Large-Scale Constructed Wetland key to affordable and effective wastewater treatment in Orhei, Moldova

After the first year of operation, one of the largest constructed wetlands in the world demonstrates its advantages for small and medium sized towns. Andrew Greenbank, Riccardo Bresciani and Giancarlo Cigarini report on the design, construction and results of this ambitious project.

Introduction

Orhei is an agricultural market town in Moldova, Eastern Europe, located approximately 40 kilometres north of the capital, Chişinău and close to the historic site of Old Orhei. The existing 40 year old wastewater treatment plant in the town has been replaced with a Constructed Wetland, which commenced operations in October 2013 and is now coming to the end of the first year start-up phase. The plant treats about 20,000 PE and, at 5 ha, it is currently the largest worldwide for secondary treatment. The investment costs were approx. 5 million USD, which was funded by the EU, the Moldovan Ministry of Environment and the World Bank.

The design work and the supervision of the construction was implemented by an international Joint venture composed of Posch & Partners (Austria) and SWS Consulting, IRIDRA and HYDEA (Italy) and it was constructed by the German Joint-Venture Heilit-BioPlanta.

Why a constructed wetland in Orhei?

The preliminary proposal of a feasibility study conducted in 2007 was for a new activated sludge plant to be constructed to replace the existing old treatment plant. However, due to more recent guidelines which indicated constructed wetlands (CW) as being one of the best management practices for smaller towns, a constructed wetland was finally proposed and accepted as being the optimum solution for Orhei. This was due to ease of construction and operation, low energy consumption, limited needs for spare parts and no need for chemicals. Constructed wetlands are also a technology that is well developed for cold climates (e.g. Germany, Denmark, or Canada) and together these characteristics made this the recommended option, which then received the full backing and support of the Moldovan Ministry of Environment.

French Reed Beds with pre-treatment building and equilisation tanks in the background. Credit: Riccardo Bresciani

This decision resulted in the commencement of this ambitious project to design, construct and put into operation one of the largest constructed wetlands worldwide, overcoming the challenges of limited local experience, linked with scepticism about the suitability, reliability and performance of such technology, particularly in cold climates.

Constructed wetlands

Constructed wetlands (CW) are natural wastewater treatment systems, where a variety of treatment processes take place, such as filtration, sedimentation, and biological degradation, which together effectively remove the contaminants in wastewater. The most efficient are the subsurface flow type (SSF), where the wastewater is filtered in extensive gravel or sand basins planted with emergent macrophyte plants. In the horizontal flow type (SSF-h), the water flows horizontally in a gravel media, ensuring good organic and solids removal. In the vertical flow type (SSF-v or VF), a distribution system on the surface allows the wastewater to percolate vertically through the filter bed, enhancing oxidation processes and permitting not only the high removal of organics and solids, but also a strong nitrification. Intermittent hydraulic loading of VFs further increase the aeration, because pores of the filter bed refill with air during the resting intervals between the flushes.

The “French scheme”, as selected for Orhei, was originally developed by the French research institute IRSTEA (formerly CEMAGREF). It is a 2 stage vertical flow system that allows direct application of raw sewage, without the need for primary sedimentation, using the first stage for sludge stabilisation. A major advantage of this is that it requires the minimum footprint, because there is no need for additional sludge drying beds for managing primary sludge, as would be the case with other options.

Constructed wetlands have a very low impact on the environment compared to classical activated sludge plants, including typically:

- no aerosol production
- no requirement for chemicals
- no energy needed for aeration
- less sludge production
- less greenhouse gas emissions
- better environmental landscaping, with the possibility to recover degraded and abandoned areas
- prevalent use of local materials for construction

The main challenges associated with CW are generally thought to be the relatively large land area required for their construction, the perceived maximum size that can be constructed and their perceived unsuitability for cold climates. However, theoretically, there are no upper size limits for their application for both secondary and tertiary treatment, except for the availability of land. CW are also proven in cold climates and they are actually one of the best choices for many small and medium sized communities, which is now reflected in many guidelines.

What type of constructed wetland technology for large applications?

Following the analysis of the wastewater pollutant load, a two-stage Constructed Wetland system was selected because this was assessed as being best suited to the specific conditions, including ensuring a satisfactory treatment level during the cold winter periods, with regular sub-zero temperatures.

Finding a suitable site of sufficient size is usually the main problem with constructed wetlands, but in this case the site available was ideal, being fairly flat and protected from possible flooding. The fact that there were no houses or settlements for a radius of about 1 km meant that a “French system” configuration (see box) for the new CW could be selected (French guidelines advice a minimum distance of 300 m from the nearest house). The biggest advantage of this system is the on site management of sludge and hence the minimum footprint, because there is no need for thickeners, digesters and sludge drying beds, as with other options.

The finally selected design consisted of a compact pre-treatment unit, with intake screen and grit removal; 2 equalisation tanks of 1200 m^3 (equipped with mixers and aerators for limited pre-aeration) to better distribute the day flow, especially the seasonal peaks from agro-food industries; 4 independent 2 stage treatment lines (each with 1st Stage French Reed Bed for raw sewage and 2nd Stage Vertical Flow) with a total net area of 35,000 m^2; and an emergency chlorination disinfection system, located upstream from the outlet pumping station.

In the treatment lines, degradation and stabilization of the pollutants contained in the wastewater is performed by the billions of bacteria which populate these extensive natural filters, facilitated by the large quantity of oxygen transferred by the natural circulation of air and by the plants. In the "French" Stage the water is filtered vertically by a fine gravel medium, removing 70-80% of organics, solids and ammonia, with the sludge remaining on the surface, from where it will be removed every 8-10 years. The 2nd Stage consists of a classical vertical flow system with sand, which refines the treatment, permitting also the completion of nitrification processes. Sufficient disinfection is ensured by the process, with the 99.9% removal rate meaning a low concentration of pathogens in the effluent, therefore use of additional chlorination is only foreseen for emergencies.

Plant start-up and operation and maintenance

The start-up and operation of a large and technological advanced CW, such as that in Orhei, is clearly more complicated compared with the more common CWs for smaller applications, which often operate solely by gravity and involve minimum mechanical equipment. Also, the natural processes involved in a CW can take up to 2 years to fully develop and optimisation of the plant is best done with monitoring and fine-tuning during this period. A further challenge was the operator's very limited experience of CW, linked with their scepticism about the reliability and performance of such technology. Therefore, substantial Technical Assistance was invested in supporting the plant management and operators for the first period of operations.

The CW was started-up in October 2013, with an initial capacity of 1000 m^3/d and with the aim to progressively reach the design capacity over the first year, in tandem with the growth of the plants in the filters, the optimization of the various sections of the facility and the training of the operators. Since the end of December 2013 already about 1200-1500 m^3/day have been continuously loaded to the plant and in November 2014, after the completion of various works on the sewer system, the old treatment plant will be stopped and the CW will receive the entire quantity of wastewater from the town. This currently totals about 2000 m^3/day, with seasonal peaks up to 2700 m^3/day due to agro-food industries.

First Stage French Reed Beds during the first growing season. Credit: Riccardo Bresciani.

During the first year of operations detailed data and information on the operation and performance of the plant were collected and used to define the optimum future operation strategies, especially during the cold winter periods. In fact the performance of all the electro-mechanical equipment was found to be satisfactory over the winter, with recorded temperatures as low as -25°C, and no significant breakages or damage occurred. However, the first winter did lead to the identification of some critical points in the hydraulic connections that caused some localised freezing problems, which could be overcome by defining specified operational strategies for the coldest periods.

Effluent quality during the first year of operation

After about 1 month of adaption, especially in the first stage where the growth of the biomass is related to the formation of an initial sludge layer and reduction of the infiltration velocity, the system quickly demonstrated a good level of treatment performance, with the outfall limits continuously respected. Even during the first winter biological removal was good, despite the very low temperatures and the coverage of the basins by ice and snow for several weeks, with an organic and solids removal rate higher than 80% and with a nitrification of 30-50%. In fact, the accumulation of the snow on the platforms didn't affect the functioning of the system, and actually provided thermal protection to the filtration layer below. Already during the first 9 months of operation the mean efficiency was 94% for SS and 75% for COD and BOD5 (see Figure 1). The removal rate further increased over the duration of the start-up and in spring and summer was very high, were COD was always under 40 mg/l and nitrification was almost complete.

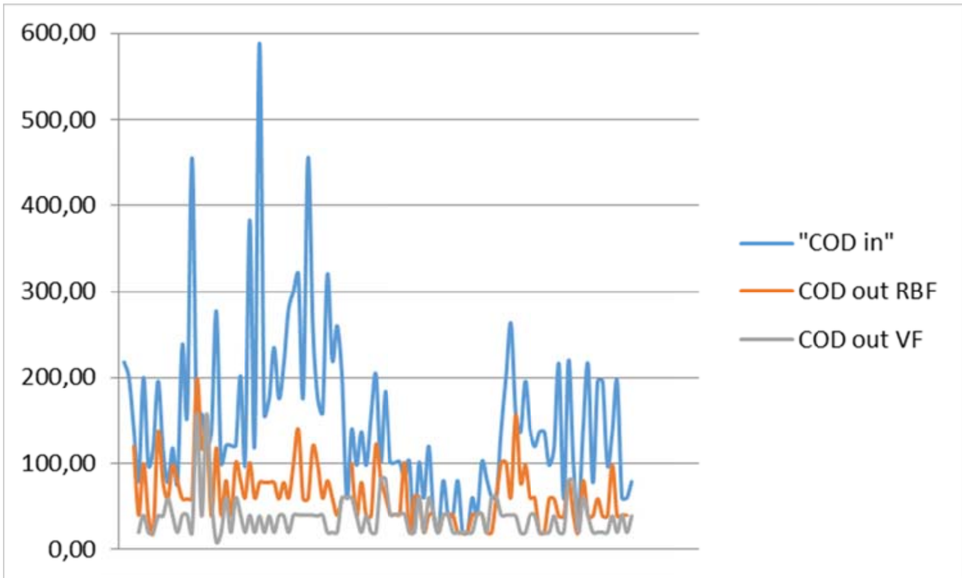

Figure 1: Concentration of COD (mg/l) at the inlet and at the outlet of the two treatment stages, from October 2013 until June 2014 (106 samples)

Energy consumption

On the basis of the measured power consumption up to now, the expected final energy consumption is about 0.4 kWh/m³, which compares very favourably with the consumption of an average activated sludge plant of the same capacity, which in this case was estimated would be at least 1.75 kWh/m³.

About 70% of the total energy is consumed by the pumping stations, which are needed to transfer the wastewater though the various stage of treatment and then finally 1.5km to the river. This pumping is necessary due to the flat morphology of the area and also because of the recourse to vertical systems that, especially for large installations, have to be loaded under pressure. For smaller CWs, if enough difference in level is available, this energy consumption can be reduced by the use of special energy-free self-priming siphons.

The remaining 30% of the energy is consumed by the flowjets and mixers in the equalization tanks, which were especially specified for this large CW so as to avoid sludge sedimentation in the equalization tank, to improve mixing conditions and to reduce odour diffusion during the loading of raw sewage on the first stage. However, for smaller applications these are not usual, and hence this energy consumption would be negated.

Conclusions

After the first year of operation, one of the largest constructed wetlands in the world has clearly demonstrated its advantages for small and medium sized towns, with excellent treatment levels obtained and with significantly reduced operation costs compared with conventional treatment processes. Substantial input was required from all parties to make this ground-breaking project a success, particularly considering the very limited local experience with this technology, but it is now expected that this will become a model for the wider acceptance and application of CWs for other similar situations.

References

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Author Information:

Andrew Greenbank, Senior Project Engineer, Posch & Partners Consulting Engineering, Innsbruck, Austria, greenbank@pap.co.at

Riccardo Bresciani, Project Manager, IRIDRA Constructed Wetlands, Florence, Italy, bresciani@iridra.com

Giancarlo Cigarini, Project Manager, SWS Consulting Engineering, Rome, Italy, g.cigarini@swsconsulting.it