Focus (texte en anglais)

Constructed wetland technology in Austria – History, current practices and new developments

Constructed wetland systems for wastewater treatment have been proven to be effective, low cost and sustainable alternative for wastewater treatment technologies. This paper is about the Austrian experience in constructed wetland systems.

Constructed wetlands (CWs) are a simple technology in construction as well as in operation and maintenance. They have a high buffer capacity for hydraulic and organic load fluctuations as well as a high robustness and process stability. CWs are therefore a suitable technological solution for small villages and single households.

The population in Austria is about 8.4 million, the area about 84 000 km^2. About a third of the population lives in cities, a third in villages and a third in rural, mountainous areas. About 1 500 wastewater treatment plants with a capacity larger than 50 population equivalent (PE) serve about 94 % of the population. This percentage can be extended in future to a maximum of 95-96 %. The remaining 4-5 % of the population lives in single houses and small settlements (< 50-500 PE) that require on site and decentralized wastewater treatment technologies. The estimated number of small treatment plants needed is 30 000 to 40 000.

Regarding the Austrian regulation a maximum ammonia nitrogen (NH_4-N) effluent concentration of 10 mg.L^{-1} for wastewater treatment plants less than 500 PE is allowed (this has to be met for effluent water temperatures higher than 12°C only). For organic matter the maximum effluent concentrations (i.e. 90 mg COD.L^{-1} and 25 mg BOD5.L^{-1}) have to be met throughout the year. For plants with a capacity less than 500 PE, there are no legal requirements regarding nutrient removal. However, in the case of small and sensible receiving waters additional requirements for nutrient removal can be set by the authorities.

This paper tries to give an historical overview on the development of the use of CWs in Austria, describes the current practices and new developments are discussed.

History of CWs in Austria

Do to the demand for simple solutions for wastewater treatment in rural areas first experiments with CWs in Austria, using soil based horizontal flow CWs, started in the 1980s. These horizontal flow systems turned out to be very appropriate technologies providing high stability in their efficiencies regarding the elimination of organic matter, with low levels of operation and maintenance. However, problems concerning the hydraulic conductivity when using soil as a filter medium occurred, resulting in clogging of the filter and poor performance (Haberl and Perfler, 1990).

In 1990, the legal requirements changed and requested now nitrification for all sizes of treatment plants. Consequently, the research focus changed to the development of vertical flow (VF) sand based CWs with intermittent loading. In contract to HF beds VF beds with intermittent loading endure that oxygen is transferred into the filter bed and nitrification can occur. Figure 1 shows a single-bed VF CW in Wolfern, one of the first VF beds constructed in Austria. In 1997, these experiments lead to the development of the first Austrian design standards for single-stage VF beds requesting a specific surface are requirement of 5 m^2 per PE. The Austrian single-stage VF CW system requires a mechanical pre-treatment to reduce the load of particulate suspended matter.

Current practices – Single-stage VF CW systems

Since the release of the first Austrian design standard for CW systems in 1997, a lot of scientific and practical experiments showed that single-stage sand and gravel based VF CW systems with intermittent loading are able to meet the stringent Austrian effluent demands especially regarding nitrification.

Investigation at an outdoor pilot scale CW system, within the research project « Optimization of subsurface vertical flow constructed wetlands » (Bepflanzte Bodenfilter) had the main goal to optimize, i.e. minimize, the surface area requirement for VF beds. To investigate the behaviour of differently loaded beds, three VF beds were constructed and have been operated in parallel with different organic loads for a period of 2 years. It could be shown that with VF beds operated with an organic load of 20 g COD.m^{-2}.d^{-1} (i.e. 4 m^2 per PE) the requirements of the Austrian standards regarding maximum effluent concentrations can be met (Langergraber et al., 2007). These experiments led to an amendment of the Austrian design standards which now requests a specific surface area requirement of 4 m^2 per PE (ÖNORM B 2505, 2009).

1 Experimental single-bed VF CW in Wolfern, Upper Austria (designed for 10 PE, constructed in 1990).

1 Ammonia nitrogen effluent concentration measured in 847 samples of CW systems in 2011 (adapted from Mitterer-Reichmann, 2012).

NH_4-N ($mg.L^{-1}$)		Samples	%
from	to		
0	1	596	70
1	10	172	20
10	20	50	6
20	30	14	2
30	40	7	1
>40	–	8	1
		847	100

VF beds according to the Austrian design standards (ÖNORM B 2505, 2009) have a 50 cm main layer that consists of sandy substrate (grain size 0.06-4 mm, d_{10} = 0.2 mm ; d_{60} = 0.8 mm) at the top, a 10 cm intermediate layer with a gravel size of 4-8 mm (which prevents fine particles to be washed out into the drainage layer), and a 15 cm drainage layer (gravel size 16-32 cm) where the effluent is collected by means of tile drains. Additionally, a 5-10 cm top layer with a gravel size of 4-8 mm can be applied. The minimum volume of the mechanical pre-treatment is 0.25 $m^3.PE^{-1}$. The intervals between intermittent loadings should be between 3 and 6 hours, the duration of a loading should be less than 15 minutes. To ensure even distribution of the wastewater on the surface area, the area of a single bed should be less than 400 m^2.

Currently, the estimated number of CW systems in Austria is more than 3 000. About 1 600 systems have been built by the company « *Ökologisches Projekt* » in Graz (Mitterer-Reichmann, 2012). Besides constructing CW systems, the company also provides an operation and maintenance (OM) service to their customers. This is frequently required by authorities as it is generally agreed that even CW systems require a minimal OM. These requirements have to be provided otherwise the systems are no longer efficient. Such OM service contracts usually also include the regular monitoring of the effluent quality requested by authorities. Table 1 shows the NH_4-N effluent concentrations of CW systems from samples taken during the year 2011 by *Ökologisches Projekt*. More than 90 % of the systems fulfil the requested effluent standard of 10 mg NH_4-$N.L^{-1}$.

New developments – Two-stage VF CW systems

To increase nitrogen removal a two-stage VF system has been developed (Langergraber et al., 2008). The two-stage system has two VF beds operated in series

2 Comparison of effluent concentrations, removal efficiencies and eliminated loads for single-stage CW and two-stage CW systems (Median values) (according to Langergraber *et al.*, 2008).

		Single-stage CW system				Two-stage CW system			
		BOD_5	COD	NH_4-N	TN	BOD_5	COD	NH_4-N	TN
Effluent concentration	($mg.L^{-1}$)	4	27	0.37	57.2	5	21	0.29	33.9
Removal efficiency		98.9 %	95.2 %	99.1 %	32.8 %	98.7 %	95.9 %	99.7 %	54.5 %
Removed load	($g.m^{-2}.d^{-1}$)	11.77	16.39	2.06	0.85	20.44	31.03	3.86	2.70

and, is designed and operated with an organic load of 40 g COD.m^{-2}.d^{-1} (i.e. 2 m^2 per PE). Each stage has a surface area of 10 m^2. The main layers of the two stages consist of sand with different gravel sizes, 2-3.2 mm and 0.06-4 mm (d_{10} = 0.2 mm ; d_{60} = 0.8 mm) for the first and second stage, respectively. The drainage layer of the first stage is impounded whereas the drainage layer of the second stage has free drainage. Table ❷ compares median values of effluent concentrations, removal efficiencies and eliminated loads for a single-stage CW designed and operated according to the Austrian design standards (i.e. 20 g COD.m^{-2}.d^{-1}, 4 m^2 per PE) and two-stage CW systems. Both systems show similar effluent concentrations for BOD_5, COD and NH_4-N but due to the double loading of the two-stage CW system the removed loads are twofold.

Additionally, besides meeting the requirements of the Austrian regulation regarding organic matter removal and nitrification, stable nitrogen removal could be achieved with the two-stage CW system. Compared to nitrogen removal rates of other CW systems treating municipal wastewater, a high nitrogen removal rate can be achieved using the two-stage VF CW system.

The first full-scale implementation of the two-stage VF CW system is for the Bärenkogelhaus restaurant which is located on top of a mountain located in Styria 1168 m above sea level. The restaurant has 70 seats and 16 rooms for overnight guests and is a popular site for day visits especially during weekends and public holidays. The system was designed for a hydraulic load of 2 500 L.d^{-1} with a specific surface area requirement of 2.7 m^2 per PE.

Both beds of the two-stage VF CW system have a surface area of 50 m2 and are loaded intermittently with mechanically pre-treated wastewater. The 50 cm main layer of stage 1 consists of sand with a grain size distribution of 2-4 mm, the 50 cm main layer of stage 2 of sand with a grain size distribution of 0.06-4 mm. Both stages have a 10 cm top layer of gravel (4-8 mm) and are planted with *Phragmites australis*.

The system was built in fall 2009 and started its operation in April 2010 when the restaurant was opened. Samples have been taken since July 2010 and analysed in the lab of the Institute of Sanitary Engineering. During the period July – December 2010 the hydraulic load of the system was 10.1 mm.d^{-1} and the organic load 10.3 g COD.m^{-2}.d^{-1}. In average the two-stage system received in 32 % of its design load. In general measured effluent concentrations where low and the removal efficiencies high. During the whole period the ammonia nitrogen effluent concentration was below 1 mg.L^{-1} even at effluent water temperatures below 3°C.

Future investigations at the Bärenkogelhaus restaurant will focus on investigating the performance of the two-stage CW system under peak loads as they occur at the restaurant on weekends especially during special event (e.g. concerts, weddings). The long-term goal is to make the two-stage CW system state-of-the-art in Austria by including its design in the Austrian design standards for CWs. ■

Authors

Günter LANGERGRABER and Raimund HABERL
Institute of Sanitary Engineering and Water Pollution Control, University of Natural Resources and Life Sciences, Vienna (BOKU), Muthgasse 18, A-1190 Vienna, AUSTRIA
guenter.langergraber@boku.ac.at

Key bibliographical references

HABERL, R., PERFLER, R., 1990, Seven years of research work and experiences with wastewater treatment in a reed bed system, *in :* Cooper, P.F., Findlater, C. (eds.), *Constructed wetland in Water Pollution Control, Adv. Wat. Pollut. Control, n° 11*, Pergemaon Press, Oxford, UK, p. 529-534.

LANGERGRABER, G., PRANDTSTETTEN, C., PRESSL, A., HABERL, R., ROHRHOFER, R., 2007, Removal efficiency of subsurface vertical flow constructed wetlands for different organic loads, *Water Sci Technol,* 56(3), p. 75-84.

LANGERGRABER, G., LEROCH, K., PRESSL, A., ROHRHOFER, R., HABERL, R., 2008, A two-stage subsurface vertical flow constructed wetland for high-rate nitrogen removal, *Water Sci Technol,* 57(12), p. 1881-1887.

MITTERER-REICHMANN, G., 2012, Treatment wetlands in Austria : Practical experience in planning, construction and maintenance. Sustainable Sanitation Practice 12 (July 2012), will be accessible online at http ://www.ecosan.at/ssp on 15 July 2012.

ÖNORM B 2505, 2009, Bepflanzte Bodenfilter (Pflanzenkläranlagen) – Anwendung, Bemessung, Bau und Betrieb (Subsurface-flow constructed wetlands – Application, dimensioning, installation and operation), *Norm*, Österreichisches Normungsinstitut, Vienna, Austria [*in German*].

L'épuration des eaux usées par filtres plantés de roseaux est une technique très répandue dans les petites et moyennes collectivités.