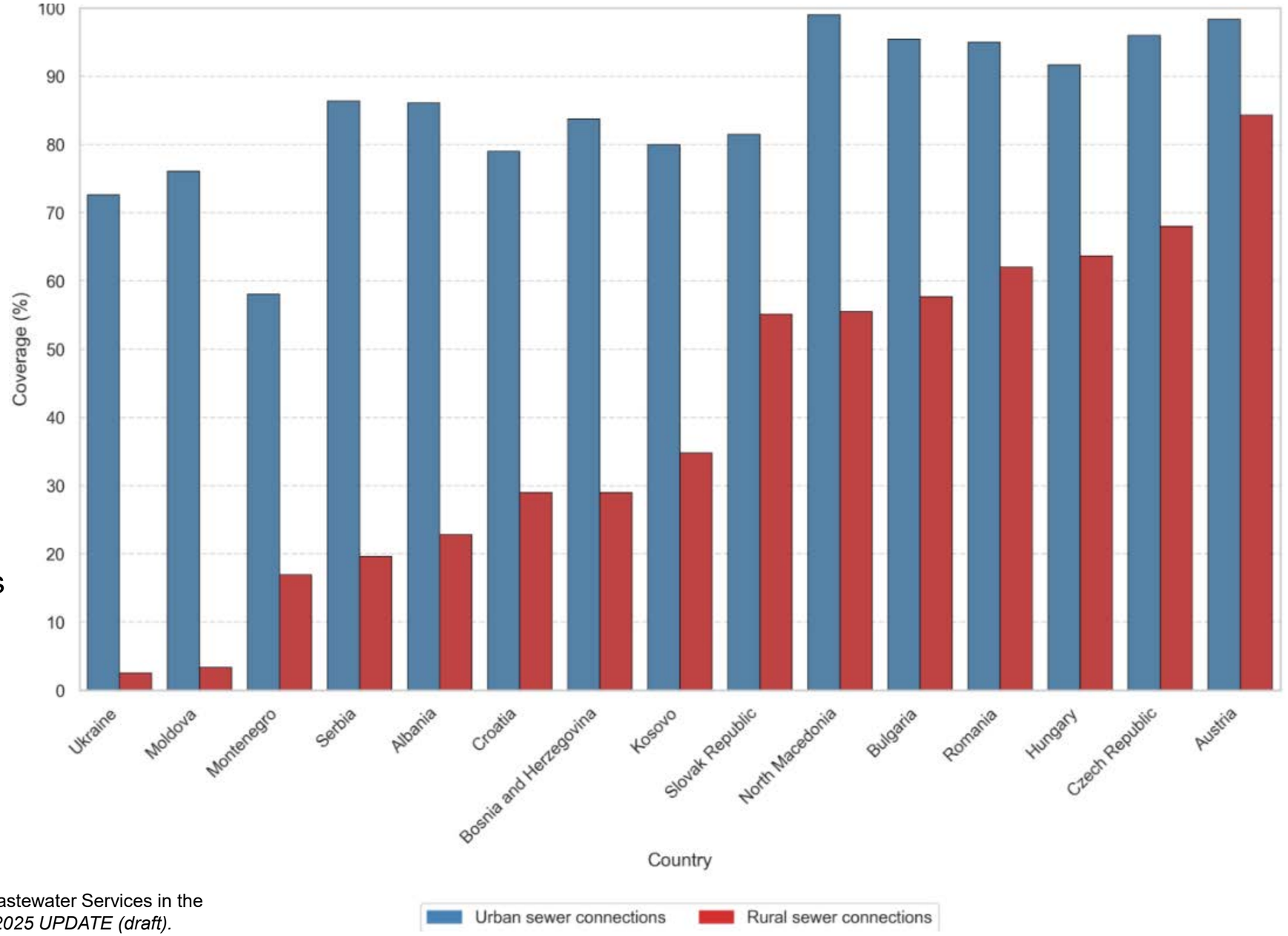
Wastewater collection and treatment

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 notable efforts in some countries, decentralized wastewater management remains a regional challenge, with approximately 85 % of the load still untreated.

Conventional, technical systems are the most widespread (> 67 %), while the adoption of nature-based solutions remains limited.

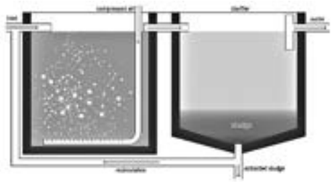
Share of Population with Sewer Connections in Danube Region, reference year 2024



Danube Water Program (2025): Water Wastewater Services in the Danube Region - A State of the Sector - *2025 UPDATE (draft).*

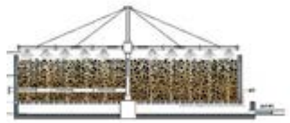
Technologies for rural wastewater treatment

- **On-site collection with off-site treatment**
  - Cesspits (with transport to next WWTP or faecal sludge treatment unit)
- Soil as recipient of treated (or partially treated or untreated) wastewater
  - Soak pits, leach fields, etc.
- Solutions with less than secondary treatment
  - Septic tanks, etc.
- **Solutions with at least secondary treatment**
  - Technological solutions with suspended biomass [*Suspended growth treatment systems*] (e.g., conventional activated sludge plants, SBR – Sequencing Batch Reactor, MBR – Membrane BioReactor)
  - Technological solutions with fixed biomass [*Attached growth treatment systems*] (e.g., Trickling filter, RBC – Rotating Biological Contactor, filtration systems)
  - Nature-based solutions (e.g., *treatment wetlands*)

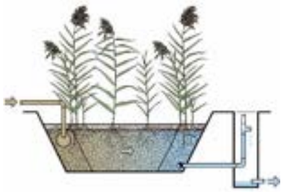


Conventional Activated Sludge (CAS)

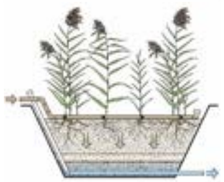
Sequencing Batch Reactor (SBR)



Trickling filter



Horizontal flow (HF) wetland



Vertical flow (VF) wetland

Technologies for rural wastewater treatment

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.

Example Austria

Size class (PE)	Number of treatment plants		Organic design capacity of plants	
	[n]	[%]	[PE]	[%]
≤ 50	27'452	93.7%	260'500	1.1%
51 - 500	958	3.3%	259'287	1.1%
501 – 1'000	120	0.4%	96'023	0.4%
1'001 – 1'999	135	0.5%	191'000	0.8%
2'000 – 10'000	361	1.2%	1'715'593	7.5%
10'001 – 15'000	48	0.2%	620'725	2.7%
15'001 – 150'000	202	0.7%	9'073'908	39.8%
> 150'000*)	20	0.1%	10'578'434	46.4%
Total	**29'296**	**100%**	**22'795'470**	**100%**

* Includes three big industrial WWTPs

References:

- Langergraber et al. (2018)
- ÖWAV (2025)
- BMLUK (2024)
- Müller-Rechberger and Lenz (2025)

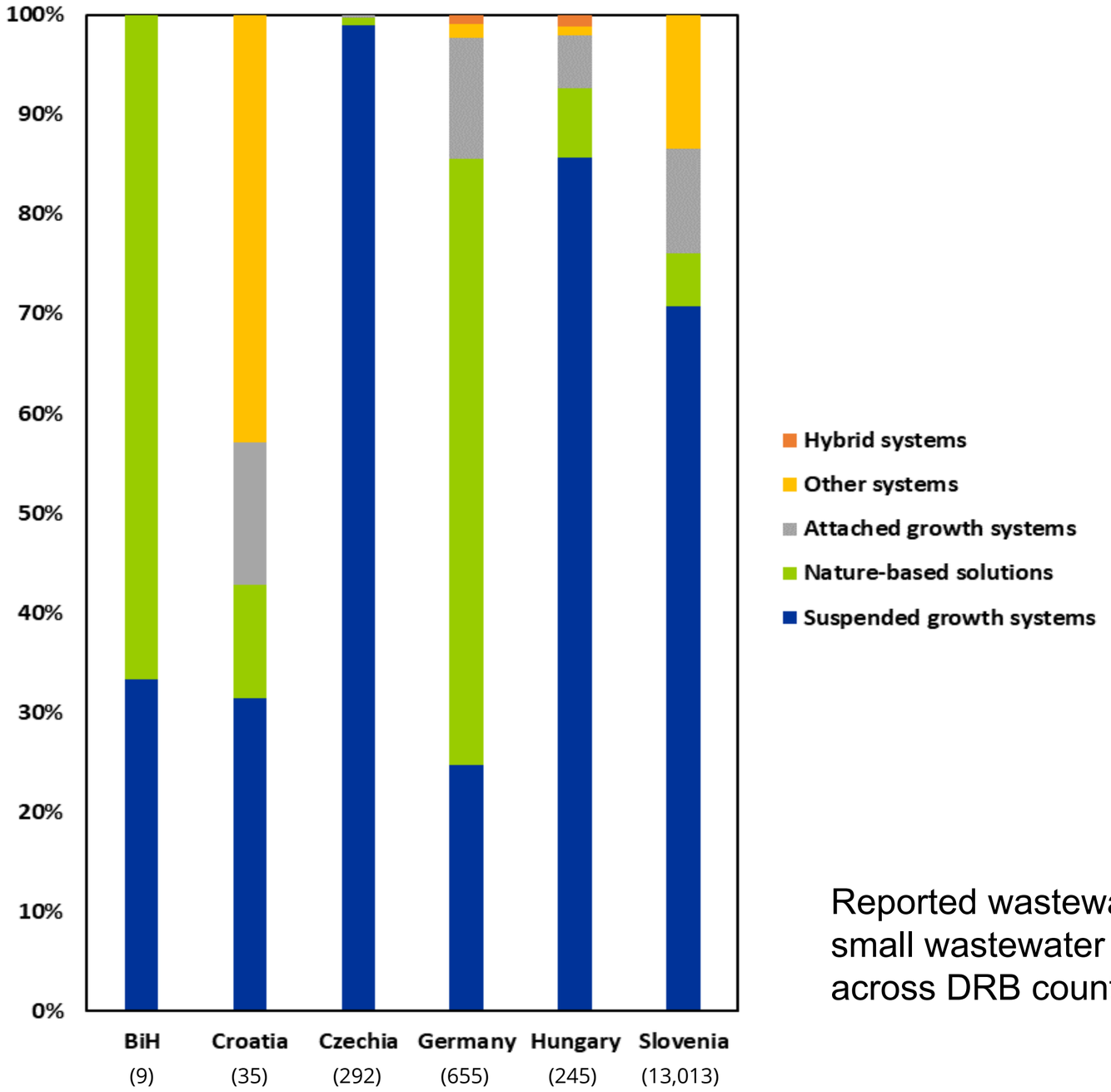
Technologies

- ***840 WWTPs > 500 PE***
  - 660 CAS plants (79%)
  - 135 SBR plants (16%)
  - 1 VF wetland (0.12%)
- ***960 WWTPs 51 - 500 PE***
  - 350 SBR plants
  - 300 CAS plants
  - 100 VF wetlands (> 10%)
- ***27’500 Small WWTPs (≤ 50 PE)***
  - 7,000 CAS plants
  - 5,600 VF wetlands (> 20%)
  - 5,200 SBR plants
  - 6,250 septic tanks left (ca. 0.4% of the design capacity)
- ***Cesspits***: ca. 200'000 people

Number of small WWTPs by size category and their total design capacity in the DRB

	Number of WWTPs				Total design capacity (PE)			
	≤ 50 PE	51-500 PE	501-1000 PE	1001-1999 PE	≤ 50 PE	51-500 PE	501-1000 PE	1001-1999 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 sWWTPs (IAS), owned and operated by individual households.



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

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 notable efforts in some countries, decentralized wastewater management remains a regional challenge, with approximately 85 % of the load still untreated.

Conventional, technical systems are the most widespread (> 67 %), while the adoption of nature-based solutions remains limited.

Discharge limits

National legislation

All countries regulate discharge limits for small WWTPs (50< PE < 2000)

The scope, stringency and parameters vary widely.

Discharge limits for individual systems (< 50 PE) are set in:

(Austria), Czechia, Germany, Slovakia, Slovenia

Limits based on plant capacity

- Austria, Germany, Serbia, Slovakia, Slovenia

Limits based on type of recipient (independently of plant size)

- Hungary, Romania

Limits based on broader water laws and government decrees

- Croatia, Czechia

Limits same for all plants

- BiH (variations depending on the entity)

Special limits for special locations

- Austria (remote locations), Slovenia (bathing waters)

Discharge limits

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		35-60			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		20		15	2	2	1	0.7		10	
max	200	80		200		55	20	28	10	10		1000	

Monitoring protocols

High variability in monitoring protocols

Frequency

Larger plants → more frequent monitoring

Financial responsibility

Public ←→ private WWTPs

Public utilities ←→ owners

Level of ordinance

National regulations (same for all) ←→ site-specific

Monitoring frequency by size

	10 < PE < 49	< 50 PE	50 ≤ PE < 200	50 < PE < 500	50 < PE < 1000	200 ≤ PE < 1000	1000 < PE < 2000	501 < PE < 5000
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

Management plans

National operational programmes

Obligation under UWWTD; **impact of the revision (2024) by 1 January 2028:**

- 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 to provide information to the public, especially in agglomerations above certain thresholds (e.g., 1,000 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

Country	National	Regional	Legal framework (WWTD)
Austria	x		
BiH	X	X	
Croatia	X (2021-2030)		
Czechia			X
Germany			X
Hungary	X (2002-2015)		
Romania	X (2024 – 2033)		
Serbia	X (until 2034)		
Slovakia	X (2021-2027)		
Slovenia	X (2020-2027)		

A fragmented planning landscape:
Most reported countries have a national WWM plan; prepared by different institutions and timeframes.

WW management plan for small settlements 1000<PE<2000

New directive 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).

Many rely on the deadlines stipulated in the Directive 2024/3019

Country	Schedule of the proceeding plan
Austria	100% connected
BiH	EU Accession framework (6-18 y after accession)
Croatia	31.12.2035
Czechia	31.12.2035
Germany	100% connected
Hungary	31.12.2035
Romania	Possible derogation; +14 years (<25% of collecting systems in small settlements)
Serbia	31.12.2035
Slovakia	31.12.2035
Slovenia	31.12.2027 (50<=PE<2000 PE)

In most countries, planning and regulatory coverage for these smaller agglomerations remains limited or absent.

Local management plans

No uniform approach to local wastewater management planning:

- municipalities legally required to prepare WW management plans
- municipalities may be assisted by regions

Country	Municipal level	Regional level	Centralised nationally
Austria	x		
BiH	x	x	
Croatia			x
Czechia	x		
Germany	x		
Hungary	x		
Romania			x
Serbia	x	x	
Slovakia	x	x	
Slovenia	x		

Majority of reported countries has at least some extend of local planning of wastewater collection and treatment.

Regulation for settlement with less than 1.000 PE

Large gaps reported

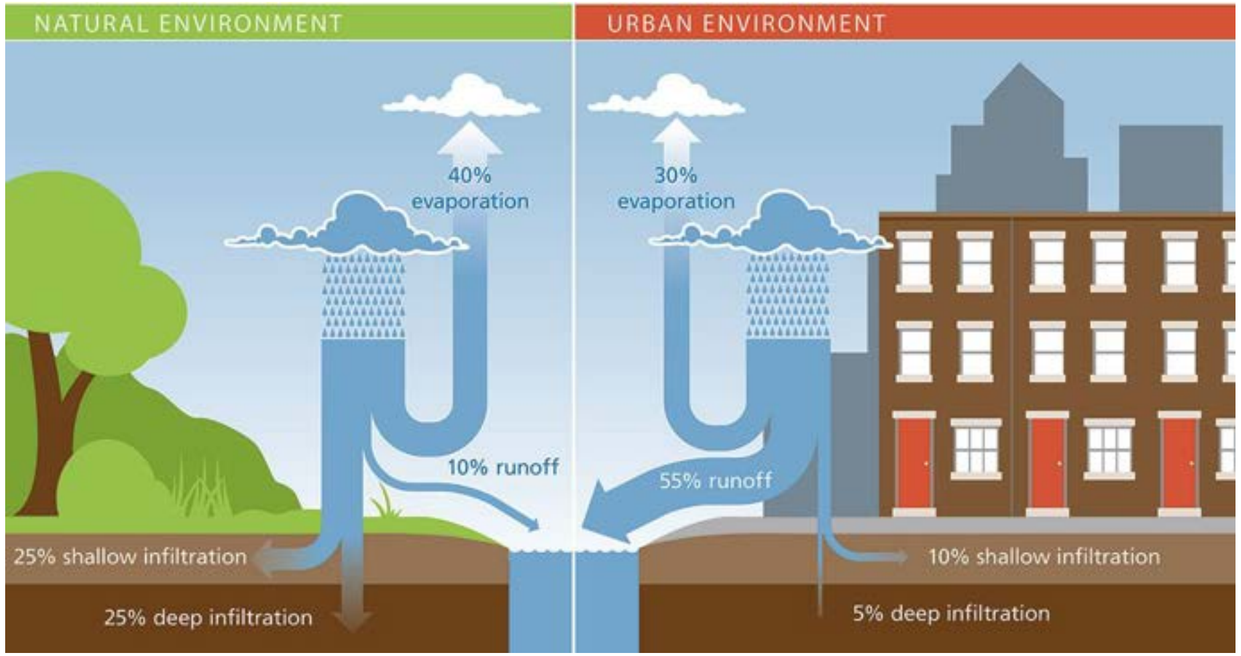
- Small settlements under-regulated
- Depend on local capacity, funding, and technical support
- Local authorities implement decentralized and nature-based solutions

Country	Local plans	Project based approach	National	Case-by-case	No regulation
Austria				x	
BiH	x	x			x
Croatia					x
Czechia				x	
Germany					x
Hungary					x
Romania					x
Serbia		x			x
Slovakia				x	x
Slovenia			x		

Reliance on local initiatives or regional frameworks.

Stormwater management

Stormwater management



Source: City of Detroit Water and Sewerage department

Pluvial floods in Ljubljana, September 2021 and July 2022

Photo: M. Radinja, 2021

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Main challenges in the small settlements:

- pluvial flooding
- combined sewer overflows
- infrastructure and land constraints

National regulation varies:

Treatment at central WWTP

Routing of uncontaminated to natural surface / subsurface drainage / discharge

BAT for SW treatment; context sensitive design

Oil/grase separators/traps

Drainage ditches along roads

Core infrastructure practices

Infiltration and percolation

Ditches, channles and retention

Separate drainage for specific land uses

NBS awareness varies:

- mixed acceptance
- result of consultative **spatial planning** (main toolof SW integration)

Rainwater harvesting: generally yes

→ Enforcement and maintenance vary in smaller communities.

Strengths and weaknesses

Decentralized wastewater collection and treatment

Table: Advantages and disadvantages of decentralized wastewater systems (from –2 = very disadvantageous to +2 = very advantageous)

	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

Table: Advantages and disadvantages of nature-based solutions (from –2 = very disadvantageous to +2 = very advantageous)

	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				

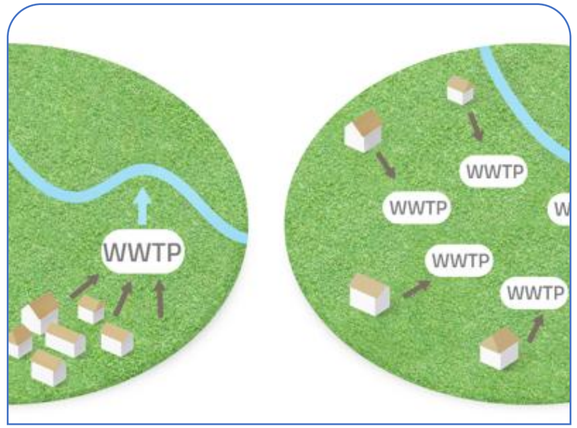
Best practices

Highlight the importance of:

training and cooperative models,

integration of nature-based solutions into local planning,

low-cost, sustainable systems such as constructed wetlands, which offer reliable treatment and additional environmental benefits for small communities.



Decentralised treatment aproach

Sustainable organisational models

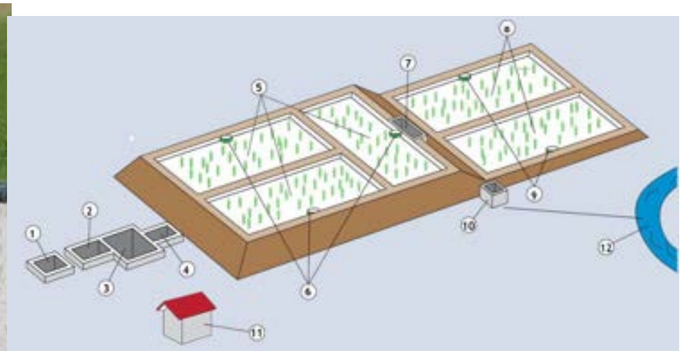
Pilot cases for SW management

Share your best cases, practices and experiences with us!

Constructed wetlands for WWT

Constructed wetland and sludge drying reed bed Raka, Slovenia (400 PE)

Constructed wetland Gložan, Vojvodina, Serbia (2.200 PE)



Constructed wetland and sludge drying reed bed Bušinja vas, Slovenia (250 PE)

Constructed wetland Ljubijankići, Cazin, BiH (600 PE)

Advantages for small communities - sustainable wastewater treatment; operational simplicity, environmental benefits, and low long-term costs.

Stormwater management best practices

Raingarden for surface runoff retention and treatment, Austria

Lagoons for receiving rainwater, Dunjkovec/Novo Selo Rok, Croatia

NBS can locally retain, store, evaporate, and release rainwater slowly, preventing the overload of technical systems and contributing to the natural water balance.

Climate resilient/adaptive solutions

Source: [LIFE-MICACC project](#) (des. *Csaba, Ruzics)*

Municipalities can use ecosystem based adaptation to bridge the broken balance in the small water cycle in case of extreme rain events; rainwater retention; retention and utilization of grey water for climate change adaptation.

Organizational models for small wastewater treatment plants (any technology)

Training courses

- the owner of the sWWTP carries out operation and maintenance
- training courses for sWWTP operators to improve the performance

Wastewater cooperatives

- public-law bodies where the users of the services share ownership and responsibility for the sWWTP

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

Thank you for attention

D-CLEAN - Improving Water Quality in the Danube River Basin: Nature-Based Solutions for Sustainable Wastewater and Stormwater Management in Small Settlements

Darja Istenič darja.istenic@fgg.uni-lj.si

Günter Langergraber guenter.langergraber@boku.ac.at

Alenka Mubi Zalaznik alenka@limnos.si

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