ApaSan Proiectul Elveţiei de Apă şi Sanitaţie în Moldova

Introduction of Constructed Wetland Technology for the Treatment of Wastewater in Rural Areas of Moldova

A Review of the Experience with 6 Pilot Wastewater Treatment Plants

March 2019

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

AUSTRIAN DEVELOPMENT COOPERATION

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Cover pictures: (top) constructed wetlands in Iurceni (July 2018), (bottom left) secondary stage horizontal subsurface flow constructed wetlands in Rusca (June 2018) and (bottom right) French system constructed wetlands in Iurceni (September 2010)

Swiss Water and Sanitation Project in Moldova (ApaSan) (2008–2019)

ApaSan received financing from the Swiss Agency for Development and Cooperation (SDC) and co-financing from the Austrian Development Cooperation (ADA). It was being implemented by Skat Consulting Ltd. And the Moldovan Branch of the Skat Foundation.

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1 Introduction

1.1 Purpose of This Document

The Water and Sanitation Project in Moldova (ApaSan) (2008—2019) was funded by the Swiss Agency for Development and Cooperation (SDC) and co-funded by the Austrian Development Cooperation (ADC). It was implemented by Skat Consulting Ltd. (Skat), which opened the Moldovan Branch of the Skat Foundation for the purpose of the project. The aim of the project was to develop and promote sustainable models for water and sanitation services in rural areas of Moldova. As part of these efforts, Skat introduced constructed wetland technology for the treatment of wastewater in Moldova. This document describes the project activities and lessons learned regarding constructed wetland technology.

1.2 Constructed Wetlands

Wetlands have been used for the treatment of wastewater all over the world for hundreds of years. In the 1950s, the properties of wetlands began to be investigated more closely, leading to the creation of various wastewater treatment systems for tertiary, secondary and, later, primary treatment. In several countries (e.g. France), constructed wetlands have become a well-established technology for decentralized wastewater treatment in small settlements.

Constructed wetlands (CWs) are wastewater treatment units that mimic natural wetlands. CW treatment units consist of large gravel and sand filled basins that are planted with wetland vegetation. The basin acts as a filter as wastewater flows through it and a biofilm forms at the gravel's surface and removes organics. The vegetation helps to ensure the permeability of the filter through the root system. This also allows oxygen to be transferred into the water, thereby creating aerobic conditions that allow for the better removal of organics.

Throughout the decades since first being constructed, several kinds of CWs have been developed. The two basic types are horizontal flow systems and vertical flow systems.

In **horizontal subsurface flow CWs**, wastewater flows horizontally through the filter (see Figure 1). This technology requires a large amount of space as well as primary treatment to remove any solids from the waste water, to avoid clogging issues.

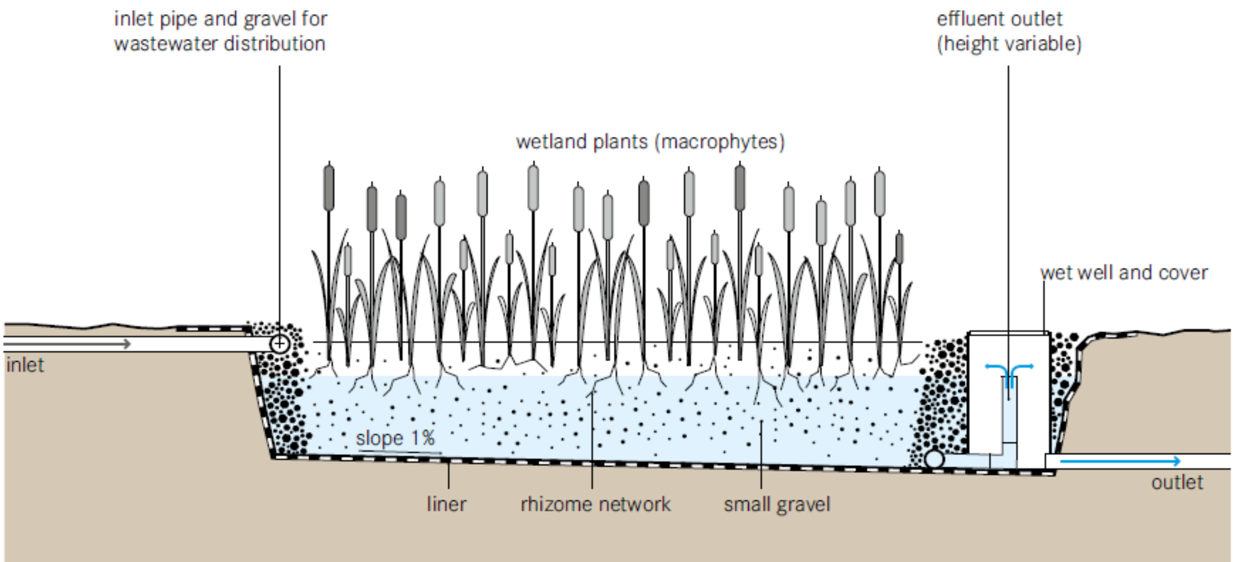


Figure 1: *Horizontal flow constructed wetland (Tilley E., 2014)*

In **vertical flow CWs**, wastewater is distributed vertically and intermittently onto the filter (see Figure 2). Vertical flow CWs has an enhanced oxygen transfer, as percolating water allows for the presence of oxygen into the pores. Due to the enhanced oxygen transfer, space requirement is lower than in horizontal flow constructed wetlands as the aerobic zone is bigger[1]. This technology can be used for either primary or secondary treatment.

Vertical flow beds can be used as a first treatment step (i.e. without any previous treatment): raw wastewater is fed intermittently onto the filter, with the liquid percolating through it and a sludge layer forming on top of it. This sludge remains on the filter, where it is mineralized by microbiological processes that reduces the volume of the sludge. Because wetland plants maintain the permeability of the filter, the sludge does not need to be removed after each cycle as it would in unplanted drying beds. This is often referred to as *French system constructed wetlands*.

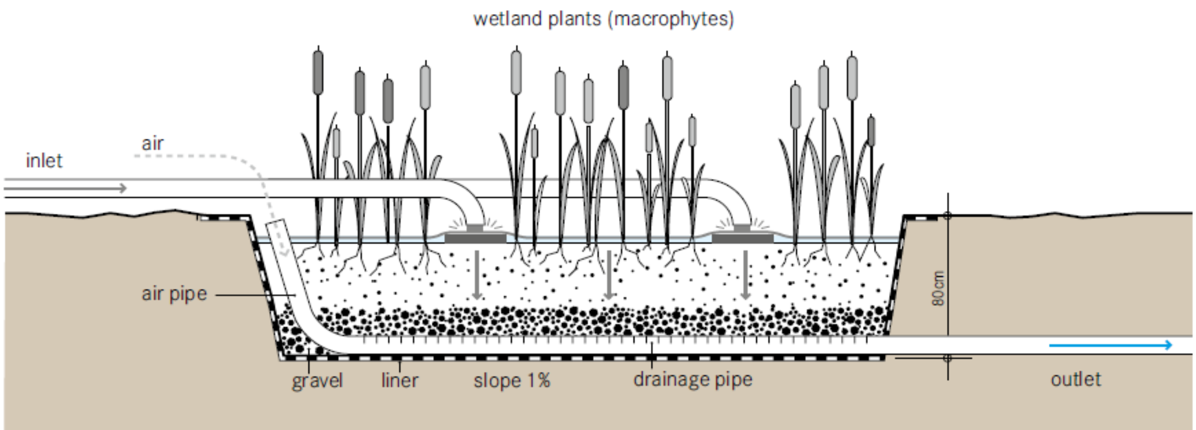


***Figure 2**: Vertical flow constructed wetland, French system (Tilley E., 2014)*

Although CWs have comparatively high land requirements and may produce odors, they have the advantage of low investment and operational costs as well as easy maintenance. As the CW process is natural and robust, CW technology is suitable for decentralized application. If designed and built properly, the treatment efficiency of CWs is excellent, and their operation is simple and cheap.

1.3 Wastewater in Rural Moldova

Access to collective sewer-based systems is rare in rural areas of Moldova. Most people rely on simple pit latrines in their backyard, many of which are unhygienic or need of repair. Only a small proportion of people living in rural areas have in-home flush toilets, with wastewater mostly being disposed of via underground soak pits or septic tanks.

Where sewer systems do exist in rural areas, they are rarely connected to a functioning treatment system. The several hundred sewerage systems and wastewater treatment plants (WWTPs) built in rural areas during the Soviet era are based on the use of activated sludge technology, which has a high energy consumption and requires skilled maintenance. These plants were state-managed enterprises. Following Moldova’s declaration of independence from the Soviet Union in 1991, many of these enterprises were dismantled, and most communities were unable to continue operating water supply, wastewater collection and treatment infrastructures due to the high operational costs and the lack of required management organizations and skilled labor. As a result, most of these WWTPs are no longer in operation (UNECE, 2005).

[1] Bacteria present in the aerobic zones remove organics more efficiently than in anaerobic zones.

1.4 Motivation

Given that one of the aims of ApaSan was to introduce sustainable technologies and operational models for water and sanitation services in rural areas, Skat invested in the introduction of CW technology. As this technology offers efficient treatment capacities with low operational requirements, it was considered as having a high potential for application in rural areas in Moldova. Due to the lack of prior experience with CWs in Moldova, Skat initiated the construction of six pilot and demonstration CWs and assisted in developing the capacities of local engineers, construction companies and operators. Skat also helped to produce documents to guide in the construction and maintenance of additional CWs in other rural areas of the country.

2 Constructed Wetlands Built within ApaSan

2.1 General Approach

In 2008, the first CW was implemented as a pilot WWTP at a kindergarten in Brătuleni (Nisporeni district). This effort was undertaken by SDC as humanitarian aid support. Later that same year, the ApaSan project took over SDC's humanitarian aid program and between 2009 and 2011, six more CW-based WWTPs were implemented in order to further assess the suitability and sustainability of the technology in the Moldovan context.

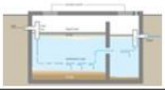
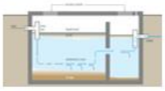
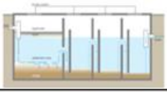
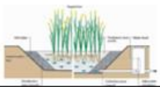
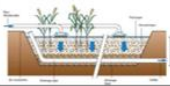
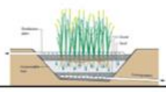
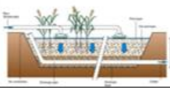
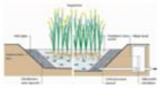
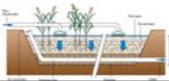
The adopted strategy of the ApaSan project was the implementation of CW-based WWTPs to treat wastewater from both public institutions and private households. While Skat supported the construction of these WWTPs and main sewer lines, private connections to the network had to be done by households themselves. In order to raise the feeling of ownership and show their commitment, local communities had to provide partial funding for these projects. Only once the construction was completed and local operators were trained to appropriately operate and maintain the WWTPs, the plant were donated to local public authorities or beneficiary institutions.

Different configurations of CW-based WWTPs were implemented. This served a two-fold purpose: (1) demonstrating the various options available and (2) helping identify the most efficient and sustainable solutions for rural Moldova.

In a first phase of the project (2009), Skat supported the construction of three WWTPs, each with either a septic tank or an anaerobic baffled reactor as the primary treatment step and a horizontal subsurface flow CW as the secondary treatment step. Three more WWTPs were built in the second phase of the project (2010). These WWTPS were built using French system CWs as the first treatment step and one of three different technologies (vertical flow filters, horizontal flow filters and ponds) as the secondary treatment step. Details regarding the location, set-up and capacity for each of these six WWTPs is presented in Table 1 below. All beds were planted with locally-available common reeds (*Phragmites australis*).

Following the construction and handover of the WTTPs, Skat conducted several monitoring campaigns (2012 and 2014) to assess the treatment efficiency of the plants as well as a sustainability assessment (2018). No specific treatment efficiency analysis was conducted by Skat in 2018 due to the availability of 2017 data on quality of WWTP's effluent from the State Ecological Inspectorate regarding the Cristești, Iurceni and Rusca WWTPs.

Table 1: WWTPs implemented by ApaSan

Location	Primary treatment	Secondary treatment	Plant capacity (m³/ day)
Sărata-Galbenă	 Septic tank	 HF	5
Negrea	 Septic tank	 HF	5
Rusca	 ABR	 HF	30
Drăguşenii Noi	 FS	 VF	50
Iurceni	 FS	 HF	50
Cristeşti	 FS	Polishing pond 	50
FS: French System CW, VF: Vertical Flow CW, HF: Horizontal Subsurface Flow CW, ABR: Anaerobic Baffled Reactor			

2.2 WWTP's Design

The skills necessary for designing and building CWs were lacking in Moldova at the time of the WWTPs' construction. Therefore, members of the ApaSan team and engineers from a local design company were trained in France and Switzerland. This served to develop the local capacities necessary to ensure the long-term viability of CWs as a realistic option for rural communities in Moldova.

At that time, CW designs were derived from the French *Epuration des eaux usées domestiques par filtres plantés de macrophytes: recommandations techniques pour la conception et réalisation* (Agence de L'Eau R.M.C, 2005) and *Cadre guide pour un cahier des clauses techniques particulières : filtre plantés de roseaux* (Ministère de l'agriculture et de la pêche, 2007) guidelines. Additional support in this regard was provide by Mr. Pierre Henri Dodane, an international expert in CWs.

In 2016, with support from the ApaSan project, the government of Moldova developed the *CP G03.01:2016: Sisteme de epurare biologică naturală a apelor uzate comunale în filtre plantate cu macrofite (fitofiltre)* (Ministerul Dezvoltării Regionale şi Construcțiilor al Republicii Moldova, 2016), a code of practice for the implementation of CWs that defines the framework for the construction of new CWs in Moldova.

2.3 Sărata-Galbenă

The WWTP in Sărata-Galbenă (Hîncești district) was built in 2009 and treats the wastewater from a retirement home (50 residents and 6 permanent staff members). The WWTP consists of a septic tank as the primary treatment step and one horizontal subsurface flow CW as the secondary treatment step. Wastewater originates from the kitchen, flush toilets inside the building and cleaning processes. The institution has also preserved the old outside pit toilets, which are used in times of water shortages.

According to the monitoring conducted in 2012, the WWTP was near its full hydraulic capacity, although its organic load was far below plant capacity. Removal efficiencies for total suspended solids (TSS), chemical oxygen demand (COD) and biological oxygen demand (BOD_5) satisfied legal requirements, and outlet concentration of the same elements almost satisfied legal requirements (see Annex 1). Results from the monitoring conducted in 2014 were less satisfactory in terms of satisfying legal requirements, with concentrations at outlet above the norms for wastewater disposal (see Annex 1). This WWTP was not monitored by the State Ecological Inspectorate in 2017.

In 2018, apart from some sludge accumulation at the constructed wetland inlet, the plant was working normally and is expected to be sustainable in the long term. The WWTP's operator did not report any financial issues, and funds are available to cover eventual repair expenses.

2.4 Negrea

The WWTP in Negrea (Hîncești district) was built in 2009 and consists of a septic tank as the primary treatment step and one horizontal subsurface flow CW as the secondary treatment step.

This WWTP was initially linked to the village's kindergarten (82 children) and school kitchen (serving 235 students). The monitoring conducted in 2012 revealed that the hydraulic capacity of the WWTP was exceeded; however, that the plant was still effectively treating water due to the low organic load, with outlet concentrations and removal efficiencies for TSS, COD and BOD_5 mostly satisfying legal requirements (see Annex 1). Later in 2012, the school was equipped with flush toilets, increasing the volume of wastewater and the organic load on the WWTP. The monitoring conducted in 2014 revealed a lower removal efficiency, with effluent concentrations higher than those allowed by legislation (see Annex 1). Since 2014, 17 households and the village's medical center have linked to the sewer system. This WWTP was not monitored by the State Ecological Inspectorate in 2017.

The septic tank has only been emptied once since 2009 and the sludge was buried in a field. The operator does not face any maintenance issues, except a too low wastewater production in the summer months due to the kindergarten and school being closed. This, however, does not threaten the sustainability of the WWTP.

2.5 Rusca

Penitenciarul Numarul 7 (Penitentiary Number 7), located in Rusca (Hîncești district), was selected for a pilot WWTP in relation to an SCD program that supports rehabilitation of social institutions. In 2007, an anaerobic baffled reactor (ABR) was established as the first treatment step by SDC. In 2010, Skat supervised the addition of two times two horizontal subsurface flow CWs in series as the secondary treatment step. As of 2018, this WWTP treats water for 400 prisoners and staff as well as 43 households from the nearby village.

During the monitoring campaign in 2012, clogging problems were observed on the filter bed, resulting in the presence of supernatant wastewater. The problem was due to both the hydraulic overload of the ABR, mainly due to failure to remove sludge from the ABR at a sufficient frequency. This resulted in the carry-over of solids into the filter beds.

In order to improve the treatment efficiency and resolve the issue of sludge carry over, several improvement measures were implemented:

- A grid chamber prior the ABR was installed to remove coarse solids before entering the ABR.
- A clarifier (in the form of a sand filter) was built after the ABR as an additional measure to reduce sludge carry-over from the ABR.

- To allow more frequent and easier desludging of the ABR, a sludge drying bed was installed next to the ABR, and a sludge pump was purchased. This also helps reduce external operational expenses (i.e. vacuum trucks).

Despite these efforts, excess sludge was still found to reach and clog the clarifier due to low hydraulic retention time inside the ABR.

The monitoring campaign in 2014 did not indicate any improvement in treatment efficiency since 2012 (see Annex 1). Additionally, the clogging problem was found to still be present, as supernatant wastewater did not disappear. By 2018, the clogging problem had become such an issue that:

- The clarifier was modified into a septic tank, as clogging was happening too often. The operator removed the gravel and replaced the outlet pipe with a 'T' pipe. Too much sludge is still reaching the CWs, causing bed clogging.
- The water distribution system in the first CW of each line has been modified to allow an even distribution of wastewater. The distribution pipe has been taken off, and the operator made a "small dam" out of gravel (right image of Figure 3) to distribute water across the entire length of the wetland. Sludge, however, still accumulates, requiring monthly removal.
- The water level is no longer regulated to avoid an overflow of the wetland. Instead, the level is always set to its minimum, thereby reducing hydraulic retention time.

Figure 3: *(left) Rusca CW in 2012 showing supernatant wastewater, with the distribution pipe still in place. (right) Rusca CW in 2018 with presence of supernatant wastewater, the distribution pipe (white pipe) having been removed and a small dam created to ensure the distribution of water across the entire length of the wetland*

The person in charge with operation meets problem dealing alone with big maintenance works, such as reed cutting, reason why prisoners are sometimes used as labor, thus keeping operational costs low. In the event of system failure, the penitentiary can appeal to state authorities for funds to make necessary repairs.

This WWTP was monitored by the State Ecological Inspectorate in 2017, with data being published in the 28th edition of the *Revista Apelor* journal[2]. The effluent quality was shown to be worse than in Cristești and Iurceni, although it was still better than the average for all Moldovan WWTPs (see Annex 1).

[2] Publicaţie trimestrială dedicată protecţiei şi utilizării raţionale a resurselor de apă "Revista Apelor" nr.28, Chişinau, December 2017 (ISSN 1857-2774)

Filter bed clogging appears to be an increasing problem for the Rusca WWTP, and the filter material may have to be replaced in the near future. The bad state of the WWTP appears to have a negative impact on treatment capacity. The 2017 monitoring conducted by the State Ecological Inspectorate showed that COD and BOD_5 concentration in the effluent had drastically increased since 2014. This WWTP can be expected to be sustainable in the medium term only if the filter bed problem is resolved.

2.6 Drăgușeni Noi

The WWTP in Drăgușeni Noi (Hîncești district) was constructed in 2011 and consists of three parallel French system CWs (left side of Figure 4) that serve as the primary treatment step and two parallel vertical flow CWs (right side of Figure 4) that serve as the secondary treatment step. Initially, the village's kindergarten and school (approximately 300 children) and approximately 85 households were connected to the WWTP. As of 2018, additional households (exact number not available) had connected themselves to the system. According to the operator, the maximum hydraulic capacity is expected to be reached in the near future. An additional wastewater treatment plant and sewer line is being planned by the municipality to treat wastewater from other areas of the village.

The operation of the WWTP has encountered a number of problems over the years. Shortly after construction, an electric generator, needed to supply the pump with electricity, was stolen. In 2015, a severe drought and low loading killed the reeds in half of the wetlands, as shown in Figure 5.

Figure 4: *(left) French System CW (primary treatment) in Drăgușeni Noi and (right) vertical flow CW (secondary treatment) in Drăgușeni Noi*

The monitoring conducted in 2014 showed an average removal efficiency above 65% for COD, BOD_5 and Ammonium (NH_4^+); however, discharge norms were not met (see Annex 1).

In 2018, the plant was still in operation, although several issues need to be addressed due to the overall lack of proper maintenance. These issues include the low coverage of reeds in some of the CW units, a siphon being broken and sludge accumulation in the storage tank. Additionally, the operator has reported instances of vandalism and the presence of solid waste in manholes (see Annex 2).

This WWTP was not monitored by the State Ecological Inspectorate in 2017.

2.7 Iurceni

The WWTP in Iurceni (Nisporeni district) was constructed in 2011 and designed to treat water from the entire village. It consists of three parallel French system CWs that serve as the primary treatment step and two parallel subsurface flow CWs that serve as the secondary treatment step. Initially, only main sewer lines were built, leaving individual connection works to households themselves. These connections, however, occurred only to a low extent, resulting in wastewater flow to the WWTP being low. In order to increase the wastewater flow, Skat supported the conversion of village's school toilets to flush toilets in 2012. In 2018, the municipality, without the involvement of the ApaSan project, began construction works to develop the sewer network for the entire village. As a result, the connection rate increased drastically, and the operator is now worried that plant capacity will soon be exceeded. In July 2018, the plant treated water for 300 people in institutions and approximately 130 households.

The monitoring campaign in 2014 monitoring campaign revealed that the Iurceni WWTP did not satisfy discharge norms (see Annex 1), although the average removal efficiency was above 55% for COD, BOD_5 and NH_4^+.

This WWTP was monitored by the State Ecological Inspectorate in 2017, with data highlighting TSS and BOD_5 effluent concentration levels close to those required by the legislation. This indicates that increased wastewater input has not made this WWTP less efficient.

As of 2018, the Iurceni WWTP appeared to work at a satisfactory level. Apart from a pump problem (which was undergoing repairs at the time of the visit), no major problems were detected. During the process of extending the sewer lines to cover the entire village, a low monthly service fee (MDL 20 per household per month) was requested from connected households, thus allocated funds for the WWTP's maintenance were too low. However, once the extension works will be completed, the operator plans to request higher monthly service fee, on a payer polluter basis, in order to ensure the financial sustainability.

2.8 Cristești

The WWTP in Cristești (Nisporeni district) was constructed in 2011 to serve part of the village and consists of three parallel French system CWs that serves as the primary treatment step and a polishing pond that serves as the secondary implementation step. In 2012, flush toilets were installed in the local school, resulting in an increased amount of wastewater. As of 2018, 24 households and local institutions (220 people) were connected to the sewer system. Although discharge is very low (which is a potential risk to the health of reed growth), the operator has managed to maintain healthy vegetation in all treatment units thus far by running the WWTP in batch mode.

The monitoring campaign in 2014 revealed that the Cristești WWTP did not satisfy discharge norms (see Annex 1) for disposal, although the average removal efficiency is above 70% for COD, BOD_5 and NH_4^+. The data from 2017 shows an increase of the BOD_5 concentration at the effluent since 2014, and stable COD concentration.

As of 2018, the WWTP appears to be operating well. They only main issues are: (1) too much rainwater entering the sewers (the current pumps are too weak to sustain discharge during heavy rains) and (2) broken manhole covers allowing solids to entering the system (see Annex 2). Additionally, fees collected from sewer users are reportedly not sufficient to cover operational expenses (extra costs are covered with funds from other activity sectors).

2.9 Performance Summary

A synthetized overview of the treatment efficiency and WWTP sustainability data collected since 2012 is presented in Table 2 below. With the exception of in Rusca, the treatment efficiency of the WWTPs appears to be mostly satisfying, and the WWTPs are treating water better than the national average (see Annex 1). As such, it can be reasonably-assumed that CWs represent a suitable technology to improve wastewater treatment in rural Moldova. The WWTPs do, however, appear to be less efficient over time, although this is likely due to an increased volume of wastewater being treated and not a degradation of the treatment systems themselves.

Table 2: Summary of treatment efficiencies for the six ApaSan CWs

	2012 monitoring campaign (ApaSan)	2014 monitoring campaign (ApaSan)	Available 2017 data (State Ecological Inspectorate)	2018 plant condition assessment (ApaSan)	2018 financial sustainability assessment (ApaSan)
Sărata-Galbenă	Some parameters meet norms	Some parameters close to norms	-	Good	Good
Negrea	Some parameters meet norms	Some parameters close to norms	-	Good	Good
Rusca	Some parameters close to norms	Most parameters worse than norms	Most parameters worse than norms	Bad	Fragile
Drăgușeni Noi	-	Some parameters meet norms	-	Bad	Bad
Iurceni	-	Some parameters meet norms	Some parameters close to norms	Good	Fragile
Cristești	-	Some parameters meet norms	Some parameters close to norms	Good	Fragile

Two of the six WWTPs (Rusca and Drăgușeni Noi) are facing severe issues as they are in bad condition and lack available local financing sources/ willingness for necessary repairs/improvements.

3 Lessons Learned

Although the overall results have proven to be mixed (with several WWTPs struggling to function efficiently), CW-based WWTPs are, nevertheless, a viable technology for wastewater treatment in rural areas of Moldova and have a strong potential in the future as well. The several challenges Skat observed are detailed in the following subsections of this document and may serve to improve future design, implementation and operational efforts.

3.1 Low Need for Sewer Systems and Wastewater Treatment in Rural Areas

A main lesson learnt in Skat's experience with constructed wetlands and in several investigations conducted by Skat, was that the actual production of wastewater in Moldovan villages remains low (less than 30 liters per person per day on average), even when a drinking piped water supply is available. Moreover, most of this wastewater can be (and is) disposed of in private households' gardens, meaning rural households in Moldova only discharge very small amounts of wastewater into sewer systems[3]. Therefore, the actual need for sewer connections in Moldovan villages is low. This explains one of the main challenges met in Skat's strive to establish constructed wetlands for rural wastewater treatment: much less households than expected were ready to invest into a connection to the sewer system.

This finding is often contradicted by the high priority given to sewer infrastructure projects by mayors, local council members and other important village figures. This contradiction may be partially-explained by political considerations and the personal priorities of decision-makers outweighing actual need.

[3] This may be different for residential multi-story buildings, larger social institutions (larger schools, hospitals, prisons, etc.) and economic enterprises. Such buildings can produce considerable amounts of wastewater that require sewer systems for effective waste management.

As long as the need for wastewater disposal in sewer systems is low in rural areas, the willingness of the population to invest into sewer connections and pay wastewater tariffs will also remain low, and it will be difficult to cover the investment and operational costs of a sewer network and wastewater treatment system. This situation may very well change as Moldovan villages develop economically. For the time being however, there appears to be little need for municipal-level wastewater collection and treatment in most Moldovan villages, and the CWs constructed for this project represent a good solution for a problem that is only beginning to emerge.

3.2 Estimation of Wastewater Production and Quality

A major challenge for the proper design of CW-based WWTPs is the lack of data regarding the volume of wastewater produced. Whereas in Western European countries, good data allows for the precise estimation of wastewater production, this is not possible in the Moldovan context due to a number of reasons:

- Water supply systems do not work properly all year long, mostlyv due to droughts in the summer months (see Figure 5) and pipes freezing in the winter months.
- Water consumption per household in rural Moldova remains low, as does their wastewater production.
- Only a few beneficiaries tend to connect to sewer system without external incentives.
- Wastewater producing infrastructures (flush toilets, bathrooms, washing machines, kitchen sinks, etc.) are not systematically present in rural households.
- Wastewater disposal habits vary greatly, with many rural inhabitants already having developed a solution for greywater disposal (reuse in gardens, disposal in yards or fields, etc.), which does not encourage them to invest for the few remaining wastewater.

Organic pollution loads and concentrations in wastewater are also difficult to estimate due to the small number of connections and the small level of wastewater production per household in rural Moldova, with wastewater pollutant loads varying over time and not corresponding to either European standards or the Moldovan standards measured during the Soviet era. Moreover, drag reduction in the sewers (due to lower flow rates) results in relatively long retention times in sewers and leads to partial degradation of pollutant loads prior to them reaching a WWTP. As such, the actual organic load estimated to be input into a WWTP is difficult to determine. It should be noted, however, that such estimation issues around wastewater quality and drag are expected to lessen with increased wastewater production.

Figure 5: *French system CW in Drăgușeni Noi, with 2 of the 3 compartments without reeds*

Standard per capita values for wastewater production and pollution loads (as given in terms of Moldovan standards or in terms of Western European standards) tend to be much higher than reality for most Moldovan villages. Designing WWTPs based on these values will, therefore, result in over-sized plants, an inefficient use of investment funds and operational difficulties.

A careful analysis and realistic projection of wastewater quantities and pollution loads are necessary in each village. Equally important is an open dialogue with design engineers and the authorities responsible for approving the designs in order to justify and explain any needed deviation from unsuitable norms and standards as well as the appropriateness of chosen designs to each village's context.

3.3 Operation Activities and Maintenance

3.3.1 Organization of operation and maintenance

The operational and maintenance activities of WWTPs (and the associated costs) were covered by each WWTP in a different way. Usually, operational and preventive maintenance[4] activities are affordable and are conducted. In some cases, these activities are organized by the owner of the WWTP using local volunteer and/or unemployed labor. However, as the qualifications and motivation of local operators are often low (likely due to low-income), some activities are neglected, accelerating the deterioration of the WWTP.

Corrective maintenance is more problematic as local operators usually have little spare financing available, especially the solve system failures. Thus, larger-scale repairs are typically not affordable for them and require external funding sources to be completed. This situation, however, could change with new household connections and/or increased fee amounts. It should be noted that some WWTPs are operated by a municipal enterprise instead of a local water consumer association. Municipal entreprises appear to have fewer financial problems in these events as they can pull the necessary funds from other activities.

As assessed by both staff of the ApaSan project and local operators, long-term sustainability is currently ensured in 1/6 of the WWTPs and short-term sustainability is not ensured in 1/6 of the WWTPs (Annex 2). This illustrate the difficulty of establishing a sustainable WWTP in the rural Moldovan context.

3.3.2 WWTP Maintenance Plan

A list of operational and maintenance tasks specific for each stage and technology implemented within the diverse WWTP supported by the framework of ApaSan project has been developed to increase the likelihood of successful CW-based WWTP projects (see Annex 3).

3.3.3 Common Maintenance Problems and Solutions

The present chapter will focus on some of the most relevant practical problems encountered in the Moldovan context and their related solutions.

[4] A difference has to be done between preventive and corrective maintenance. Preventive maintenance consists in all activities aimed at keeping the infrastructure in good condition, whereas corrective maintenance consists of replacing or repairing infrastructure, sometimes due to the lack of preventive maintenance.

Figure 6: *Perforated bucket for coarse particle removal*

- *Coarse Particle Removal from Pumping Stations*

A simple screening device can be made to help keep coarse particles from entering pumping stations and damage pumps. This device, a perforated bucket attached to a rope (see Figure 6), is placed below the wastewater inlet and collects all heavy objects reaching the station, is emptied daily. This simple system is effective and much cheaper than the construction of a screening chamber.

- *Distribution System and Filter Bed Clogging*

Clogging of the wastewater distribution system happens often if proper maintenance activities are not completed. This, in turn, leads to an uneven distribution of the water on the filter bed, which can cause clogging in some area of the filter due to organics overload and/or create dry areas. Thus, it is important to frequently clean the distribution system and take daily action to ensure the even distribution of wastewater across the filter. Twice-daily checks for clogs (performed simply by inserting a stick into distribution pipe holes that need to remain unclogged) is recommended. In the event of larger clogging issues, it is recommended to use a pipe-cleaning brush or close some wetlands until the biomass has been completely cleared.

- *Sludge Removal*

For WWTPs that use a septic tank or an anaerobic baffled reactor (ABR) as the primary treatment step, sludge management is an additional challenge. Functioning systems for sludge management are rare in Moldova (e.g. sludge treatment is almost nonexistent). Because of this, services for tank emptying and sludge transport are often expensive, leading to low emptying frequencies. In Rusca, an additional sludge drying bed was built, and a sludge pump was purchased in order to decrease costs and increase emptying frequency at the primary treatment facility. Such investments may be cost-effective for a medium-scale treatment plant, as it will need frequent emptying of the accumulated sludge, but is likely to be too expensive for small-scale treatment plant such as the ones in Sărata-Galbenă and Negrea, which does not produce much sludge

- *Winter and Freezing*

During winter months, temperatures in Moldova typically fall down to -20°C. Specific measures have to be taken to avoid pipes and filter beds freezing, as this could damage the structure or simply block

Figure 7: *(left) cut reeds forming an insulation blanket on the top of the filter bed and (right) a partially frozen pipe*

the flow. The key measures taken during design and construction were aimed at avoiding water stagnation in pipes (i.e. ensuring a sufficient slope and that valves and chambers do not allow for water to stagnate). If water is kept flowing, it rarely freezes, even in very low temperatures. To prevent freezing in the constructed wetland filter beds, the water level inside the filter bed should be kept at a minimum level, and reeds should be cut and left on the top of the filter bed to create an insulation blanket (see Figure 7). Some reeds can also be laid around inlet and outlet pipes for the same purpose.

- *Sewer Network and Manhole Conditions*

The proper maintenance of sewer networks is not always ensured in Moldova. Moreover, manholes are frequently in very bad shape. This can lead to gravel or sand entering into the system, which may disturb normal operation of the plant.

While less is known about the condition of sewer networks in the country, any leakage can cause groundwater contamination.

4 Comparison of the Different Treatment Process Options

Taking into account the lessons learned from the different pilot WWTPs installed through the ApaSan project, disadvantages and advantages of each technology set-up can be pointed out.

4.1 Treatment Efficiency

Although the monitoring campaign in 2012 indicated satisfactory results for the WWTPs located in Sărata-Galbenă, Negrea and Rusca (with treatment efficiencies and outlet concentrations of TSS, COD and BOD_5 nearing norms (see Annex 1)), the outcomes of the monitoring campaign in 2014 showed slightly decreased treatment efficiencies, as shown in Figure 8. The data collected in 2017 indicates stable effluent quality in Iurceni and a deteriorated effluent quality in Rusca and Cristeşti.

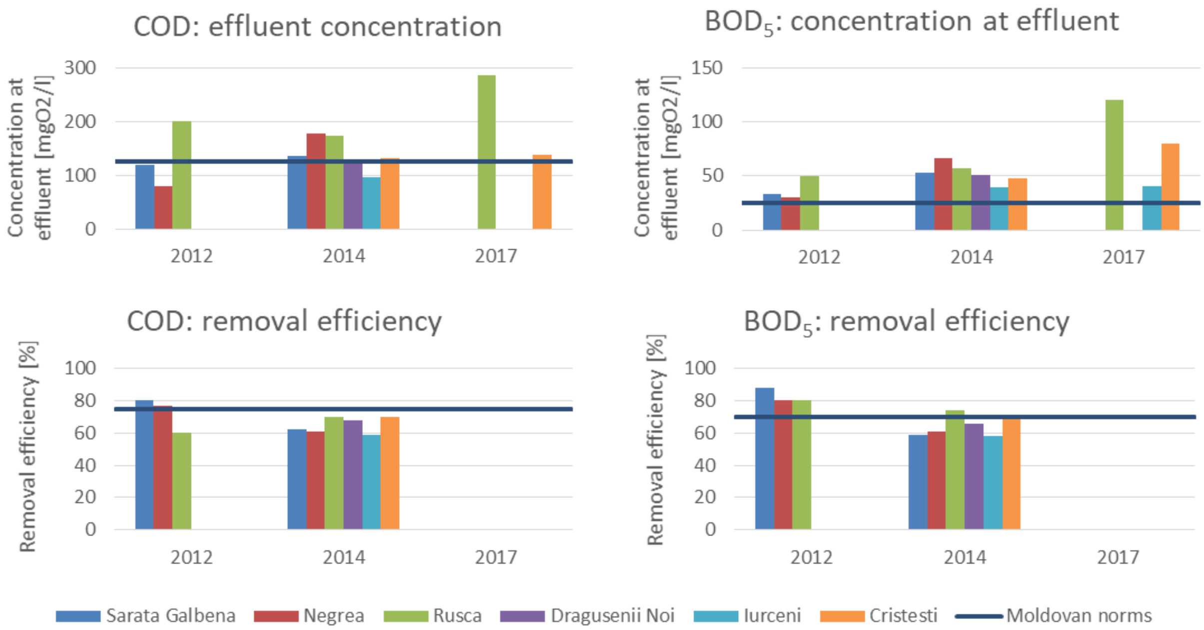


Figure 8: *Concentrations at effluent and removal efficiencies for COD and BOD_5 for all project WWTPs, with comparisons to Moldovan norms. Detailed data available in Annex 1*

Given the above, it is logical to conclude that, with the exception of Rusca WWTP that faces operational issues (see chapter 2.5), the results from each WWTP are relatively consistent and do not significantly diverge from Moldovan norms.

In relation to COD and BOD_5, no plant has a significantly better removal efficiency than any other (see Figure 8). Thus, it can be concluded that all tested technology set-ups are adequate regarding treatment efficiency.

4.2 Primary Treatment

Although all set-ups demonstrated a similar treatment efficiency, there are some notable advantages and disadvantages for each of the two primary treatment steps, as outlined in Table 3 below.

French system CWs appear to be better-suited for those areas requiring higher treatment capacity levels, especially given the relatively high cost of sludge removal in Moldova.

Table 3: Main advantages and disadvantages of the two primary treatment steps

Primary treatment set-up	Main advantages	Main disadvantages
French system CW[5]	• No need for sludge management	• Problems with pumps frequently being out-of-order or broken, exacerbated by a funding issues to resolve this among WWTP operators (likely a non-issue with the use of gravitational flows) • Requires expert input to design and build in order for it work properly
Septic tank/anaerobic baffled reactor	• Low relative set-up cost (as compared to the French system CW)	• Need for frequent desludging activities (especially at larger scales of operation), with sludge accumulation on filter beds causing clogging issues (hindering plant sustainability) if not operated properly

4.3 Secondary Treatment

All set-ups appear to be suitable for secondary treatment steps as most of the problems observed in this step were caused by issues in the operation and maintenance of the primary treatment step.

[5] It should be noted that that French system CWs were only for CWs with a larger treatment capacity.

5 Conclusion

Overall, the CW-based WWTPs constructed within the framework of ApaSan project are treating wastewater adequately. Even if not always fully-reaching legal requirements, the treatment efficiencies of the ApaSan-built WWTPs are above that of other decentralized wastewater treatment solutions present in rural Moldova.

That being said, there are still a number of problems local operators face in ensuring the proper operation and maintenance of their systems, especially those related to a lack of adequate funding and necessary skills. Moreover, mitigation measures applied to resolve these problems are not always optimal and may, in fact, cause a decrease in efficiency.

In general, all the applied set-ups work reasonably-well. Based on Skat’s experience in Moldova, it can be argued that the use of French system vertical flow CWs represent the most appropriate solution for larger facilities as the other systems (i.e. septic tanks and anaerobic baffled reactors) require proper sludge management, which is still a complicated and expensive issue in the country and improper sludge removal can lead to clogging in secondary treatment steps.

Considering that the implemented WWTPs were pilot efforts, the results are overall positive, and CW technology appears to be an adequate sanitation technology for use in rural Moldova.

However, the experience also shows a range of challenges to rural wastewater treatment in general. Real demand for wastewater collection and treatment is generally low, and onsite wastewater disposal/ the use of dry toilets is often more suitable than collective solutions (at least until rural areas of Moldova become more economically-developed). As balancing the maintenance, efficiency and cost recovery of WWTPs is a difficult proposition at the moment for rural Moldovan areas (as is long-term sustainability), it is recommended that any such future project be developed according to step-wise development and business plan that ensures adequate connection rates and budgeting to allow for smooth operations.

References

Agence de L'Eau R.M.C. (2005). *Epuration des eaux usées domestiques par filtres plantés e macrophytes: recommandations techniques pour la conception et réalisation.*

Ali Hannouche, C. G. (2011). *Relationship between turbidity and total suspended concentration within a combined sewer sytsems.* Water Science and Technology, IWA Publishing.

Bin Omar, A. F., & Bin MatJafri, M. Z. (2009). *Turbidimeter Design and Analysis: A Review on Optical Fiber.* Penang Malayisa.

Ministère de l'agriculture et de la pêche. (2007). *Cadre guide pour un cahier des clauses techniques particulières : filtre plantés de roseaux.*

Ministerul Dezvoltării Regionale şi Construcțiilor al Republicii Moldova. (2016). *CP G03.01:2016.*

Tilley E., U. L. (2014). *Compendium of sanitation systems and technologies. 2nd revised edition.* Dübendorf: Swiss Federal Institute of Aquatic Science and Technology (Eawag).

UNECE. (2005). *2nd Environmental Performance Review of Republic of Moldova.* Geneva: United Nations Economic Commission for Europe UNECE.

Annexes

Annex 1: Summaries of Available Data on Effluent Quality and Removal Efficiencies for Implemented WWTPs

Data from the 2012 and 2014 monitoring campaigns by the ApaSan project as well as from the State Ecological Inspectorate's 2017 monitoring campaign has been synthesized and presented and compared with Moldovan legal obligations[6] and existing standards for the disposal and treatment of wastewater.

Table 4: Effluent concentration for project WWTPs, as compared with legal requirements

Effluent concentration	Year	TSS [mg/L]	COD [mgO2/L]	BOD_5 [mgO2/L]	NH_4^+ [mgN/L]
Norm[6]	2013	35	125	25	2
Average for rural Moldova	2017[8]	89	719	173	90
Sărata-Galbenă	2012	20	120	33	-
	2014	944[7]	136	53	154
	2017[8]	-	-	-	-
Negrea	2012	40	80	30	-
	2014	1,257[7]	177	66	79
	2017[8]	-	-	-	-
Rusca	2012	40	200	50	-
	2014	1,326[7]	173	57	47
	2017[8]	49	285	120	60
Drăgușeni Noi	2012	-	-	NA	NA
	2014	862[7]	128	51	11
	2017[8]	-	-	-	-
Iurceni	2012	-	-	-	-
	2014	1,066[7]	96	39	1
	2017[8]	42	-	40	100
Cristești	2012	-	-	-	-
	2014	1,092[7]	131	48	24
	2017[8]	63	138	80	46

Color code: green = within the norm; yellow = exceeds the norm, but below the average of for rural treatment plants in Moldova; red = equals or exceeds the average of for rural treatment plants in Moldova.

[6] According to Government Decision No. 950 (dated November 25, 2013) on the approval of the *Regulation on the Requirements for the Collection, Treatment and Wastewater Discharge into Sewer Systems and/or into Bodies of Water for Urban and Rural Settlements*, Republic of Moldova. Either the required effluent concentrations or removal efficiencies should be fulfilled.

[7] Not plausible figures given the measures of the 2012 monitoring campaign, the turbidity test done in 2018, and the data from the State Ecological Inspectorate in 2017 (all turbidity assessed in 2018 was below 100 NTU, thus the concentration found in 2014 could not be correct when considering the relation between turbidity and TSS in wastewater) (Bin Omar & Bin MatJafri, 2009) (Ali Hannouche, 2011). Reason for such high TSS values may be (1) a punctual event or (2) an error in the sample analysis procedure.

[8] Data published in the 28th edition of the *Revista Apelor* journal (December 2017), compiling the results of the 2017 monitoring done by the Moldovan State Ecological Inspectorate.

Table 5: Removal efficiencies for the project WWTPs, as compared with legal requirement

Removal efficiency	Year	TSS [%]	COD [%]	BOD_5 [%]	NH_4^+ [%]
Legislation[6]	2013	90	75	70	-
Sărata-Galbenă	2012	95	80	88	-
	2014	15[7]	62	59	61
	2017[8]	-	-	-	-
Negrea	2012	87	77	80	-
	2014	17[7]	61	61	29
	2017[8]	-	-	-	-
Rusca	2012	87	60	80	-
	2014	14[7]	70	74	28
	2017[8]	-	-	-	-
Drăgușeni Noi	2012	-	-	-	-
	2014	15[7]	68	66	65
	2017[8]	-	-	-	-
Iurceni	2012	-	-	-	-
	2014	14[7]	59	58	78
	2017[8]	-	-	-	-
Cristești	2012	-	-	-	-
	2014	15[7]	70	70	72
	2017[8]	-	-	-	-

Color code: green = within the norm; yellow = exceeds the norm, but still efficient; red = widely below the standards.

Annex 2: 2018 Monitoring Campaign Summary

Location	Cristești	Iurceni	Drăgușeni Noi	Rusca	Sărata-Galbenă	Negrea
Date	2018-07-19	2018-07-19	2018-07-19	2018-08-16	2018-08-16	2018-08-17
Inspection						
Manholes	Good	Good	Good	Good	Very good	Good
Collector	Good	Good	Bad	Good	Good	Good
Plant: protection zone integrity	Very good	Good	Very good	Bad	Very good	Very good
Plant: general aspect	Good	Good	Bad	Bad	Very good	Very good
Pumping station	Bad	Bad	Good			
Siphon: condition	Good	Good	Very bad			
Siphon: sludge accumulation	No	No	Yes			
Bed filter: condition	Very good	Good	Good	Bad	Good	Good
Bed filter: reeds	Good	Good	Bad	Good	Good	Very good
Polishing pond	Good					
Septic tank/ABR				Bad	Good	Good
Operator interview						
Plant: connection rate	Stable	Increase	Increase	Stable	Increase	Stable
Plant: condition	Good	Good	Bad	Bad	Very good	Very good
Plant: evolution of condition throughout the years	Stable	Stable	Deteriorated	Deteriorated	Stable	Stable
Plant: presence of supernatant liquid	No	No	No	Yes	Yes	Yes
Plant: abnormal smells	No	No	Yes	No	No	No
Operations and maintenance: problems	Yes	No	Yes	Yes	No	No
Operations and maintenance: documentation	Yes	No	No	No	Yes	No
Economical aspect: economic situation	Fragile	Fragile	Bankrupt	Good	Good	Good
Economical aspect: funds for repairs	No	No	No	No	Yes	Yes
Overall sustainability	Medium-term	Medium-term	Short-term	Medium-term	Long-term	Long-term

Annex 3: Task List for CW Operation and Maintenance

Pumping Chamber

Check	Point(s) of interest	Operation	Reason	Regularity
Condition of pump	Is pump working and/or water level rising?	If the pump is not working and the water level is raising, the person in authority (PIA) has to be contacted immediately.	Avoid overflow in the pumping chamber	Daily

French System CW (1st Stage)

Check	Point(s) of interest	Operation	Reason	Regularity
Condition of vegetation	Color of leaves, density of plants	Note if the reed seems to decayed and contact the PIA (no reed cutting necessary)	Avoid the decay of reeds	Daily
Infiltration	Water height on the filter bed	Is the water height on the filter bed decreasing between loadings? Is the filter bed drying out during resting periods? Contact the PIA if not.	Ensure infiltration capacity of the filter bed	Daily
Filter loading with solids	Are solids present in the distribution chamber?	If there are no solids in the distribution chamber (only liquid wastewater phase), it can be assumed that all solids are remaining in the pumping chamber. In this case, the PIA should be contacted.	Avoid accumulation of solids in the pumping chamber	Daily
Loading device (self-priming siphon) in distribution chamber	Is the loading device working?	Contact the PIA immediately if the loading device is not working.	Enable regular flooding of the filter bed and avoid an overflow in the distribution chamber	Permanent during work
Filter bed loading	Change applied to the filter bed every week*	Change the composition of the vertical pipes in the distribution chamber (*periods for loading and resting can be adjusted, depending on loading rates per day and strength of the wastewater).	Sufficient resting time is required after the loading period (6-8 days according to GIZ (2011))	Weekly

Horizontal Flow CW (2nd Stage)

Check	Point(s) of interest	Operation	Reason	Regularity
Condition of vegetation	Color of leaves, density of plants, invading plants	Contact the PIA if reeds seem to be decaying (after 1 week). Cut reeds by hand if excessive growth is observed (only in the spring) and remove invading plants. Note that, normally, no reed harvesting is necessary (contact the PIA if this is necessary).	Avoid reed decay and excessive reed growth and biomass accumulation on the filter bed as well as the presence of invading plants	Daily
Smell of the filtration bed	Sulfuric/ foul egg smell	A continuous smell of foul eggs should be noted (contact the PIA after 1 week).	Avoid anaerobic conditions	Daily
Uniform distribution of the wastewater	Outflow of the distribution pipe	Clean distribution pipe holes. If necessary, empty the distribution pipe by removing the end caps and blush the distribution pipe clean (access for flushing required). If there are several distribution pipes per filter bed, adjust the distribution valve. Keep the distribution pipe closed by installing end caps (except during emptying and cleaning).	Enable the uniform distribution of wastewater and the full use of the filter bed	Daily
Surface flow	Surface flow, puddles on the filter bed	Continuous surface flow, puddles or water levels close to filter surface should be noted (contact the PIA after 1 week).	Avoid anaerobic conditions, ensure subsurface flow and sufficient oxygen supply	Daily

Vertical Flow Constructed Wetland (2nd Stage)

Check	Point(s) of interest	Operation	Reason	Regularity
Condition of the vegetation	Color of leaves, density of plants, invading plants	Contact the PIA if reeds seem to be decaying (after 1 week). Cut reeds by hand if excessive growth is observed (only in the spring) and remove invading plants. Note that, normally, no reed harvesting is necessary (contact the PIA if this is necessary).	Avoid reed decay and excessive reed growth and biomass accumulation on the filter bed as well as the presence of invading plants	Daily
Infiltration	Water height on filter bed	Is the water height on the filter bed decreasing between loadings? Is the filter bed drying out during resting periods? Contact the PIA if not.	Ensure infiltration capacity of the filter bed	Daily
Loading device (self-priming siphon) in the distribution chamber	Is loading device working?	Contact the PIA immediately if the loading device is not working.	Enable regular flooding of the filter bed and avoid an overflow in the distribution chamber	Permanent during work
Filter bed loading	Changing applied filter bed every week*	Change the composition of the vertical pipes in the distribution chamber (*periods for loading and resting can be adjusted, depending on loading rates per day and strength of the wastewater).	Sufficient resting time is required after the loading period (2 weeks according to GIZ)	Weekly

General Tasks

Check	Point(s) of interest	Operation	Reason	Regularity
Manholes	Are manholes closed?	Close manholes.	Safety, keep the system clean of garbage, etc.	Included in daily inspection
Clean CW area	Is there garbage on the CW area?	Remove garbage on the CW area.	Good overall impression of the plant	Included in daily inspection

Task List for Person in Authority (PIA)

Pumping Chamber

Point(s) of interest	Operation	Reason
Condition of the pump	Keep spare parts (and maybe a reserve pump) in order to enable the operation of plant at all times.	Avoid overflow of the pumping chamber

French System CW (1st Stage)

Point(s) of interest	Operation	Reason
Condition of vegetation	Shorten resting periods if plant decay is observed (taking into account sufficient time for filter regeneration).	Enable water access for plants, reduce die-off during resting period
Infiltration	If infiltration is insufficient, increase resting periods or, if necessary, shut down filtration beds for longer periods (2 weeks and more). For severe cases, remove (i) sludge accumulation on the filter and, if necessary, (ii) replace filter material.	Enable sufficient infiltration by restoring infiltration capacity
Filter loading with solids	Lower the location of the pump. Maintain or replace the pump if solids are accumulating in the pumping chamber. Try to break up any accumulated sludge layer at bottom.	Enable the degradation of solids on the filter bed, avoid the accumulation of solids in the pumping chamber
Loading device (self-priming siphon) in distribution chamber	Keep spare parts in order to fix the loading device. If necessary, empty the distribution chamber by opening the bottom outlet, shutting down the pump and replacing loading device (taking care of possible overflow in the pumping chamber).	Enable loading of the filter bed at all times, avoid overflow
Filter bed loading	Change the period of filter loading based on the following: • Loading rates per day and strength of the wastewater • Accurate resting periods • Sufficient water access for plants	Enable adequate loading and restoring of the filter bed
Sludge accumulation on the filter	Remove accumulated sludge on the filter every 10-15 years (after about 20 cm of sludge has been reached). Transfer sludge for treatment (has to be defined).	Remove (partially mineralized) sludge, restore infiltration capacity, lower the filter bed height

Horizontal Flow CW (2nd Stage)

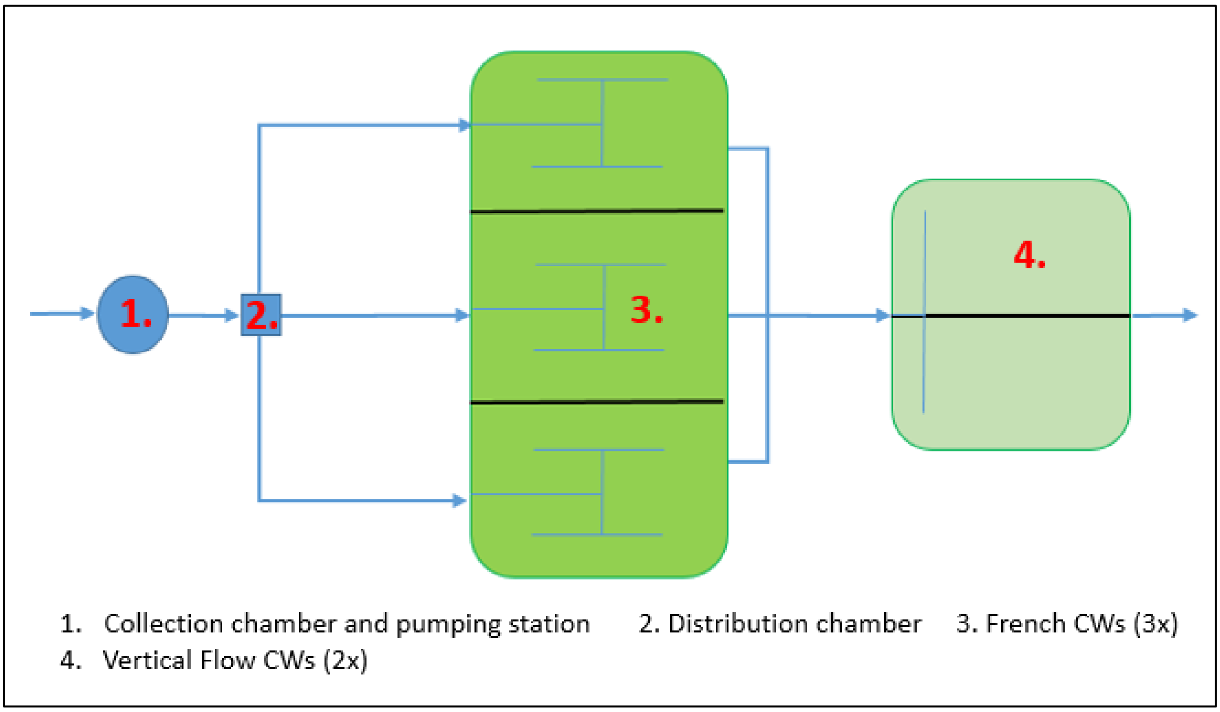
Point(s) of interest	Operation	Reason
Reeds seem to decay	Raise the level of outlet. Young plants with rudimentary root systems need higher water levels.	Improve access to water for plants
Excessive reed growth	Only in spring: Cut the reeds by hand, avoiding the removal of roots (only in the spring). Note that, normally, no reed harvesting is necessary. Harvesting is only necessary in order to avoid the accumulation of dead plant material on the filter bed. Remove reeds in the inlet and outlet areas.	Cut only in spring due to leave insulation materials for winter. Large amounts of dead plant material could cover filter surfaces and decrease oxygen supply. Ensure visibility of the distribution pipe, avoid root growth into the drainage system
Invading plants	Remove invading plants by hand (including the roots).	Support the growth of deep-rooted swamp plants
Surface flow	Adjust the outlet level lower than ½ of the filter bed height. Drain and shut down the filter bed for several weeks (if parallel beds for continuing operations are available). Replace filter material (if no improvement after a resting period is observable). Generally, no need for summer/winter heightening of the outlet.	Surface flow happens due to blocked filter material (excessive biofilm growth, clogging by solids) or high outlet levels. In the case of blocked filters, the biofilm has to be forced to decay by draining in order to reestablish infiltration capacity. If shutting down does not improve infiltration capacity, filter material has to be replaced.
Uniform distribution of WW	Adjust holes in the distribution pipe to a higher position for holes closer to inlet pipe and to a lower position towards the end of the distribution pipe. Adjust the slope of distribution pipe, with the slanting slope towards the end of distribution pipe and a similar slope for both distribution pipes (if arranged a T-shape)	Ensure uniform distribution of wastewater and the full use of filter width
Leveling of outlet	Level the elevation of different outlet positions in relation to the filtration bed. Mark different elevation levels (in relation to the filter bed) in the outlet manhole.	Outlet height is the only control mechanism. Outlet position should be adjustable in relation to the filter bed dimension.
Outlet height and position of outlet	Adjust the outlet height according to relevant literature (GIZ 2011). Position the outlet tube horizontally to avoid outflow over in the outlet tube.	Ensure sufficient hydraulic conditions and enable oxygen supply, protect the outlet tube in order to prolong service life

Vertical Flow CW (2nd Stage)

Point(s) of interest	Operation	Reason
Condition of vegetation	Shorten resting periods if plant decay is observed (taking into account sufficient time for filter regeneration).	Enable water access for plants, reduce die-off during the resting period
Infiltration	If infiltration is insufficient, increase resting periods or, if necessary, shut down filtration beds for longer periods (2 weeks and more). For severe cases, replace filter material.	Enable sufficient filtration by restoring infiltration capacity
Loading device (self-priming siphon) in the distribution chamber	Keep spare parts in order to fix the loading device. If necessary, empty the distribution chamber by opening the bottom outlet, shutting down the pump and replacing loading device (taking care of possible overflow in the pumping chamber).	Enable loading of the filter bed at all times
Filter bed loading	Change the period of filter loading based on the following: • Loading rates per day and strength of the wastewater • Accurate resting periods • Sufficient water access for plants	Enable adequate loading and restoring of the filter bed

Annex 4: Illustrations and Photographs

Drăgușeni Noi



Drăgușeni Noi layout sketch

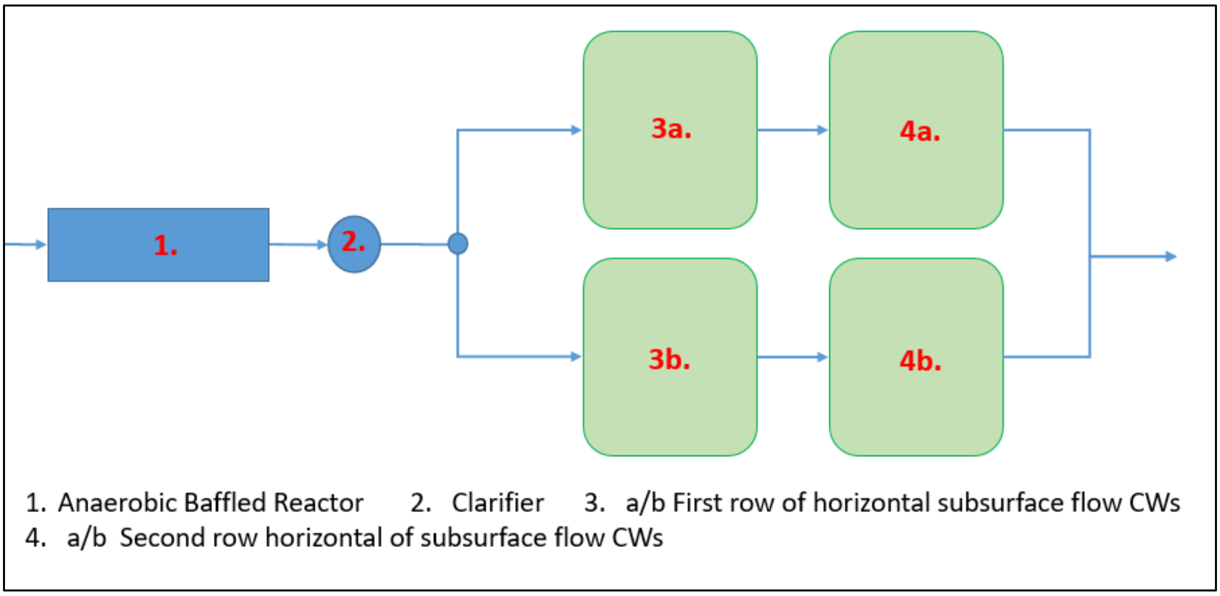
Dried reeds on the vertical flow CWs (#4 on the sketch above), with uneven reed coverage caused by a drought the previous summer (winter 2015)

View of the storage tank/pumping station (#1 on the sketch above), including an installed arrangement ("crane") for the removal of solids accumulated via a perforated bucket (summer 2018)

Cristești

Level difference between the first and secondary treatment steps that allows for gravitational flow (summer 2018)

Rusca



Rusca layout sketch

Summer 2012: Horizontal Subsurface Flow CW in the first CW row (3a on the sketch). Only few months after the plant start-up, supernatant wastewater is appearing, highlighting that the filter bed is already clogged, only few month after the CW started to run. The distribution pipe has been opened at its end to allow water flow when smaller holes are clogged by biomass.

Summer 2015: Horizontal Subsurface Flow CW in the first CW row (3a on the sketch). Due to clogging, the distribution system was removed and a dam (out of gravel) was created to ensure the even distribution of wastewater. Presence of supernatant wastewater before and after the "distribution dam", indicating a severe clogging of the filter bed.

Summer 2015: Back view of the Horizontal Subsurface Flow CW in the first CW row (3a on the sketch). The supernatant wastewater is not visible, indicating that the wastewater was able to infiltrate the filter bed. This indicates the filter bed is only partially clogged, which still allow an effective treatment, even if the available volume for treatment has been reduced, thus reducing the wetland efficiency.

Summer 2018: Horizontal Subsurface Flow CW in the first CW row (3a on the sketch), despite the addition of the clarifier, the clogging problem persists. The situation remains similar to the one in summer 2015

Summer 2015: Horizontal Subsurface Flow CW in the second CW row (4a on the sketch). No clogging visible at that time. This highlights the first row of CWs (3a and 3b on the sketch) is still efficient despite the clogging, as no biomass/particles clogs the distribution pipe of the second row of CWs.

Negrea

Well-functioning horizontal subsurface flow CW, with reeds growing (summer 2015)

Horizontal subsurface flow CW, with reeds cut (winter 2015)The cut reeds have been gathered around the inlet of the distribution pipe to insulate it and avoid water freezing. The CW act as a filter and still treat water well, even if the benefits from reeds (oxygen transfer and nutrient uptake) does not happen.

Sărata-Galbenă

Horizontal subsurface flow CW, with well-developed reeds (1.80 to 2.00 m height). (summer 2015)