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A COMBINED CONSTRUCTED WETLAND FOR TREATMENT OF MILK HOUSE EFFLUENTS IN HÓDMEZŐVÁSÁRHELY, HUNGARY

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ABSTRACT - A COMBINED CONSTRUCTED WETLAND FOR TREATMENT OF MILK HOUSE EFFLUENTS IN HÓDMEZŐVÁSÁRHELY, HUNGARY
Constructed wetlands can be a cost effective solution to decrease the unfavourable impacts to free- and groundwater in Hungarian agriculture sector. This article shows the experiences of a combined constructed wetland, this was built by an international co-operation named TOKAI-project. One of the project's aims is to analyze the applicability of constructed wetlands to agricultural wastewater treatment at Hungarian emission limit values and environmental conditions. Operational experiences of 1 year period are shown in this article. The results are compared to international experiences. The main considerations of comparison are: specific load of organic substances, removal efficiency, specific hydraulic loading rate, etc.

ÖSSZEFOGLALÁS - EGY HÓDMEZŐVÁRSÁRHELYI KOMBINÁLT (GYÖKÉRZÓNÁS-TAVAS) TEJHÁZI TERMÉSZETKÖZELI SZENNYVÍZTISZTÍTÓ TAPASZTALATAI
A gyökérzónás, illetve tavas szennyvíztisztítási eljárások egy költségkímélő megoldási lehetőséget nyújthatnak a felszíni és felszín alatti vizet terhelő mezőgazdasági emissziók csökkentésében Magyarországon. Jelen cikkben bemutatásra kerülnek a TOKAI-projekt névvel ellátott, nemzetközi együttműködés keretében épült természet-közeli szennyvíztisztító eddigi üzemelési tapasztalatai. A nemzetközi együttműködés egyik célja annak vizsgálata volt, hogy a gyökérzónás szennyvíztisztítási technológia alkalmazható-e a mezőgazdasági szennyvizek kezelésére a magyarországi éghajlati viszonyok mellett, megfelelve a hazai jogi szabályozásnak. A bemutatásra kerülő egyéves üzemeltetési tapasztalatok összehasonlításra kerülnek a nemzetközi szakirodalmi értékelésekben foglaltakkal. Az összehasonlítás alapja, többek között a fajlagos szervesanyag-terhelés, tisztítási hatékonyság, fajlagos hidraulikai terhelés, stb.

Keywords: milk house effluent, constructed wetlands, agricultural wastewater, combined systems, wastewater treatment
Kulcsszavak: tejházi szennyvíz, gyökérzónás szennyvíztisztítás, mezőgazdasági szennyvíz, kombinált természetközeli technológiák, szennyvíztisztítás

INTRODUCTION

The management of point pollution sources is one of the important issues of environmental protection. There are many technologies available to meet the water quality standards. However, the selection among these technologies is still a challenge and requires a detailed analysis of the local situation. There is especially difficult to find the golden mean between the environmental aims and the economical opportunities.
The agriculture needs to decrease the emission of the sector in Hungary, especially at the area of water and groundwater protection. This article discusses the subsurface-flow constructed wetlands (SF-CW-s) as one of the cost effective natural sewage treatment technology. The Hungarian experiences in operation of SF-CW-s are matter of discussion because of the strict former effluent standards and the limits of this technology. This was one of the reasons why SF-CW-s are not a widely used technology in Hungary. The effluent standard values have been harmonized to EU limits from 1. January 2005 with less rigorous emission limit values for many

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components. That can give more opportunity to the low-cost (in other words: natural) wastewater treatment technologies in our country.
CW-s are used as wastewater treatment systems from the 70's, when KICKUTH (1977) published his root-zone method. These constructions are popular as wastewater treatment systems in West-Europe, USA and Australia and are getting popular worldwide. Two main different types can be designed within CW-s: (a) Free-surface flow systems (FS-CW-s), (b) Sub-surface flow systems (SF-CW-s). In FS-CW the wastewater flows through the system with free surface. In the SF-CW-s the – usually pre-treated –wastewater flows through the filter media is planted with macrophytes (f.e. *Phragmites australis*).
The first Hungarian SF-CW was constructed in Tóalmás in 1991 (SOMLYÓDY ET AL. 2002). Now there are 18 SF-CW-s in Hungary. Table 1 shows a summary of Hungarian SF-CW-s with an alignment of construction year, hydraulic capacity and type of wastewater.

Table 1 Summary of Hungarian SF-CW-s (E. Dittrich 2008)

	Settlement	Start of operation	Status of operation	Type of wastewater
1	Aparhant	2001	in operation	septic tank disposal
2	Sióagárd	2000	in operation	domestic wastewater
3	Ófalu	2006	in trial operation	septic tank disposal
4	Szépalmapuszta	1995	closed in 2001	domestic wastewater
5	Kám	1999	in operation	domestic wastewater
6	Kacorlak	1996	in operation	domestic wastewater
7	Tóalmás	1991	in operation	domestic wastewater
8	Boldog	1994	as polishing stage since 1999	domestic wastewater
9	Salgótarján	1992	closed in 2001	domestic wastewater
10	Szügy	1994	in operation	domestic wastewater
11	Kerecsend	2001	in operation	food industrial wastewater (mushroom)
12	Demjén1	2001	in operation	food industrial wastewater (germ)
13	Demjén2	2004	in operation	food industrial wastewater (winery)
14	Magyarbóly	2005	in operation	septic tank disposal
15	Magosliget	2006	in trial operation	domestic wastewater + septic t.d.
16	**Hódmezővásárhely**	**2007**	**in trial operation**	**agricultural wastewater (milk)**
17	Röjtök-Muzsaj	2007	in trial operation	domestic wastewater
18	Kaskantyú	2007	in trial operation	domestic wastewater

The TOKAI-project started in 2003. The cooperation partners are the University of Szeged, Faculty of Agriculture (Hódmezővásárhely, Hungary) and the Katholieke Hogeschool Kempen Geel (Belgium). Apropos of this project a small scale pilot plant was built in 2006. The aim of this research was to analyze the applicability of constructed wetlands to agricultural wastewater treatment at Hungarian emission limit values and environmental conditions.

MATERIAL AND METHODS

Site description

The pilot plant consists of 6 different stages: septic tank, pump chamber, subsurface vertical flow wetland, subsurface horizontal flow wetland, stabilization pond, drainfield planted with trees.
The wastewater is discharged in an existing septic tank with a volume of 7.5 m^3 (www.constructedwetlands.net). The effluent of septic tank flows into pumping chamber.

The wastewater is pumped from a pumping chamber four times per day into the distribution pipes of the wetland. The wastewater drains vertically through the medium and takes up oxygen. Collector drainage pipes on the bottom, move the pre-treated wastewater to the next stage. The wetland is planted with *Phragmites australis*, common reed, 9 plants per square meter. This wetland has effective area of 8.4 m². From top to bottom the wetland is made of a 10 cm layer of gravel 1-8, 15 cm gravel 6-12 appr. 60 cm gravel sand, 10 cm layer of gravel 1-8 and 20 cm gravel 6-12.

From the vertical flow wetland (VF-SFCW) the wastewater flows into the subsurface horizontal flow wetland by gravity. The wastewater is distributed across the width of the wetland. It flows slowly through the porous medium under the surface of the bed in a more or less horizontal path until it reaches the outlet zone. The water level appr. 5 - 10 cm below the surface is maintained. The wetland was planted with *Carex elata* tufted-sedge, 5 plants per square meter. The wetland has 14.2 m² effective surface area. Aspect ratio is appr. 2/1. The average depth is 0.6 m. In the inlet and outlet zone gravel 16-32 is used. The wetland is filled with gravel 4-16 mm.

The wastewater flows by gravity in a stabilization pond covered with *Lemna minor* or duckweed. Duckweed is a fast growing free-floating plant. Under ideal conditions it can double its biomass in 2 or 3 days. Some *Lemna* species are able to grow at temperatures as low as 1 to 3°C. The main use of duckweeds is in removing nitrogen and phosphorus from secondary treated wastewater. (www.constructedwetlands.net)

The wastewater is discharged through a drainfield, so the receiver of the treated wastewater is the groundwater after the filtration in soil matrix. The total surface area is appr. 270 m² and this area is planted with 30 poplar trees.

Water sampling and analysis

Water samples were collected by the operational employee of the university and analyzed in the lab of University of Szeged, Faculty of Agriculture. The analyzed parameters and methods are summarized in Table 2, and the sampling points are collected in Table 3. There were more problems that put back the research procedure, so the database is not detailed enough well. So there are in short supply analyzed samples. Because of this, need to continue this project in the future to make more certain about project results.

Table 2. Parameters and analyzing methods

Parameters	Methods/Instruments
COD	Photometric Method/ PC-Multidirect
TN	Photometric Method/ PC-Multidirect
NH_4-N	Photometric Method / PC-Multidirect
TP	Photometric Method / PC-Multidirect
PO_4-P	Photometric Method / PC-Multidirect
pH	Standard method / OP-264/1 pH-meter

Type and amount of wastewater

The wastewater is collected in a concrete chamber at the cow milk house. The retention time of wastewater is about 5-10 days in this tank. The wastewater is transported to the septic tank of pilot plant. Because of these reasons the characteristic of wastewater is like septic tank disposal. It has strong anaerobic conditions and higher concentration of COD, TSS, TN, and TP. Unfortunately we don't know quality of raw wastewater

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exactly, because the first sampling point is the pumping chamber of pilot plant. The amount of the transported wastewater is approximately 6-8 m^3/week. The pump loads appr. 1 m^3/day mechanically pre-treated wastewater into the first stage of CW.

Table 3. Description of sampling points

Sampling points	Description
I.	In pump chamber
II.	Effluent of vertical flow SF-CW
III.	Effluent of horizontal flow SF-CW
IV.	Effluent of stabilization pond

RESULTS

Characterization of influent

Data of each experiment and some calculated parameters are summarized in Table 4. The quality of influent (after mechanical pre-treatment in septic tank) is like than the raw wastewater of Hungarian small communities, with stronger anaerobic conditions. One time the BOD:COD ratio was measured. The value of this ratio was 1:5.3. The relatively high value indicates that the organic compounds of wastewater are probably less biodegradable than the "normally" communal wastewater. So treating of this wastewater keeping Hungarian ELV-s is not a simple challenge with a constructed wetland system. The calculated specific loading of population equivalent (PE) is 3.8 – 8.6 (Table 4.).

Table 4. Summary of experiment results at pump chamber (I. sampling point)

		COD [mg/l]	TN [mg/l]	NH_4-N [mg/l]	TP [mg/l]	PO_4-P [mg/l]	pH
measured samples	2007.09.12	624	57	28.0	24	23.5	7.2
	2007.09.19	678	71	34.2	25	24.8	7.3
	2007.09.26	625	55	45.9	18	17.6	6.8
	2007.10.03	343	85	49.8	25	24.8	7
	2008.08.18	223	65	38.4	-	22.2	-
	2008.09.02	431	-	-	-	23.5	6.92
	2008.09.11	365	98	-	37	29.0	7.18
	2008.09.18	335	-	-	-	-	7.15
calculated parameters	Min.	223	55	28.0	18	17.6	6.8
	Max.	678	98	49.8	37	29.0	7.3
	Av.	453	71.8	39.3	25.8	23.6	7.1
	PE*	3.8	6.5	4.4	8.6	-	-

* calculated by mechanical pre-treated wastewater

Experiences of vertical flow bed

The average efficiency of this stage is low to all measured components (Table 5.). Presumably the main reasons are the low specific area (1 – 2.2 m^2/PE), and the very high specific COD loading rate (53.9 g/m^2,d), and hydraulic loading rate (119 mm/d). Because of the strong anaerobic condition of raw wastewater need more effective oxygen transfer at this stage. The organic substances loading is one of the main reason of clogging processes, so it has to be limited. It can cause long term operational problems. The suggested maximum values from the literature are different: 20 gCOD/m^2,d (K.J. WINTER AND D. GOETZ, 2003), 25 gCOD/m^2,d (C.M. WEEDON 2003). There is not conformity between the high COD loading rate and the oxygen transfer capacity of this CW. It can be seem from the low specific area, and the high

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hydraulic loading rate (HLR). The maximum value of HLR should not exceed 60 mm/d at vertical flow systems (MASZESZ 2003). The efficiency of the COD removal and nitrfication can be favourable with higher specific area.

Table 5. Summary of experiment results and some calculated parameters to vertical flow bad (II. sampling point)

		COD [mg/l]	TN [mg/l]	NH_4-N [mg/l]	TP [mg/l]	PO_4-P [mg/l]	pH
measured samples	2007.09.12	283	18	17.1	-	-	7.1
	2007.09.19	620	57	38.9	17	17.0	7.1
	2007.09.26	374	-	-	23	22.8	7.2
	2007.10.03	130	39	23.3	-	-	7.3
	2008.08.18	226	51	44.9	-	22.8	
	2008.09.02	209	51	49.8	-	15.7	7.06
	2008.09.11	48	67	65.0	27	24.0	7.33
	2008.09.18	89	30	23.2	34	16.3	7.51
calculated parameters	Min.	48	18	17.1	17.0	15.7	7.1
	Max.	620.0	67.0	65.0	34.0	24.0	7.5
	Av.	247.4	44.7	37.5	25.3	19.8	7.2
	Av. efficiency (%)	45.4	37.8	4.6	2.1	16.3	-
	Specific area (m^2/PE)	2.2	1.3	1.9	1.0	-	-
	Av. loading (g/day)	453	71.8	39.3	25.8	23.6	-
	Specific loading rate (g/m^2,d)	53.9	8.5	4.7	3.1	2.8	-
	Hydraulic loading rate (mm/d)	119					

Experiences of horizontal flow bed

The average efficiency of this stage is low to most measured components (Table 6.). The efficiency of nitrification is very good considering the horizontal flow systems oxygen transfer capacity. The specific COD loading rate (17.4) is good and the specific area is better, still the average COD removal efficiency is low in this stage too. Probably the reason of this is the low biodegradable property of wastewater. The TP removal efficiency is fit with the international literature (O. URBANC-BERCIC ET AL 1995, S. O'HOGAIN 2003).

Experiences of stabilization pond

Data of each experiment at stabilization pond and some calculated parameters are summarized in Table 7. The theoretical retention time is 12 days. The removal efficiency of TN, NH_4-N and PO_4-P is very high. The removal efficiency of organic substances is adequate. This result is very interesting. The duckweed growth may cause big amount of N and P assimilation related to the biomass. The sediment aggregation is very high in the pond too. The PO_4-P assimilation rate is 0.94 g/m2,day, and the TN assimilation rate is 1.53 g/m2,day. G.B.REDDY ET AL (2001) measured the TN (3.3 – 9.3 N/m^2,d) and P uptake of duckweed biomass (0.19 – 0.59 N/m^2,d). The realistic TN:P uptake ratio is about 1:10. In our analysed pond that ratio is only 1:1.6, so biomass uptake is less important process, than the sediment aggregation.

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Table 6. Summary of experiment results and some calculated parameters to horizontal flow bed (III. sampling point)

		COD [mg/l]	TN [mg/l]	NH_4-N [mg/l]	TP [mg/l]	PO_4-P [mg/l]	pH
measured samples	2007.09.12	300	17	14.8	-	-	7.2
	2007.09.19	430	58	27.2	23	22.8	7.1
	2007.09.26	265	-	-	22	21.9	7
	2007.10.03	119	48	18.7	24	17.9	7.5
	2008.08.18	104	23	15.0	-	-	-
	2008.09.02	77	25	18.9	-	-	7.85
	2008.09.11	33	22	10.6	5.9	5.2	8.04
	2008.09.18	89	-	-	29	11.7	7.46
calculated parameters	Min.	33	17	10.6	5.9	5.2	7
	Max.	430.0	58.0	27.2	29.0	22.8	8.0
	Av.	177.1	32.2	17.5	20.8	15.9	7.5
	Av. efficiency (%)	28.4	28.1	53.2	17.7	19.5	-
	Specific area (m^2/PE)	3.8	2.2	3.3	1.7	-	-
	Av. loading (g/day)	247.4	44.7	37.5	25.3	19.8	-
	Specific loading rate (g/m^2,d)	17.4	3.1	2.6	1.8	1.4	-
	Hydraulic loading rate (mm/d)	70					

Table 7. Summary of experiment results and some calculated parameters to stabilization pond (IV. sampling point)

		COD [mg/l]	TN [mg/l]	NH_4-N [mg/l]	TP [mg/l]	PO_4-P [mg/l]	pH
measured samples	2007.09.12	125	5	4.7	-	-	7.3
	2007.09.19	74	25	8.6	-	-	7.4
	2007.09.26	135	21	12.4	22	7.2	7.8
	2007.10.03	93	15	4.7	-	-	7.8
	2008.08.18	74	6	-	-	3.9	-
	2008.09.02	75	10	0.2	-	3.9	7.89
	2008.09.11	177	18.7	0.28	3.9	3.4	8.22
	2008.09.18	171	10	4.0	6.1	4.6	7.04
calculated parameters	Min.	74	5	0.22	3.9	3.4	7.04
	Max.	177.0	25.0	12.4	22.0	7.2	8.2
	Av.	115.5	13.8	5.0	10.7	4.6	7.6
	Av. efficiency (%)	34.8	57.0	71.6	48.7	71.1	-
	Specific area (m^2/PE)	3.2	1.8	2.8	1.4	-	-
	Av. loading (g/day)	177.1	32.2	17.5	20.8	15.9	-
	Specific loading rate (g/m^2,d)	14.8	2.7	1.5	1.7	1.3	-
	Hydraulic loading rate (mm/d)	83					

Operational experiences and Hungarian ELV-s

The efficiencies are very good (Table 7.) for the complete system especially if it is noted that values do not contain the removal of mechanical pre-treatment. The elimination of nitrogen forms is positively high. The removal efficiency of COD is fit to the international literature. The wastewater low biodegradable condition shows that this value is better than suitable. The pilot plant hadn't overrun the ELV for COD, TN and NH_4-N. The TP removal efficiency is adequate too, but not enough to keep the

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Hungarian ELV for free surface water. The technology need to be developed to increase TP removal efficiency. Some technical opportunity:

- Use iron salts at mechanical pre-treatment stage
- Use iron salts in horizontal flow bed or in pond
- Use clay in horizontal flow bed
- Regular harvesting duckweed
- Regular sediment taking out from the pond

At this technology the most favourable solution can be the using iron salts at mechanical pre-treatment stage, because it decreases the COD and TSS loading of vertical flow system and decreases the long-term clogging problems.

Table 7. Comparison of Hungarian ELV and effluent quality

Component	ELV (mg/l)	Quality of effluent from pond			Total efficiency (%)
		min.	max.	av.	
COD	300*	74	177	115.5	74.5
NH_4-N	20*	0.22	12.4	5	87.3
TN	55*	5	25	13.8	80.7
TP	10*	3.9	22	10.7	58.7

*ELV under 600 PE (Hungarian law number: 28/2004 (XII.25) KvVM r.)

CONSCLUSIONS

The efficiencies are very good (Table 7) for the complete system especially if it is noted that values do not contain the removal of mechanical pre-treatment. The elimination of nitrogen forms is positively high. The removal efficiency of COD is fit to the international literature. The wastewater low biodegradable condition shows that this value is better than suitable. The pilot plant hadn't overrun the ELV for COD, TN and NH_4-N. The TP removal efficiency is adequate too, but not enough to keep the Hungarian ELV for free surface water. The technology need to be developed to increase TP removal efficiency. The most favourable solution can be the using iron salts at mechanical pre-treatment stage. The effectiveness of the plant can increase with higher specific area of VF-SFCW. Because of the sporadic data, need to make a more detailed measuring program focused on the long-term and winter time processes.

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