Global Water Partnership
Central and Eastern Europe

Wastewater collection, treatment, and reuse in rural areas of Central and Eastern Europe

Report of the Sustainable Sanitation Task Force

Wastewater collection, treatment, and reuse in rural areas of Central and Eastern Europe
Report of the Sustainable Sanitation Task Force

Darja Istenič[1,2], Igor Bodík[3], Magdalena Gajewska[4], Maret Merisaar[5], Alenka Mubi Zalaznik[6]

[1]University of Ljubljana, Faculty of Health Sciences, Zdravstvena pot 5, 1000 Ljubljana, Slovenia
[2]Universtiy of Ljubljana, Faculty of Civil and Geodetic Engineering, Jamova cesta 2, 1000 Ljubljana, Slovenia
[3]Slovak University of Technology Bratislava, Faculty of Chemical and Food Technology, Radlinského 9, 812 37 Bratislava, Slovak Republic
[4]Gdansk University of Technology, Faculty of Civil and Environmental Engineering, Narutowicza St. 11/12, 80-233 Gdańsk, EcoTech Center, Poland
[5]Tallinn University of Technology, Faculty of Civil Engineering and Architecture, Ehitajate tee 5, Tallinn 19086, Estonia
[6]LIMNOS Company for applied ecology Ltd., Požarnice 41, 1351 Brezovica pri Ljubljani, Slovenia

Global Water Partnership Central and Eastern Europe
December 2021

Table of contents

1 Introduction

Under the currently valid EU legislation wastewater collection and treatment in small settlements (<2000 PE) is not clearly regulated. Revision of the Urban Waste Water Directive (91/271/EEC) is currently under discussion and considers policy changes for remaining pollution, which comes from urban sources such as stormwater overflows and urban runoff, small villages and towns not falling within the scope of the Directive, and individual collection systems. In central and eastern Europe there is a very large number of small settlements and inappropriate treatment of wastewater from these settlements causes pollution of surface and groundwaters. Simple and robust technologies (such as nature-based solutions - NBS) that have low operation and maintenance requirements and costs, are recognised as most suitable and their implementation needs to be promoted. Moreover, the reuse of wastewater treatment products (i.e., water, nutrients, biomass) must be integrated in rural wastewater management and coupled with agriculture and/or energy production.

In this context Global Water Partnership Central and Eastern Europe (GWP CEE) has organized a sustainable sanitation task force joining the experts from the region to review the situation of sanitation in small settlements in the region, expose main challenges and develop ideas on how to improve the situation. The task force was first established in 2011 when a first survey on sustainable sanitation in small settlements of the region was carried out. The main findings of the study (Bodík et al., 2012) were that there is a significant number of small settlements in the region, inhabiting 30% of total population, and many of those were without appropriate wastewater collection and treatment. Additionally, the study pointed out numerous legislative and administrational barriers, and lack of knowledge on extensive technologies. Based on the results of the survey a technical textbook presenting sustainable technologies for wastewater treatment in rural areas was elaborated (see Rozkošny et al., 2014). Few less-active years of the task force have followed while this year the group of experts was recruited again.

As a starting point a similar survey to the one ten years ago was repeated to see the progress in sustainable sanitation in small settlements and to get a detailed insight into implementation of nature-based solutions (NBS) for wastewater treatment in the region. The online survey was followed by a workshop to discuss the results of the survey and provide a pool of needs and activities towards sustainable sanitation in the region and potential pathway for their implementation.

1.1 Questionnaire 2021

The questionnaire 2021 was divided into six chapters:

1. **Personal information** was collected for internal use to come back to respondents in case of additional questions regarding reported country data
2. **Country information** included basic information on population, number of settlements, small settlements, water consumption and water price
3. **Wastewater collection and treatment** chapter gathered data on the percentage/number of inhabitants connected to water supply and wastewater treatment, number of wastewater treatment plants, individual systems, discharge limits, monitoring and applied technologies
4. **Nature-based solutions** chapter gave special focus to applied NBS number and size, general status of NBS in the country, available guidelines, awareness, and main challenges towards wider implementation of NBS
5. **Use of reclaimed water and nutrients** was a new set of questions regarding to the study from 2012. The aim was to gather information on ongoing wastewater and treatment products

reuse (what kind of systems are in use and how often they are applied) and also on the awareness and application of circular economy

6. **Potential transboundary cooperation** included two questions to gather potential ideas for international activities.

The questionnaire was sent to the members of the task force group and to the country water representatives of the GWP CEE region. Additionally, the questionnaire was sent to contacts in Western Balkan countries. From 18 targeted countries, the answers were received from 12 countries (67%). From the CEE region, the answers were not received from Czechia and Lithuania, while from Western Balkan states only two out of 6 were interested in collaboration (Croatia and Montenegro). For Czechia some data were provided by Slovak contact.

The respondents to the questionnaire are experts in the field of sanitation or water management and belong to different sectors, namely non-governmental organisations (2 respondents), authorities (4 respondents), academia (3 respondents), and enterprises (3 respondents). Their distribution between the sectors is well balanced and presents a good pool for future cross-sectoral activities.

2 Presenting the region

Central and eastern European region of GWP comprises 12 countries, namely Bulgaria, Czechia, Estonia, Hungary, Latvia, Lithuania, Moldova, Poland, Romania, Slovakia, Slovenia, and Ukraine. The common denominator of all the countries is communist regime in the past, reflected also in current economic, political and social situation. Geographically the countries belong to two drainage basins - the Baltic sea (Estonia, Latvia, Lithuania, Poland) and Black sea (Slovakia, Hungary, Slovenia, Bulgaria, Romania, Moldova, and Ukraine). Czechia drains to both as well as to the North Sea basin. Historically and geographically the western Balkan countries (Croatia, Bosnia and Hercegovina, Serbia, Montenegro, Republic of North Macedonia and Albania) would belong to this region too; therefore, these countries were invited to participate in the study too. Most of the surface of western Balkan countries drains to Black sea.

The total population of the CEE region is 152 million people and of the western Balkan states is 20 million which together present almost a quarter of European population. According to the data from 2012, the population in some countries is stable while it is decreasing especially in Latvia (-10%), Romania (-10%) and Bulgaria (-7%). In Romania and Bulgaria also the total number of settlements in the country has decreased. Despite the decrease in total number of settlements in Romania, the small settlements below 2,000 increased significantly (from 702 reported in 2012 to 1,214 reported in 2021) which could be due to migration of people to the rural areas or simply just because different counting approaches.

Most settlements in the region belong to the group of small settlements below 2,000 inhabitants. In accordance with this, the data show that one third of the total population in the region live in these small settlements (Table 1) indicating a strong rural character of the region. Only in Moldova and Romania the population seem to be more centralized and small settlements represent only one third of total settlements and give home to around 10% of population. The high percentage of rural population living in small settlements can present dispersed pollution with untreated or insufficiently treated wastewater which was recognised also in the Evaluation of urban wastewater treatment directive.

Table 1: Demographic characteristics of examined countries.

Country	Population	Settlements < 2000 PE (%)	Population in settlements < 2000 PE (%)
Bulgaria	6,888,147	90%	26%
Croatia	4,284,889	97%	39%
Estonia	1,300,000	99%	31%
Hungary	9,890,640	75%	17%
Latvia	1,900,000	91%	43%
Moldova	2034100	33%	no data
Montenegro	621,700	98%	20%
Poland	37,660,000	no data	27%
Romania	19,186,201	38%	10%
Slovakia	5,459,781	85%	30%
Slovenia	2,108,977	98%	52%
Ukraine	41,342,500	95%	32%
average			30%

Average water consumption among the examined countries is 109 litres per person per day which is well below the average of the European Union which is 128 litres per day (EurEau, 2017). There are also quite big differences between the countries ranging from 50 in Moldova to 200 litres per person per day in Montenegro (Figure 1). According to the data available from the Questionnaire in 2012 we can draw comparison for seven countries, i.e., the water consumption in Hungary, Slovakia and Slovenia has decreased while it increased Poland and Romania and stayed almost the same in Bulgaria and Latvia.

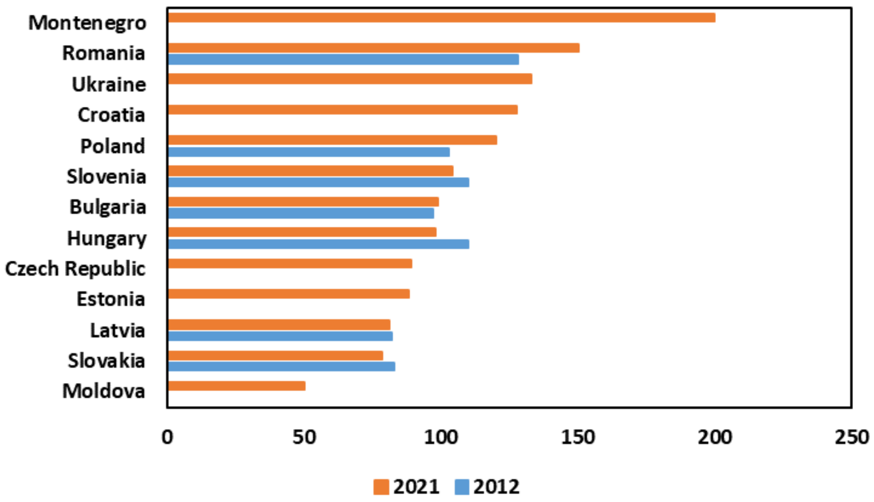

Figure 1: Average water consumption in litres per person per day in the studied countries for 2012 and 2021.

The questionnaire also included a question on water price, namely what the water price (including VAT) is together for tap water supply and wastewater collection and treatment in €/m^3. The answers were received from all the countries except Montenegro. The prices varied significantly, from 0.52 €/m^3 in Moldova to 3.77 €/m^3 in Czechia. Respondents also reported that there are big differences between the regions or municipalities also according to the wastewater collection and treatment system. For example, in Estonia the average water price for people connected to public wastewater collection and treatment system is 2,23 €/m^3, but for the people not connected to municipal sewage system the price for collection of domestic wastewater is around 14,33 €/m^3 and depends on the transportation distance and other factors.

Comparing with the results from 2012 data for 6 countries are available for comparison. The water price increased for 70, 92 and 123% in Romania, Slovenia, and Bulgaria, respectively, for 13% in Latvia and Slovakia, while it decreased in Hungary from 2.5 to 1.29 €/m^3, which is for 48%).

3 Wastewater collection and treatment

In the past, the development of countries has often been compared based on economic indicators such as steel production per capita, wheat production, maize per capita, etc. Today, we often encounter comparisons of countries in environmental indicators such as recycling rates, CO_2 production reductions, etc. Information on the connection of the population to public water supply and public sewerage also gives some information on the country's environmental development. This chapter presents connectivity to public water supply and public sewerage in the investigated countries as well as the number of wastewater treatment plants with the emphasis on small systems.

3.1 Public water supply

Public water supply means the connection of the population to drinking (tap) water, the quality of which is regularly checked by state authorities in accordance with the legislation in the given state. The use of private water sources (own wells) is not considered to be a public water supply. Connection to public water supply varies from country to country on a fairly wide scale (Figure 2). Moldova (53%) has the lowest connection, on the other hand, Bulgaria (99%) the highest one. Half of the countries have a connection of at least 90%, which is indicative of very good environmental conditions, not only in urban but also in rural settings.

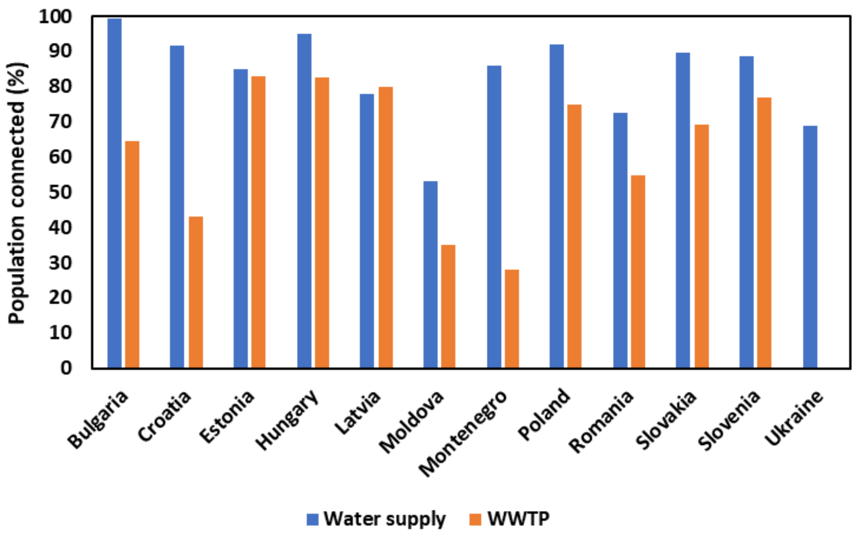

Figure 2: Population connected to public water supply and public wastewater treatment plants in investigated countries.

In general, public water supply is gradually increasing in all countries, with each country seeking to ensure the highest possible proportion of the population with drinking water. The connection to public drinking water encounters an economic barrier, when, especially in rural areas with high diffusion, the construction of water mains is very expensive. Therefore, even a 100 % connection to a public water supply is almost unattainable for many countries. Many countries have a duty in legislation to connect residents to the existing network of water mains, where technically and economically feasible. The willingness to connect to the existing public water supply is also quite high in these countries because in rural areas private wells are often contaminated by intensive agricultural activity (nitrates, pesticides) or sewage from leaking cesspools (ammonia, faecal bacteria, etc.).

3.2 Public wastewater treatment

Public wastewater treatment means the drainage of sewage by public sewerage and subsequent treatment at (biological) wastewater treatment plants (WWTPs). In this segment, the situation is rather more complicated and less favourable than in the case of public water supply. This is because, historically, the construction of water pipes than wastewater treatment has been more supported in these countries. The supply of drinking water to the population was generally a higher priority in terms of health and epidemiological aspects.

In all investigated countries, there is a higher connection of the population to public water supply than to treatment systems, except in Latvia, where it slightly exceeds the connection to public WWTPs. The average difference between connection to public water supply and public WWTPs is about 20%. Even with public WWTPs, there is a gradual increase in the share of the population connected to these systems, especially in recent years thanks to the support of EU funds. However, this support was focused as a priority on agglomerations above 2,000 PE, where the connection is significantly higher than in small rural municipalities.

The total number of WWTPs varies depending on the population in the country. In terms of number of plants, the country is usually dominated by size groups of 50-2,000 PE and 2,000-10,000 PE; however, the largest share of wastewater usually passes through a size group of 10,000-100,000 PE. As can be seen from Table 2 in most countries WWTPs with a capacity above 2,000 PE are accurately registered.

Table 2. Number of wastewater treatment plants in the country according to the capacity.

	WWTP capacity (PE)					
	<50	50-2,000	2,000-10,000	10,000-100,000	>100,000	Total
Bulgaria	64		109			173
Croatia	1	80	54	55	5	195
Czechia						2,795
Estonia	96	429	39	18	6	588
Hungary	4254*	210**	380	197	21	808**
Latvia	15	1,005	63	16	1	1,100
Moldova		>300	73	1		
Montenegro	No data	5	2	7	1	15
Poland	8,000*	No data	1,095	535	102	1,732**
Romania	12	354	633	132	66	1,197
Slovakia	15,000*	441	236	74	6	757**
Slovenia	No data	430	88	37	4	559
Ukraine		780	343	417	44	1,584

*unofficial data for small individual WWTPs
** the total is not including the preliminary data for <50

The construction of treatment systems in municipalities up to 2,000 PE appears to be a topical priority for all monitored countries for the coming years. The proportion of the population in small municipalities is relatively high and represents more than 37 million, which is almost 30% of the total population in these countries (see Table 1 in Chapter 2). On the other hand, the connection of residents from small settlements to public WWTPs is extremely low and represents only about 15% of inhabitants living in small settlements. Here too, there is a great variability between countries, from the minimum for Croatia (1%) and Montenegro (2%) up to Hungary (45%) (Table 3).

Table 3. Connection to wastewater treatment plants with capacity lower than 2,000 PE. The ratio is calculated according to the total number of inhabitants living in small settlements in each country.

	Total number of inhabitants living is settlements < 2000	Total number of inhabitants connected to WWTP < 2000 PE	Ratio of connected population in small settlements
Bulgaria	1,762,153	No data	
Croatia	1,664,400	19,669	1%
Czechia		No data	
Estonia	401,014	102,000	25%
Hungary	1,658,304	738,477	45%
Latvia	820,000	90,000	11%
Moldova		No data	
Montenegro	125,000	2,500	2%
Poland	10,000,000	No data	
Romania	1,915,072	156,598	8%
Slovakia	1,645,276	413,000	25%
Slovenia	1,086,815	No data	
Ukraine	13,093,100	780,000	6%

As has been noted for public water mains, the construction of sewerage systems and WWTPs in small and scattered settlements is costly. The population per kilometre of sewerage is often so low that construction of networks is economically unfeasible. For this reason, a large part of the population is dependent on individual sanitation systems – private WWTPs with the capacities between 4 and 50 PE or septic tanks. These are small structures that are not centrally registered in most of the surveyed countries and the authorities do not have statistically relevant data on the number or capacity of these facilities in the country. For example, in Hungary, there are about 913,000 private individual sewerage devices of septic tanks and about 6,000 residential WWTPs on the register, but many data are missing or incomplete. Similarly, in Poland, the number of individual plants (septic tanks and WWTPs) is estimated at around 233,000, and in Romania about 3.2% of population are connected to private WWTPs.

Records of small public WWTPs (50-2,000 PE) and especially private WWTPs are problematic. For example, in Slovakia, the number of private WWTPs is estimated at 15,000 (mostly in capacity up to 10 PE). Although most of them have been granted permission to build and operate, since there has been no registration system for this WWTPs group in the past, we only estimate the number based on data on sold pieces from individual dealers and suppliers.

Most countries declare that there are national strategies for the development of sanitation and for increasing the connection of the population to sewerage and WWTPs. In many countries (Romania, Slovakia, Slovenia, Hungary et al.), it is also legally supported that the property owner must connect to the existing public water or sewerage system if technical and economic circumstances allow. A significant factor in the connection of the population to sewerage is also the low level of income of the rural population, who often refuse to connect to the nearby network and continue to use "traditional" leaky septic tanks and cesspools.

However, not all countries declare a legislative obligation to residents in small municipalities to connect to sewerage (Croatia, Estonia, Latvia, Poland, Romania, and Ukraine). On the other hand, countries (Czechia, Slovakia, Hungary, Moldova, and Slovenia) have increased connection to both WWTPs and the countryside in their development plans. However, individual countries cannot define how many inhabitants will be connected to individual WWTPs in the coming years.

Project or financial support for the development of small WWTPs varies from country to country. In some countries there is only formal support from responsible ministries, in others, there is also real financial support from environmental agencies and funds in financing projects for sewer construction and WWTP (Bulgaria, Estonia, Hungary, Slovakia). Information on available technologies is usually not publicly available, it is provided only by companies that offer the design and construction of small and domestic WWTP.

The qualities and capacities of water utilities for the operation of water services vary. By larger central systems, there are usually sufficiently experienced engineers who can maintain and operate biological systems even in problem conditions. The management and operation of systems in small municipalities, or even for individual systems, is often accompanied by poor quality and experience of operators. There is also a lack of funding for the operation of these systems, as the price of water is kept at a very low acceptable level and therefore the cheapest investment solution is being sought for technology that is not always the cheapest operationally.

4 Discharge limits and monitoring

In European Union the treatment of urban wastewater is regulated by the Council Directive 91/271/EEC concerning urban waste water treatment (UWWTD). Since introduction of this Directive a time plan has been set out for the construction of necessary infrastructure for collecting and treating wastewater in agglomerations (urban areas), which generate more than 2,000 PE of wastewater. According to this Directive wastewater must be subject to secondary treatment (biological treatment), which removes a very high proportion of organic pollution, bacteria, and viruses in general; however, in catchments with sensitive waters, the urban areas that generate more than 10,000 PE of wastewater are required to apply more stringent treatment with further removal of nitrogen and/or phosphorus. The removal of nitrogen and/or phosphorus protects sensitive waters from the risk of algal blooms. In this aspect it is worth to mention that Poland, Estonia, Latvia and Lithuania belong to Baltic Sea catchment which is considered as a sensitive area.

The UWWTD sets common standards among countries for the concentrations of organic matter (BOD_5 and COD), suspended solids (TSS), total nitrogen (TN) and total phosphorus (TP) in the discharges of treated urban wastewater, as well as the necessary monitoring frequency. Each urban area that generates wastewater of more than 2,000 PE is assessed for its compliance with the UWWTD but the Directive does not set limit values for wastewater generated in small settlements out of agglomerations. Thus, all settlements with less than 2,000 PE are out of the UWWTD and the quality of wastewater discharged from WWTPs in these areas is under national regulations which differ significantly between the investigated countries (Table 4).

Table 4: Discharge limits in mg/L and CFU/100 mL (for E.coli*) for wastewater treatment plants with less than 2,000 PE in investigated countries.*

Parameter	Bulgaria	Croatia	Estonia		Hungary			Latvia		Moldova		Montenegro		Poland		Romania		Slovakia		Slovenia		Ukraine	
	All sizes	All sizes	PE<300	300<PE<2000	PE<50	PE<600	601<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000	PE<50	50<PE<2000
COD	125	125	150	125	75-150[c]	300	50-150[c]		50-70%		22	125	125		150	125	125		135/170	200	150	15	15
BOD	25	25	40	25		80	15-50[c]		50-70%		2.1-6.8	25	25	20%	40	25	25	40 / 70	30/60		30	80	80
TSS	35	35	35	35		100	35-200[c]		<35		2-3	60	60	50%	50	60	60		30/60			15	15
TN				60			20-55[c]				10	15	15		30[d]							0.39	0.39
NH_4-N					10-40[c]		2-20[c]				0.2-0.6					3	3						
NO_3-N			45[a]	45[a]							25					37	37						
NO_2-N			0.1[a]	0.1[a]							1					2	2						
TP				2			0.7-10[c]				2	2	2										
PO_4-P															5"	6	6						
E. coli			[b]	[b]			1,000				$5*10^3$												
Chlorides																500	500						
Detergents																0.5	0.5						
Phenols																0.3	0.3						
Sulphides and hydrogen sulphide																0.5	0.5						

[a]In carstic regions/lakes

[b]Can be set in the permit

[c]Depending on the discharge point (soil or water)

[d]Values required only for wastewater introduced to lakes and their tributaries and directly to artificial water reservoirs situated in flowing waters

UWWTD sets discharge limits for larger WWTPs for chemical oxygen demand (COD), biochemical oxygen demand (BOD_5) and total suspended solids (TSS) at 125, 25 and 35 mg/L, respectively. These limiting values are adopted by some countries also for small and individual WWTPs. In case of the settlements between 50 and 2,000 PE concentrations of organic matter and TSS are regulated in all investigated countries either as a required percentage of removal or final concentration. They follow the same values as in UWWTD in Bulgaria, Croatia, Estonia, while in Montenegro and Romania the TSS discharge values are a bit higher. The only exception is Slovenia where there is no regulation on TSS. In case of individual systems which are usually less than 50 PE the differences between the countries are greater. There are no discharge limits in Latvia and Moldova and in Poland only reduction of BOD_5 and TSS are required (20 and 50% removal, respectively). On the other hand, Romania has very strict discharge limits, where also private treatment systems must meet discharge limits for ammonia, nitrites, nitrates, phosphates, chlorides, detergents, phenols and sulphides.

Regarding removal of nutrients in small and individual WWTPs, in 8 out of 12 countries at least one of nitrogen compounds is regulated and in 7 countries at least one of phosphorous compounds needs to be efficiently removed from wastewater to protect the recipient against eutrophication. Only few countries like Hungary and Moldova and in special occasions also Estonia require *E.coli* removal.

As with the requirements for the quality of treated wastewater, the necessity and frequency of monitoring of small and individual WWTPs varies significantly between the investigated countries. In the case of WWTPs between 50 and 2,000 PE, majority of investigated countries decided to establish rules for their monitoring. Only Bulgaria and Ukraine have not established any control rules for these facilities. In Croatia, Estonia, Montenegro, Slovakia, Slovenia, Hungary, and Poland the monitoring should be carried out 2, 4 or 6 times per year. In case of Poland the number of average daily samples taken at the outlet must not be less than 4 samples per year, and if the wastewater meets the required discharge limits only 2 samples are taken in the following year. If at least one sample of the two taken does not meet the required conditions, 4 more samples are taken in the following year. In Latvia, Moldova, and Romania monthly monitoring of small WWTPs is required.

For individual systems, below 50 PE, in 7 out of 12 countries there are no requirements for monitoring. In Slovenia such WWTPs should be tested once every three years but in Croatia, Hungary, and Slovakia once per year. The most rigorous monitoring requirements for individual systems are in Romania where they should be tested 4-times per year.

The sampling technique also varies between the countries from 2-, 4-, 8- or 12-hour composite samples or average daily samples for small WWTPs to grab samples for individual systems. The analyses are mainly provided by accredited laboratories and financed by WWTP owner or operator. The costs of analyses can also be covered by tariffs.

There are a lot of augments for introducing comprehensive monitoring of small WWTPs as they usually discharge to surface waters, often also to sensitive waters and can be the direct reason of not meeting the requirements of good status of water bodes imposed by the Water Framework Directive (2000/60/EU). In the opinion of task force group, in sensitive areas monitoring should also include nutrients (TN and TP) and not only organic matter and TSS. In general, small WWTPs often provide only basic treatment and no nutrient removal. The UWWTD should set nutrient limits specific to the sensitivity of different areas (e.g., lakes, Baltic sea, karst).

5 Wastewater technologies applied

Technologies applied for wastewater treatment in small settlements of CEE are diverse and vary between the countries as well as between different settlement sizes. In the questionnaire a list of 12 treatment technologies was offered to the respondents with an additional option to add other applied technologies in the country. For each technology the respondent needed to mark if the technology is applied rarely, often, mostly, or never. Two separate tables were prepared to distinguish between systems for small settlements (PE<2,000) and individual systems (PE<50). Altogether 14 different technologies were identified, namely all the listed technologies are present in the region and two additional were suggested by respondents.

It must be noted that in many countries there are no official databases on applied treatment technologies in small settlements and individual systems. Therefore, the results presented here are mainly based on the expert knowledge and experience of the respondents.

5.1 Technologies in small settlements – public systems below 2,000 PE

Most applied technology for wastewater treatment in small settlements (PE<2,000) is sequencing batch reactor (SBR) (Figure 3). It especially dominates in Latvia and Ukraine, and is also often applied in Estonia, Hungary, Poland, and Romania. SBR is a fill-and drain activated sludge system where wastewater is added to a single batch reactor, treated and then discharged. For better performance and for bigger capacities two or more batch reactors can be used in a determined sequence of operation. The treatment process has more stages that all take part in one tank (reactor) therefore no additional clarifiers are needed which is one of important advantages of SBR compared to other activated sludge systems and most probably also the reason for wide application throughout the region. Other types of activated sludge treatment technology are also applied: classical activated sludge compact systems are common in Slovakia and Estonia, membrane bioreactors (MBR) are often used in Romania and moving bed biofilm reactors (MBBR) in Estonia, Poland, and Slovenia.

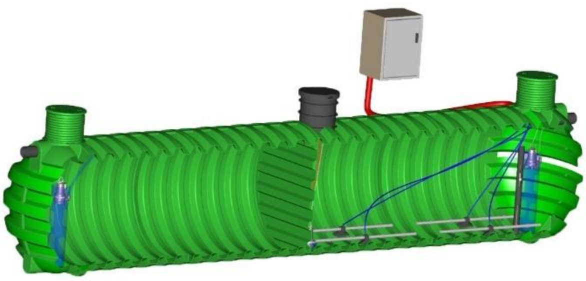

Figure 3: Scheme of a SBR treatment plant for 150 PE (source Roto Ltd.).

Following SBR and similar treatment technologies based on activated sludge also treatment wetlands are often applied, especially in Croatia, Moldova, and Montenegro (Figure 4). In accordance with this, in Croatia and Montenegro also sludge drying reed beds are often used to process excess sludge from conventional activated sludge treatment plants. Treatment wetlands and sludge drying reed beds belong to the group of NBS and do not need much or sophisticated technical equipment to treat water. They are simple to operate and maintain and need little or no energy to function.

Figure 4: Scheme of a two-stage treatment wetland plant for 50 PE (source PasivnaGradnja.si).

Among more robust and passive technologies also sand filters are often applied in Estonia, Moldova, and Romania, while soil infiltration is common in Moldova and Ukraine. Soil infiltration treatment technologies require significant areas but can be coupled with biomass production. Standard irrigation methods can be used to distribute water to agricultural fields, pastures, or forest lands (Andrews and Fedler, 2021).

Despite numerous different technologies available and applied to treat wastewater from small settlements, water-tight septic tanks remain very common solution. It has been agreed among the expert group of sustainable sanitation task force of GWP CEE that only water-tight septic tanks are accepted as appropriate treatment technology while septic tanks with outflow are not considered as appropriate. This is because septic tanks with outflow are often not designed and operated correctly, i.e., not emptied regularly and the infiltration of the outflow water is not designed according to the soil properties and site characteristics. This can cause a threat to the quality of surface and groundwaters (Withers et al., 2014). In case of water-tight septic tanks the produced wastewater is accumulated in the two or three-chamber concrete or plastic structure that enables sedimentation of particulate matter. The accumulated water and sludge need to be pumped out regularly and the wastewater is transported to the central wastewater treatment plant. For the end user, this is often the most expensive solution of wastewater disposal and should be applied only in areas where no other solution could fit (Kompare et al., 2008).

Waste stabilization ponds, aerobic ponds, up-flow anaerobic sludge blanket (UASB) reactors and willow systems are rarely applied for small settlements in the region, with an exemption of Estonia, where aerated ponds are often used.

Comparing the countries, in some countries only few different treatment technologies are reported to be in use – e.g. two in Latvia and Croatia, three in Poland and four in Montenegro, Hungary and Ukraine. On the other hand, in Estonia and Slovenia 8 or 9 different technologies are applied, respectively. The two approaches, focusing on few technologies or having a pool of numerous solutions, offer different advantages and disadvantages. Focusing on few technologies results in easier operation and maintenance practices as operators do not need to be familiar with many different technologies and can pay more attention and deepen the knowledge on selected solutions. In contrast, only few technologies may not cover the peculiarities of some specific locations or applications.

5.2 Technologies for individual settings – private systems below 50 PE

In case of individual systems (single houses or hamlets) 13 different technologies were reported, dominated strongly by septic tanks. They are mostly applied solution in Latvia and Poland and are common also in Hungary, Moldova, Montenegro, Romania, and Slovenia. For Croatia and Ukraine there was no data reported on technologies used for individual settings. As mentioned in previous chapter, water-tight septic tanks are often the most expensive solution for the end user and just transfer the wastewater treatment problem to the central location. Finally, many septic tanks in rural locations might be declared as water-tight but experience from practice often show that there are illegal outflows.

Next most common solutions for individual settings are different activated sludge systems, where SBR and conventional activated sludge systems prevail. In Romania also UASB reactors are often used for individual settings. Treatment wetlands are also commonly applied, most often in Poland and Slovenia. Sand filters and soil infiltration are, same as for small settlements, often applied in Moldova and Romania.

Same as for small settlements, waste stabilization ponds and aerobic ponds are rarely used in the region, with an exemption of Estonia, where aerobic ponds are often used also for individual systems.

5.3 Improvements in the last 10 years

The questionnaire study performed by GWP CEE in 2012 did not distinguish between technologies applied in small settlements and for individual systems; however, the data show that septic tanks were predominantly used in all the countries except in Latvia where activated sludge systems prevailed already at that time. For Romania and Bulgaria, the septic tanks were reported to be used in more than 99% of the cases. According to the results from this year, the situation in the two countries has improved. SBR, sand filters and different types of ponds were reported to be now occasionally applied in Bulgaria, while in Romania seven different technologies were reported to be in use, among them SBR, MBR and sand filters are often applied for small settlements while sand filters and UASB reactors are often applied for individual systems.

In 2012 the nature-based treatment systems were reported to be sometimes applied in Czechia and Estonia and in rare cases also in Hungary, Latvia, Slovenia, and Ukraine. Comparing to the results form this year the popularity of nature-based treatment systems increased a bit in Slovenia for individual systems while in other countries stays on the same level. Croatia, Moldova, and Montenegro which were not included in the study in 2012 use NBS often.

5.4 Nature-based solutions for wastewater treatment

A special attention in the questionnaire was given to the application of NBS for wastewater treatment. In the last 10 years the technical knowledge on NBS for wastewater treatment has increased significantly and is presented in numerous expert literature and textbooks (e.g., Von Sperling, 2007; Dotro et al., 2017; Langergraber et al., 2019; Cross et al., 2021). Additionally, EU has been financing many NBS oriented research and innovation project. In the questionnaire most applied NBS for wastewater treatment were listed and the respondents were asked to fill in the number of such systems in their country and the average size in PE. There was also an option to add additional technologies. Activated sludge systems were excluded from the list, despite according to the EU wide definition of NBS they are sometimes referred as NBS.

All listed NBS are presented in the region and two additional solutions were added (Table 5). The data on the number and size of such systems was not always available and when given, it is usually low; however, the presence of these technologies in the region is a good basis to showcase their performance and enhance further implementation throughout the region.

Besides this, given numbers of NBS systems should be interpreted with caution. For example, in Croatia there are 8 treatment wetlands reported, but around 8,000 in Poland. Despite very different numbers, both countries declare application of treatment wetlands for wastewater treatment solution as rarely

(Poland) and often (Croatia). This is due to significantly different sizes of the countries and total number of wastewater treatment plants applied for small settlements.

Table 5: The presence of nature-based solutions (marked green) in the countries of Central and Eastern Europe. Where the data were available also the number of systems is given.

	Bulgaria	Croatia	Estonia	Hungary	Latvia	Moldova	Montenegro	Poland	Romania	Slovakia	Slovenia	Ukraine	Total
Soil infiltration				12								300	>312
Willow systems											1		>1
Waste stabilization ponds				3							2		>5
Aerated ponds											10		>10
Treatment wetlands		8				7	5	8,000		150	180	80	>10.430
Sludge treatment reed beds		8			10		4	1					>23
Vermifilter						1							1
Ecosan technology						70							70

Sludge treatment reed beds are used in the region to process the sludge from conventional activated sludge treatment plants treating water from small or bigger settlements (capacities range from few hundreds to 15,000 PE). Besides this, sludge treatment reed beds can be applied also to treat sludge and water accumulated in septic tanks which is a low-tech and energy-efficient solution for rural areas avoiding the transport of sludge to central treatment facilities and producing treated sludge for agricultural application and leachate to irrigate trees for energy production (Kim et al., 2018).

In comparison with the situation in 2012, the number of soil infiltration systems has declined. 1,500 systems were reported from Ukraine in 2012, while now there are only 300. The reason for this decline is not known, the systems might be abandoned, or the data was reported differently. Back in 2012 soil infiltration systems were not in use in Estonia, Hungary, and Slovenia, but were reported as applied solutions in this study.

In 2012 treatment wetlands were reported as applied solutions also in Bulgaria and Latvia but from this study it seems the systems were abandoned. On the other hand, the number of treatment wetlands increased in Slovakia (from 5 to 150), Slovenia (from 80 to 180) and Ukraine (from 65 to 80) but for the period of 10 years the increase is not significant. The number of waste stabilization and aerated ponds is difficult to compare, since the numbers are available only for some countries. In 2012 more than 230 pond systems were reported in Czechia, Estonia and Hungary, but they were not in use in Bulgaria, Romania and Slovenia as reported in this study.

6 Awareness on nature-based solutions and barriers for implementation

The European Commission defines NBS as "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more diversity, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions."

NBS are a well-known and distributed approach for environmental problem solving that generates multiple benefits. EU Horizon 2020 programme significantly supported the research and demonstration of NBS and proved their efficiency and advanced the knowledge on their multiple benefits. Under the new funding perspective of the EU, NBS are particularly encouraged to be explored and used as climate change adaptation measures.

Status of NBS in the investigated countries varies. Not all the countries reported the existence of NBS solutions for wastewater treatment, although there are evidence that some pilot systems exist. In Bulgaria, Romania and Estonia, these systems seem to be almost unrecognised.

NBS technologies are somewhat known in several countries, in Croatia, Montenegro, Slovenia, Slovakia, Moldova, Hungary, Ukraine, Estonia and Poland; that is in 10 out of 12 investigated countries. However, the level of applicability and satisfaction with NBS differs. Treatment wetlands are applied in majority of countries, particularly in Slovakia, Poland, Estonia and Slovenia.

In Montenegro, treatment wetlands have proved themselves to be highly efficient, but constant efforts must be put into awareness raising on the suitability of NBS. The country applied NBS in a separate national strategy aligned with the political decision on environmental-friendly development of the country.

In Poland, NBS is not widely accepted due to historic deployments that were not very successful, but this is improving recently, as the acceptance of NBS has been growing, especially for <50PE, as they can be built without construction permit. Awareness raising and positive practices are a way forward for NBS in Poland. More qualified engineers and a supportive legislation are also needed.

In Ukraine, more time is needed to secure a notable market share of NBS in the wastewater treatment technology sector. In Moldova, they are not yet well accepted as there are not much good cases to demonstrate but is home to the largest constructed wetland in Europe (20,000 PE) (Masi et al., 2017). Maintenance of NBS is considered very important and more knowledge must be gained in the country for design and maintenance of NBS. Institutional barriers need to be tackled as well.

NBS in Estonia are mostly used as post-treatment or as individual systems. Individual systems are most common NBS. Guidelines and recommendations regarding installation of NBS for wastewater treatment are available. All treatment systems are accepted if the discharged wastewater follows the requirements.

In Hungary, national regulation is additionally specifying conditions for NBS wastewater treatment; wastewater must be let into the nature-based wastewater treatment plant only through a separate collecting system. Additionally, economic calculations above 600 PE must prove that the NBS is more economical than the wastewater treatment plant. A nature-based wastewater treatment plant in a nitrate-sensitive area can only be established prior of the official authority permit.

In Slovakia, NBS for wastewater treatment are not a popular approach and are not supported by the authorities. Therefore, implementation is slowly increasing as more should be done in awareness raising in efficiency and benefits of NBS, assisted with quality engineering, supportive legislation, and institutions.

In Slovenia, NBS are well accepted, the implementation is increasing and with it the awareness. There are no other stricter demands upon this technology, if they meet the discharge water quality.

Sludge drying reed beds are mostly applied in Croatia and Latvia. In Croatia, recent EU-funded investment programme into wastewater treatment stimulated investments into NBS for sludge treatment, mainly due to lack of unified strategy for sewage sludge management.

Reasons for negative attitude or decline of NBS are mostly the following:

- NBS is not accepted by authorities
    - In some countries, there is a lack of good cases
    - NBS have a bad reputation

There are several reasons identified that explain poor distribution/application of NBS solutions (Table 6). Unawareness of the technology and its' solutions are an important aspect, mainly identified in Bulgaria, Hungary, Poland, and Slovakia. Interestingly, negative experience with technology is identified in several countries, where lack of NBS applications exist, possibly indicating some early bird attempts that have not been well accepted.

Table 6: The main challenges for wider implementation of nature-based solutions (empty cell or 0 – not a chellenge/no reply; 1 – small challenge; 2 – medium challenge; 3 – large challenge).

	Unaware-ness	Negative experiences	Lack of land (area)	Institutional barriers	Natural conditions	Lack of legislation	Lack of engineering
Bulgaria	3	3	2	3	3	3	1
Croatia							
Estonia	2	0	1	2	1	2	1
Hungary	3	3	3	3	3	0	2
Latvia	2	3	3	1	3	2	2
Moldova	2	1	1	3	1	1	2
Montenegro	2	1	3	2	1	1	2
Poland	3	3	0	0		2	2
Romania	2	2	3	2	3	3	2
Slovakia	3	3	2	2	2	2	2
Slovenia	2	1	3	1	2	1	1
Ukraine				3			

Other challenges mentioned, are lack of land/available space, as NBS applications are area intensive. However, the NBS solutions are therefore recommended for rural areas and countries where lack of areas was stated as a challenge (Hungary, Romania, Latvia) have ample space available in the countryside. Smaller countries, where scattered settlements occur due to the diverse geographical landscape can be more obstructive (Slovenia, Montenegro). Natural barriers are therefore identified in all countries where lack of space was identified as a relevant barrier – except in Slovenia, where NBS are well known and are adapted to this limitation with treatment process intensification and focus to individual solutions and rural areas. Urban and coastal areas are problematic in terms of finding available land for NBS; however, numerous EU supported research and innovation project are now developing new NBS systems for application in such areas.

Climate is considered as an obstacle for proper functioning of NBSs. There is a lack of demonstrative solutions to prove otherwise.

Institutional barriers are a challenge in Bulgaria, Hungary, Moldova, and Ukraine. In Bulgaria, Ministry of Environment and Water does not accept NBS as suitable solutions for sanitation issues.

Lack of legislation that does not support NBS remains a challenge in Bulgaria and Romania, as it introduced strict efficiency levels even for individual systems, where NBS must be specifically applied to and need additional engineering or hybrid solutions. NBS for wastewater treatment in Romania are not applied at all except some aerated ponds and pilot treatment wetlands.

Lack of engineering isn't a main challenge in the responsive countries which is encouraging and indicates the opportunity of NBS spread if other challenges would be addressed. Legislation and engineering are not so problematic – if the awareness is high and negative experiences are overcome by good examples also legislation will adjust.

Other challenges that can occur:

- Maintenance is required and can be neglected (could result in malfunctioning of the systems over the years)
- High reconstruction costs in case of negligible maintenance
- Lack of knowledge and organisation of operations at public utility should be vastly improved (competence building)
- Misuse from the side of customers (introducing potentially harmful material to the sewage; resulting in microorganisms biomass depletion); costly restoration in this case

Compared to 2012, NBS is still vastly underexploited in most respondent countries. In Bulgaria, Romania, Ukraine they remain unrecognised since then. However, there is an improvement of NBS application in wastewater treatment in majority of respondent countries, particularly in Slovakia, Poland, Estonia and Slovenia, where wetland technologies are in a bigger demand. More guidelines, pilot cases and available technical knowledge generally support the wider application of NBS.

7 Water reuse and circular economy

Wastewater reuse is addressing global environmental problems such as:

- **Water deficit** in dry areas (e.g., Mediterranean) or in agricultural areas (agriculture uses 70% of fresh water)
- **Phosphorus depletion** (mineral phosphorous fertilizers are obtained from mineral ores and present unrenewable resource)
- **High energy needs** for production of nitrogen mineral fertilizers and wastewater treatment.

Wastewater reuse presents a valuable resource for water supply in areas where water is limited. There are two types of wastewater re-use: direct and indirect. **Direct wastewater re-use** is treated wastewater that is piped into a water supply system without first being incorporated in a natural stream or lake or in groundwater. **Indirect wastewater re-use** involves the mixing of reclaimed wastewater with another water supply source before re-use. The mixing occurs for example when the groundwater is too saline and needs to be improved by the treated wastewater.

In Europe the largest uptake of wastewater reuse technology is in Spain (496 M m^3/year in 2006) and Italy (233 M m^3/year in 2000). It is much more common than in similar sized countries such as Germany (43 M m^3/year in 2000), France (8 M m^3 year in 2000) and the UK (1 M m^3/year in 2000). The measure is applicable almost everywhere and allows centralised (e.g., national water authority) and decentralised (e.g., industrial plant, farmers, regional) approaches (Campling et al, 2008). Greywater recycling exists at scales ranging from very small (<0.1M m^3/year), small (0.1-0.5M m^3/year), to medium (0.5-5M m^3/year) and large (> 5M m^3/year).

Wastewater reuse could be an important part of circular economy, but today it is not controlled sufficiently. The term "circular economy" was not familiar for the respondents from Romania and Ukraine. In Croatia, Estonia, Latvia, Slovakia and Slovenia the practice has reached municipal waste systems, but not wastewater yet. Latvia unites this term with "green procurement" for public needs, use of local food produce in kindergartens and schools, zero-waste movement, Eco-schools, and local food markets. In Moldova there is a State Program for 2020-2023 on the mechanism of circular economy as well as the funding programme EU4environment.

7.1 Irrigation

From 26 June 2023 the new EU Regulation on minimum requirements for wastewater reuse /2020/741) will enter into force. According to this Croatia, Estonia, and Latvia report that relevant national level legislation is under preparation and will come into force in 2023; in Montenegro already in 2022. Ukraine already has legislation on the use of treated wastewater for irrigation in place. Moldova reports the National Protocol on Water and Health for the years 2016 to 2025, where irrigation with treated wastewater is allowed, but no limit values are indicated only the WHO recommendations are referred to. Hungary has enforced a Governmental Decree, according to which treated wastewater can be used for irrigation in agriculture. The relevant limit values (mg/L) for (heavy) metals in the discharge are as follows: Al (10,0), As (0,2), B (0,7), Ba 4,0; Cd (0,02); Co (0,05), ΣCr (2,5); Cr VI (0,5); Cu (20,0); Hg (0,01); Mn (5,0); Mo (0,02); Ni (1,0); Pb (1,0); Zn (5,0); Cl^- (150). There is no separate regulation in Poland, but there is Journal of Laws 2019, item 1311, paragraph 16, that sets the conditions for using wastewater for irrigation: BOD_5 reduced for 20%; suspended solids by 50%; limit values to various hazardous substances are listed in separate annexes. There is a requirement for microbiological and parasitological tests at least after every two months and monitoring of heavy metals in irrigated soils should be carried out every 5 years. Requirements for geological structure of the irrigated area and for the location of equipment and installations used are set in that paragraph as well.

According to the 2021 Questionnaire, it is allowed to use treated wastewater for irrigation in Croatia, Hungary, Latvia, Moldova, Poland and Ukraine. This method of irrigation is prohibited in Bulgaria, Estonia, Montenegro, Romania, Slovakia and Slovenia. The main reason is the threat on human health by pathogens and pollution with heavy metals as well as residues of various other hazardous substances that may affect people who are using the resource or eating agricultural products grown by such method. Latvia reports, that due to sufficient rainfall irrigation with treated wastewater has not been inevitable so far and the same can be said about Estonia. In Latvia national regulations on use of wastewater sludge are in place.

In Poland they are proposing since 2008 an innovative sanitary system based on closing material cycles in the environment, where the nutrients (N, P, K compounds) present in sewage should be used as fertilizers. Wastewater from individual households is treated at individual WWTPs. Treatment wetlands are suggested with primary treatment in septic tanks. Treatment wetlands work in three configurations. The sludge gathered in septic tanks is periodically removed and applied to reed treatment beds, where intensified natural processes take place. The leachate water generated in the sludge dewatering process is discharged to the treatment wetlands and treated together with wastewater (Figure 5). The dewatered and stabilized sewage sludge becomes a valuable humus substance, that can be used as soil fertilizer at the farmlands. In this way the material cycle is closed. The sewage treatment technology as well as sludge processing is simple in operation. Additionally, an effluent polishing pond is positioned after the treatment wetland increasing the retention of water in small catchments. The proposed technology for individual systems was proved as an effective and sustainable solution for wastewater treatment in the rural areas (Gajewska et al., 2011; Obaraka-Pempkowiak et al., 2015)

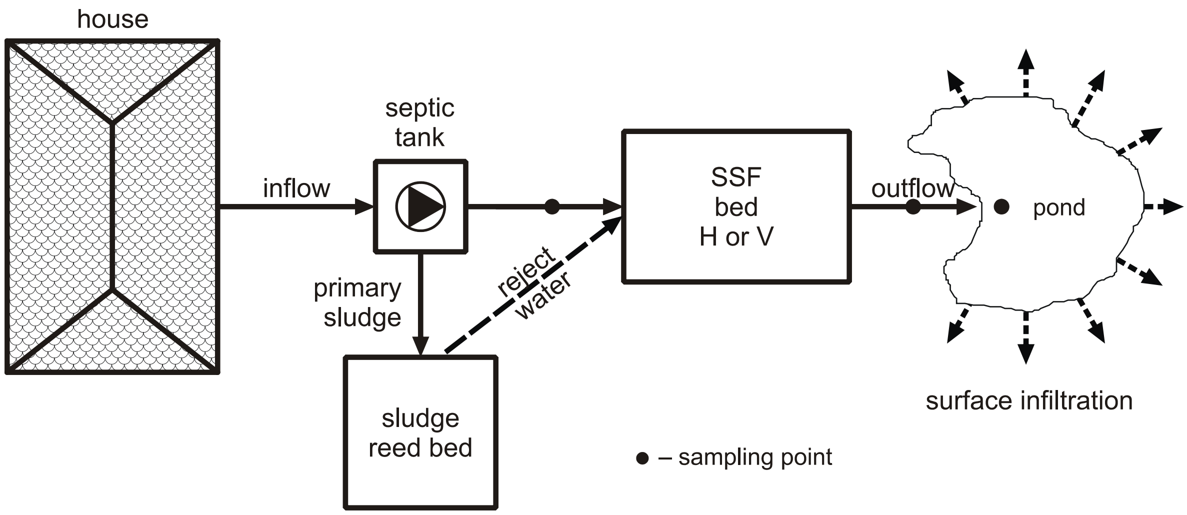

Figure 5: Wastewater treatment system for individual households proposed for rural areas in Poland (SSF bed – subsurface flow treatment wetland).

7.2 The other types of wastewater reuse

The other type of wastewater reuse reported in the questionnaire are:

- **Toilet flushing:** In Estonia greywater and harvested stormwater are used for toilet flushing in some urban pilot constructions, in Poland there is one such case described in a hotel and in Moldova greywater from the kitchen and laundry is known to be reclaimed in several rural settlements where municipal sewerage systems are missing.
- **Energy plantations:** In Hungary reuse of reclaimed water is mostly limited to irrigation of aspen and energy (willow) plantations**.**
- **Sludge recycling** for composting, horticulture, landscaping, recultivation etc. is reported by Estonia, Latvia and Montenegro. In Bulgaria in some urban WWTPs sludge is treated by red Californian worm (vermiculture). The price for 40 L biofertilizer is 9 €. Composted product from sewage sludge for production of biofertilizer or bio-humus is known in Hungary as well. In Poland phosphorus recovery from sludge combustion is practiced.
- **Heat recovery** for buildings is mentioned by Latvia. In Estonia at least one WWTP (in Haapsalu) is using the heat from wastewater for their offices, decreasing 50% of earlier heating costs.

7.3 Main obstacles for reuse of reclaimed water.

Bulgaria explains that water services are not too expensive that the use of wastewater would come into question. Low water price is also brought out by Estonia, accompanied by health risks and expensive treatment technologies. Latvia adds that due to unpleasant smell and dirt there would be no clients. Moldova, Poland, Slovakia and Slovenia mention lack of relevant legislation and awareness.

According to the literature the most important beneficial and risky **environmental factors** that influence the uptake of wastewater reuse as an alternative water supply option are:

- It reduces the demands of freshwater, but can also reduce the pollution of rivers and groundwater by nutrients (benefit); and,
- It requires strict quality controls needed to minimise the risk of environmental contamination and human health problems (water-borne diseases and skin irritations) (risk).

The most important beneficial and risky **economic factors** that influence the uptake of wastewater reuse as an alternative water supply option are:

- The capital costs are low to medium for most wastewater reuse systems and are recoverable in a very short time (benefit); and,
- It may not be economically feasible because it requires an additional distribution network (risk).

The most important beneficial and risky **social factors** that influence the uptake of wastewater reuse as an alternative water supply option are:

- The technology can be used for a wide set of water uses in agriculture, industry, recreation, and households. It can be applied almost everywhere across Europe allowing centralised (e.g., national water authority) and decentralised (e.g., industrial plant, farmers, regional) approaches (benefit);
- The general public or specific groups may refuse to consume products that are associated with the wastewater reuse – the "yuk" factor (risk).

7.4 Separated wastewater management

Separated wastewater management (grey, black, and yellow water) are very rare and mentioned in the questionnaire replies only by Estonia, Hungary, and Moldova.

Moldova has used yellow wastewater (urine) as fertilizer in 63 villages and greywater has been treated by vermifiltration (EcoSan project). The technology is described in detail in Andreev (2017) similarly in Sweden it is permitted to use diluted yellow wastewater for fertilizing in case it has been kept in closed tank for 6 months. It is believed that all pathogens have died by that period.

Recycling of blackwater is related to composting after mixing with other types of household and kitchen wastes.

The substitution of potable water with recycled greywater for applications that do not require potable water saves directly freshwater and is an effective measure. In particular, it is a reliable source during dry spells.

8 Proposed future activities of the task force

After receiving and joining the data from the questionnaires the task force had a workshop to discuss the results of the questionnaire study and formulate most important activities for improvement of sanitation in the region in terms of wider implementation of sustainable solutions like NBS, increased reuse of water and nutrient and wider implementation of circular economy. The task force will adjust activities according to available budget and will develop project proposals where activities can be implemented on a wider scale.

The outcomes of questionnaires study and the workshop present the basis for elaboration of project proposal. The project idea is structured in two main pillars: (1) wider implementation of NBS, which includes awareness rising campaigns, education activities, development of an online platform (one-stop-shop) and presentation of case studies; and (2) reuse of water and treatment products in terms of circular economy, which includes preparation of a framework for clear legislation, presenting available technologies through case studies, and investigating options for financial incentives .

8.1 Towards wider implementation of nature-based solutions

For wider implementation of NBS and improvement of sustainability of rural wastewater management, **awareness rising** and **education activities** are proposed, i.e., preparing workshops for different stakeholders (municipalities, water utilities, local communities) presenting the wide array of NBS and co-benefits they can offer to local community (Figure 6). More detailed education activities include also technical information and experiences from real examples presenting convincing facts, comparison with other technologies, operation and management costs and manpower needed. These educational activities can be formulated as in person or online courses for capacity building of local operators and technology providers.

The task force also suggests establishing a **one-stop-shop**, i.e., a platform where an end user, operator or decision maker can find all needed information on available technologies, their efficiencies, technical characteristics, co-benefits as well as national regulatory demands and implementation procedures to be taken.

One of the important steps towards wider implementation of NBS is presenting valuable **demonstration projects/case studies** and sharing experiences from end-users. According to this study, there are different nature-based technologies applied all over the region which could be used for such activities. Nevertheless, new pilot projects could be implemented to demonstrate the complete procedure of decision making, implementation and operation. Finally, the impact of NBS on wellbeing of local population needs to be communicated to the local communities to increase the bottom-up trigger.

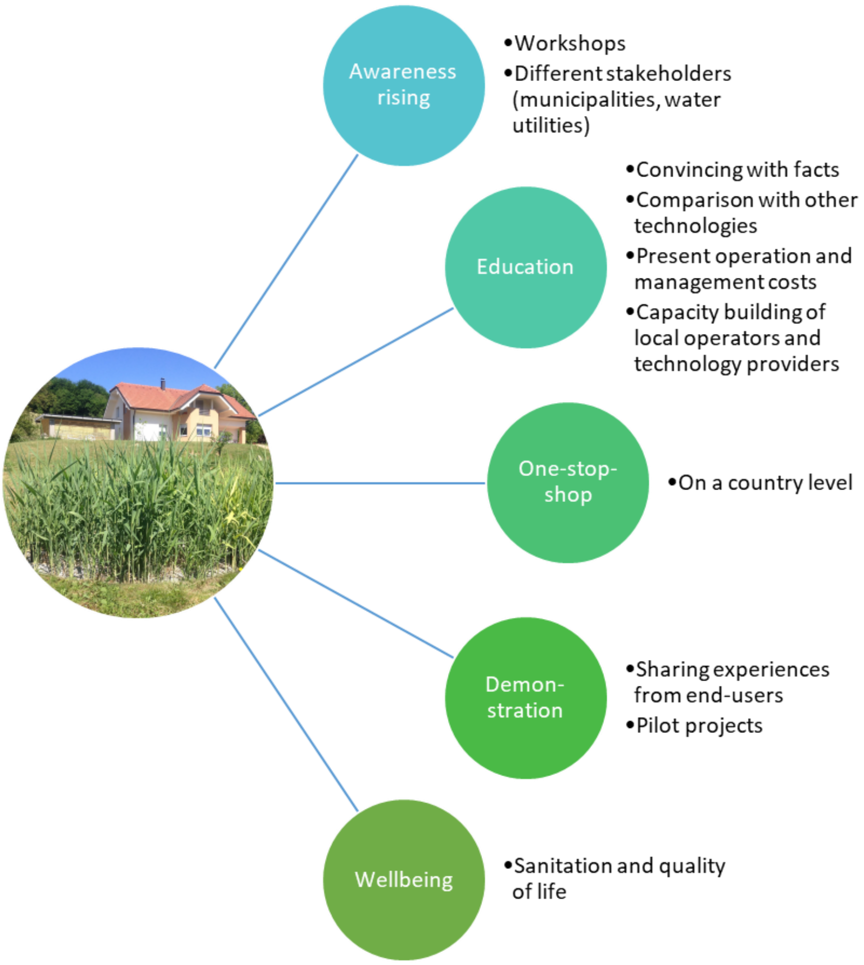

Figure 6: Activities suggested by the task force for wider implementation of nature-based solutions.

8.2 Towards reuse and circular economy

While **clear legislation** is not a main gap for wider implementation of NBS in majority of investigated countries, it presents one of main barriers towards wider implementation of reuse of water and treatment products (Figure 7). To couple wastewater management in rural areas with reuse of water and nutrients first a new EU Regulation on minimum requirements for water reuse for agricultural irrigation needs to be applied and transferred to appropriate national guidelines and local regulations. Additionally, **appropriate technologies** need to be presented and proved for safe reuse of water and other treatment products in terms of risk assessment for environment and human health (transfer of pathogens and contaminants of emerging concern, persistent/non-degradable pollutants etc.).

In addition to clear legislation and proved technologies, for upgrading sanitation systems in small settlements to work as circular economy also **financial incentives** would be needed. Currently the prices are high; however, with increasing prices of tap-water this may change soon. Finally, the reuse of water and treatment products needs to be presented as part of integrated water management to municipalities and regions.

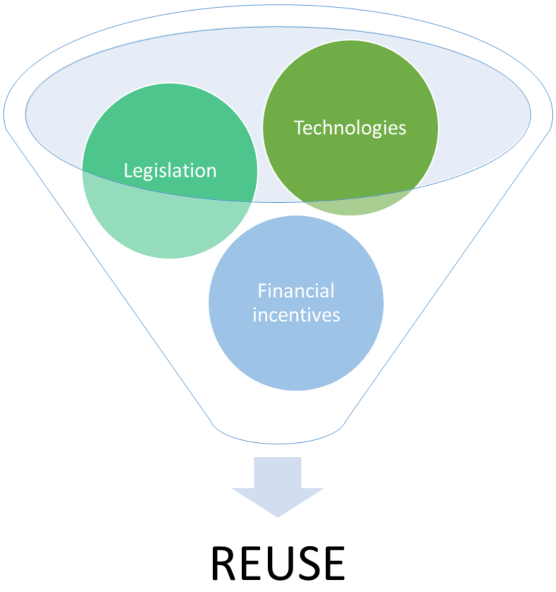

Figure 7: Main challenges towards wider reuse of water and treatment products recognised by the task force.

For wider implementation of NBS and reuse a strong case studies could play a significant role in awareness rising and education of decision makers and end users. As this study shows, there are existing examples of such solutions applied in the region, therefore we suggest selecting best examples and describe them as **case studies** that could also be **uploaded to the GWP Toolbox IWRM action hub**. The case study description should include information on design and construction, type of influent, treatment efficiency, operation and maintenance, costs, co-benefits and lessons learned.

The following activities that will be included in project application could be implemented in smaller scale via available budget through GWP organization already before the project would be granted:

- webinars for water utility representatives,
- showcasing best management practices online (regional scale),
- organizing field trips to selected NBS or water reuse sites (national scale),
- preparing case studies to be uploaded to GWP Toolbox IWRM action hub.

8.3 Project partners

Currently the task force targets at applying on Interreg Danube Transnational Programme call which is expected in early spring 2022. Six institutions of the task force members already showed an interest in collaboration on project proposal preparation, namely from Croatia (Hrvatske vode; authority), Hungary (SENEX, SME), Poland (Gdansk University of Technology), Slovakia (Slovak University of Technology), and Slovenia (University of Ljubljana and LIMNOS, SME). Together with GWP CEE (NGO) there are five countries and seven partners from different sectors; however, water utilities and more local and/or national authorities need to be recruited.

9 Conclusion

This study has shown that there are numerous gaps in managing wastewater in rural areas of Central and Eastern Europe. It is not only that small settlements (home for 30% of the population in the region) are not adequately addressed by both the European Urban Waste Water Treatment Directive (91/271/EEC) and corresponding national legislations but it is also that the data on the number and performance of small wastewater treatment plants and individual systems are frequently missing. Therefore, the evaluation of the actual situation depends strongly on the insight information of the experts that collaborated in the study. Similarly, there is also no national databases or register on existence and performance of nature-based solutions and water reuse. According to the results of the study these systems exists in all countries included in the study which presents a good pool for future dissemination and rising-awareness activities.

Comparing with the results from previous questionnaire study done in 2012, there has been an improvement both in the number of wastewater treatment plants in small settlements and in the diversity of technologies applied; however, the ratio of population connected to wastewater treatment plants in small settlements is still small and significant improvements need to be done in the following years to reduce so-created dispersed pollution of surface and groundwaters. There is also a need to improve discharge limits and monitoring requirements at least in the countries that have either too strict or too vague regulations.

There are still different barriers and challenges towards wider implementation of nature-based solutions; however, compared to the past available engineering knowledge has improved thanks to numerous expert literature and platforms also developed in different projects supported by the European Union. The main challenge is unawareness which needs to be overcome by education activities, demonstration projects, platforms with suitable information etc. In the field of water reuse and circular economy the gaps towards wider implementation are even bigger, there is a need to develop clear legislation and efficient technologies that would consider environmental, economic and social factors of water, nutrients and organic matter reuse which would then need to be supported by financial incentives.

The sustainable sanitation task force in the framework of GWP CEE will further develop activities towards wider implementation of nature-based solutions, reuse of water and treatment products, and circular economy. Different EU supported projects and potential internal GWP funds are needed.

Acknowledgements

We would like to thank Galia Bardarska (GWP Bulgaria), Damir Tomas (Hrvatske vode, Croatia), Gabor Perenyi (SENEX Ltd, Hungary), Maris Ozolis (GWP Latvia), Nadejda Andreev (WiSDOM, Moldova), Snežana Didanović (Ministry of Sustainable Development and Tourism, Montenegro), Corina-Cosmina Boscornega (National Administration Romanian Waters, Romania), Mykhilo Zakharchenko (Phytopotik Ltd., Ukraine) for their contribution to questionnaires and providing data from their countries.

References

Andreev, N. 2017. Lactic acid fermentation of human excreta for agricultural application. CRC Press, London, UK.

Andrews, L., Fedler, C.B. 2021. Advanced wastewater treatment through slow-rate soil infiltration system in Lubbock, Texas, USA. In: Nature-based solutions for wastewater treatment, a series of factsheets and case studies, Cross, K., Tondera, K., Rizzo, A., Andrews, L., Pucher, B., Istenič, D., Karres, N., McDonald, R. (Eds.), IWA Publishing, London.

Bodík, I., Boscornea, C., Istenič, D., Zakharchenko, M. 2012. GWP CEE Regional Study, Natural processes of wastewater treatment – actual status in CEE countries (Questionnaire study). GWP CEE, Bratislava. Available at: https://www.gwp.org/globalassets/global/gwp-cee_files/regional/q-study-report-cee.pdf

Campling, P., De Nocker, L., Schiettecatte, W., Iacovides, A.I., Dworak, T., Kampa, E., Alvarez Arenas, M., Cuevas Pozo, C., Le Mat, o., Mattheiss. V., Kervarec, F. (2008). Assessment of Alternative water supply options. Available at: http://ec.europa.eu/environment/water/quantity/pdf/Summary%20Report_extended%20version.pdf

Cross, K., Tondera, K., Rizzo, A., Andrews, L., Pucher, B., Istenič, D., Karres, N., McDonald, R. (Eds.), 2021. Nature-based solutions for wastewater treatment, a series of factsheets and case studies, IWA Publishing, London

Dotro, G., Langergraber, G., Molle, P., Nivala, J., Puigagut, J., Stein, O., Von Sperling, M. 2017. Treatment wetlands, IWA Publishing, London.

EurEau, 2017, Europe's water in figures, An overview of the European drinking water and waste water sectors, 2017 edition. https://www.eureau.org/resources/publications/1460-eureau-data-report-2017-1/file

Gajewska M., Kopeć Ł, Obarska-Pempkowiak H. (2011). Operation of small wastewater treatment facilities in a scattered settlement, Rocznik Ochrony Środowiska, Tom 13 (Tom 1) 207-225,

Kim, B., Bel, T., Bourdoncle, P., Dimare, J., Troesch, S., Molle, P. 2018. Septage unit treatment by sludge treatment reed beds for easy management and reuse: performance and design considerations. Water Science and Technology, 77: 279-285.

Kompare, B., Atanasova, N., Uršič, M., Drev, D., Vahtar, M. 2008. Tehnično-ekonomska analiza različnih malih in mikro čistilnih naprav za odpadno vodo za razpršeno poselitev. Symposium Vodni dnevi, 15. - 16. 10. 2008, Portorož, Slovenia

Langergraber, G., Dotro, G., Nivala, J., Stein, O., Rizzo, A. 2019. Wetland Technology: Practical information on the design and application of treatment wetlands, IWA Publishing, London.

Masi, F., Brescani, R., Martinuzzi, N., Cigarini, G., Rizzo, A. 2017. Large scale application of French reed beds: municipal wastewater treatment for a 20,000 inhabitant's town in Moldova. Water Science and Technology, 76: 134-146.

Obarska-Pempkowiak H., Gajewska M., Wojciechowska E., Kołecka K. (2015). Sewage gardens - constructed wetlands for single family households. Environment Protection Engineering 41 (4): 71-82.

Rozkošny, M., Kriška, M., Šalek, J., Bodik, I., Istenič, D. 2014. Natural technologies of wastewater treatment, GWP CEE. https://www.gwp.org/globalassets/global/gwp-cee_files/regional/natural-treatment.pdf

Von Sperling, M. 2007. Waste stabilization ponds, IWA Publishing, London

Wintgens,T., Bixio, D., Thoeye, C., Jeffrey, P., Hochstrat, R. and Melin, T. (undated) Reclamation and reuse of municipal wastewater in Europe – current status and future perspectives analysed by AQUAREC research project. Available at: http://www.iwrm-net.eu/sites/default/files/Aquarec_Policy%20Brief_final_A4.pdf

Withers, P.J.A., Jordan, P., May, L., Jarvie, H.P., Deal, N.E. 2014. Do septic tank system pose a hidden threat to water quality? Frontiers in ecology and the environment, 12:123-130.