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Wastewater treatment in wetlands: Theoretical and practical aspects

Treatment of wastewater from small slaughterhouse in hybrid constructed wetlands systems

Marek Soroko

Institute for Land Reclamation and Grassland Farming at Falenty, Regional Division in Wrocław, 7 Berlinga Str., 51-209 Wrocław, Poland
e-mail: dob@dob-imuz.pl

Abstract

Suitability of CW systems for treatment of wastewater from small slaughterhouse of pigs was tested. In the first part of the experiment, a system comprising two VF (vertical flow constructed wetlands) and an HF (horizontal flow constructed wetlands) was used. In the second part, VF + HF system was used with recirculation of outflow from VF to sedimentation tank in the range 100 to 200%.

The experiment showed that sand and gravel beds of VF can be very effective in removal of organic substances, TSS and NH_4-N from strong wastewater, BOD_5 reaching an average of 2500 $gO_2 \cdot m^{-3}$, TSS – 560 $g \cdot m^{-3}$, NH_4-N – 400 g $N \cdot m^{-3}$, and N_{tot} – 500 $gN \cdot m^{-3}$. The hybrid system of 2VF + HF removed only 78.2% N_{tot}. Application of recirculation, depending on the extent, raised this index to as high as 85.7 – 96.6%. Unexpectedly low was the effectiveness of denitrification in gravel bed of HF.

Key words: abattoir, effluent, reed beds, organic substances, suspended solids, nitrogen, denitrification, recirculation.

1. Introduction

Wastewater from small slaughterhouses is considerably more strong than domestic sewage or wastewater from large meat-processing plants. This particularly applies to wastewater from small slaughterhouses of pigs. Its BOD_5 often reaches about 3000 g $O_2 \cdot m^{-3}$, TSS concentration reaches up to 700 $g \cdot m^{-3}$ and NH_4-N as well as N_{tot} to about 500 and 600 $gN \cdot m^{-3}$, respectively. This means that up to 99% organic substance expressed in BOD_5 and over 95% NH_4-N as well as N_{tot} has to be removed from it during treatment.

Beds with vertical flow – VF are characterised by a huge possibilities with respect to aerobic processes. Wastewater flows in them in cycles through unsaturated soil, enabling intensive aeration of the beds through diffusion and convection. Their high effectiveness in removal of organic substances and ammonia nitrogen is referred to by Weedon (2004), Cooper (2004) and Kayser, Kunst (2004).

A more difficult task for CW systems is satisfactory removal of total nitrogen from wastewater of small slaughterhouses. Efficiency of VF in its elimination is assessed according to different sources as 20 – 60%. Therefore, selection of this system requires additional solutions ensuring significant improvement in effectiveness of denitrification processes. These solutions most often include, according to Platzer (1998), recirculation of outflow from VF to sedimentation tank and expansion of the system by a bed with horizontal flow – HF. In this study we tested the influence of such solutions on removal of nitrogen from waste-

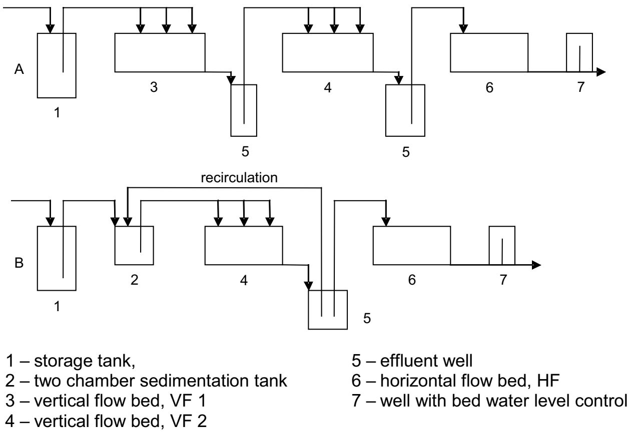

Fig. 1. Sketch of the experimental hybrid constructed wetland system in part A and part B of the experiment.

water of small slaughterhouse of pigs while applying diversified technological parameters. We also tested effectiveness of VF and hybrid systems in removal of organic substances from the wastewater expressed in BOD_5, COD and TSS.

Table I. Average hydraulic loading rates and temperatures in the system during the first part (A) of experiment.

Input to VFCW 1 ($m^3 \cdot d^{-1}$)	Hydraulic loading rate (d mm^{-1})			Water temperature (°C)		
	VF 1	VF 2	HF	min	max	mean
0.15	15	28	13	4.0	17.0	12.6

2. Materials and methods

Tested in the first part of the experiment (A) was the experimental system consisting of two beds with vertical flow – VF 1 and VF 2, and a bed with horizontal flow – HF (Fig. 1). Areas of the beds were 10 m^2, 5 m^2 and 10 m^2, respectively. The first two beds were 0.9 m high and were filled from top with layers of sand (d_{10} = 0.3 mm), fine gravel (d_{10} = 1.0 mm) and sand (d_{10} = 0.22 mm). The beds were overgrown with common reed (*Phragmites australis*). The wastewater was brought from pig slaughterhouse and held in storage tank of capacity 4 m^3, serving simultaneously as sedimentation tank. From here, it was pumped onto the beds in three equal rates per day. Part A of the experiment lasted from August 2002 to July 2003 with a break during the period from December to March.

In the second part of the experiment (B), the bed VF 1 was withdrawn from the system (Fig. 1). Recirculation of outflow from VF 2 to two-chamber sedimentation tank of volume 0.5 m^3, was undertaken. The same cycle of wastewater flow onto the beds as in part A, was maintained. Part B covered the period from September to November 2003 with 100% recirculation, period from May to August 2004 with 200% recirculation and period from September to December 2004 with 150% recirculation.

Samples were drawn in intervals of 2-3 weeks at outlet from sedimentation tank as well as at outlets from individual beds. Samples from beds were drawn as average from whole-day outflow accumulated in the tanks. Scope of analyses covered BOD_5, COD, TSS, TKN, NH_4-N and NO_3-N. They were performed using methods according with Catalogue of Polish standards (Zestaw Norm 1999).

3. Results

Part A

In this part of the experiment, fixed quantity of wastewater Q = 0.15 $m^3 \cdot d^{-1}$ was introduced into the system (Table I). This value was obtained using Cooper's formula (Cooper 1999):

$$[(BOD_{5in} - BOD_{5out}) + (NH_4\text{-}N_{in} - NH_4\text{-}N_{out}) 4.3]Q = OTR\,A \quad (1)$$

where:
Q – flow rate, A – VF area, OTR – oxygen transfer rate.

Assumed: BOD_{5in} – 2500 $gO_2 \cdot m^{-3}$, BOD_{5out} – 25 $gO_2 \cdot m^{-3}$, NH_4-N_{in} – 400 $gN \cdot m^{-3}$, NH_4-N_{out} – 20 $gN \cdot m^{-3}$, OTR – 40 $gO_2 \cdot m^{-2} \cdot d^{-1}$ and A – 15 m^2. Value of OTR was taken higher

Table II. Average (± standard deviation, n = 12) content of BOD_5, COD, TSS, NH_4-N, NO_3-N and N_{tot} at the sampling points during the first part (A) of experiment.

Parameter	InletVF 1	Outlet VF 1	Outlet VF 2	Outlet HF
BOD_5, $gO_2 \cdot m^{-3}$	2452 ± 650	6 ± 2	4 ± 4	4 ± 3
COD, $gO_2 \cdot m^{-3}$	3188 ± 860	150 ± 39	108 ± 16	100 ± 13
TSS, $g \cdot m^{-3}$	561 ± 177	49 ± 27	34 ± 19	34 ± 23
NH_4-N, $g \cdot m^{-3}$	391 ± 84	16 ± 13	5 ± 6	4 ± 3
NO_3-N, $g \cdot m^{-3}$	15 ± 14	151 ± 49	128 ± 42	111 ± 70
N_{tot}, $g \cdot m^{-3}$	494 ± 98	184 ± 43	145 ± 42	129 ± 48