VERTICAL FLOW CONSTRUCTED WETLAND TREATING HIGH STRENGTH WASTEWATER FROM SWINE MANURE COMPOSTING

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ABSTRACT

Intensive swine farms generate high volumes of manures that not always have near surfaces of culture and sufficient extension for their direct reutilization to the soil. An integral solution looking for the recovery of the fertilizer elements is the joint composting of diverse solid wastes generated in the installation or in the near rural area (solid manure, crop waste and forest and agro-industrial wastes), where the composting material was watered with liquid manure. In this system, a high percentage of the water contained in the liquid manure is evaporated while nutrients are retained in the compost produced. In this way, about 80% of liquid manure may be removed in the compost system, while the remaining volume generated as leachate from the compost piles was treated in a pilot vertical flow constructed wetland (VFCW). Results obtained indicated that the VFCW removed in general more than 94% of influent load reaching the following effluent concentrations (mg/L): 116 (TSS), 626 (TCOD), 13 (BOD_5), 6 (NH_3-N), 36 (TKN).

MATERIALS AND METHODS

The pilot VFCW system (Figure 1) was a 2×3×1.2 m (length×width×height) basin built *in situ* and lined with rubber membrane. A drainage bed, 20 cm thick, made of 10-20 mm granitic gravel was placed at the bottom of the VFCW and equipped with drainage pipes 70 mm in diameter. Above the drainage bed was a filter layer, 80 cm thick, made of 0-6 mm granitic gravel. The influent distribution pipes were placed over the filter. The system was planted with *Phragmites australis* but only a few small plants were present during the operation period.

Wastewater drained by gravity from the VFCW to the recycling tank (1000 L of capacity) where a pump was placed. The influent volume (from 100 to 300 L) was manually added to the recycling tank once a week. In this manner, the high strength influent wastewater was diluted with the treated effluent (about 600 L). Before loading the tank, a volume of effluent was removed in order to maintain de liquid volume in the tank at the level of 600 L. During high evaporation periods (first two months of operation) the volume of effluent drained out was lower than the volume of influent loaded, and the opposite occurred during raining periods. The recycling pump operated intermittently, delivering a high flow of about 360 L in only 15 minutes and then remained stopped for an overall cycle time of 6 hours.

Periodically the pump operation was checked and the effluent flow was measured for an entire dosing cycle in order to obtain the effluent flow profile.

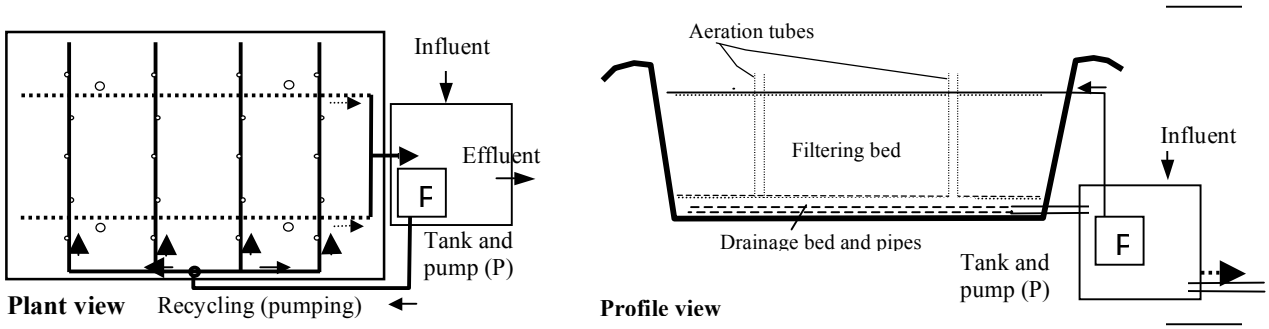

Figure 1. Plant and profile views of the VFCW system used to treat swine manure

The constructed wetland was operated for more than 200 days. During this time, a total of 24 influent and effluent samples were collected and analysed for conductivity, total and volatile suspended solids (TSS, VSS), total and soluble chemical oxygen demand (TCOD, SCOD), biological oxygen demand (BOD_5), ammonium nitrogen and total Kjedhal nitrogen. Determinations *in situ* were carried out for pH, temperature (T), dissolved oxygen (DO) and oxidation-reduction potential (ORP). Analyses were carried out following the Standard Methods (APHA, 1995).

RESULTS

Table 1 shows the characteristics of influent and effluent VFCW streams. The wastewater treated has a high load in terms of TSS and TCOD. Although the average values for BOD_5 and ammonium or NTK at the influent were lower than expected, in general these concentrations were higher than municipal wastewater concentrations by a factor of about 10 to 20. Actual influent concentration to the VFCW were reduced after the dilution of the influent in the recycling tank by a factor of about 2 to 6 times (3.5 times in average)

Effluent concentrations were in general very low, indicating that the VFCW carried out an intensive process of particulate and soluble organic matter retention and removal, together with the removal of the major part of ammonium and NTK. Provisional data also indicated that nitrate concentration was reduced (data not shown), at least during the last weeks of the investigation. Furthermore, the VFCW was highly oxygenated as indicated by the high DO concentrations and positive ORP values.

Table 1. Influent and effluent characteristics for the overall operational period

	pH	Conductivity	T	OD	ORP	TSS	VSS	TCOD	SCOD	BOD_5	NH_3-N	TKN
Influent												
Average	7.80	7066	nd	nd	nd	2549	2108	10640	6878	1382	212	599

Est. Dev.	0.49	2193	nd	nd	nd	1896	1544	6536	4847	1012	233	379
Maximum	8.60	10030	nd	nd	nd	6980	5360	24400	14933	3780	754	1182
Minimum	6.50	2200	nd	nd	nd	203	150	1034	295	123	14	67
Effluent												
Average	5.36	1673	17.6	6.2	162	116	95	626	522	13	6.29	35.8
Est. Dev.	1.18	1212	4.7	1.4	91	126	105	408	330	13	8.63	26.5
Maximum	8.30	4260	23.6	8.3	346	388	323	1413	1300	51	24.29	84.9
Minimum	4.10	306	8.5	3.4	16	7	8	10	30	0	0.10	3.0

Concentration in mg/L, Conductivity in microS/cm, ORP in mV, T in °C. Data number: 24

Table 2 shows the surface loading rates applied to the VFCW during different operational periods and the removal efficiency reached. Hydraulic loading rate (HLR) range from 2 to 7 mm/d (data not shown), although the overall HLR (including recirculation) resulted in about 240 mm/d. TSS SLR ranged from 4 to 15 g TSS/m^2·d and was high in comparison to usually values proposed for subsurface CW. TCOD SLR, ranging from 18 to 70 gTCOD/m^2·d, was comparable to usually applied values in VF CW treating municipal or domestic wastewater. On the other hand, BOD_5 and nitrogen SLR were lower than the capabilities of this kind of CW.

In these conditions, the VFCW removed in general more than 90% of influent load. Overall removal efficiencies were 95% TSS, 94%TCOD, 99%BOD_5, 97%NH_3 and 94%TKN. Only TSS and TCOD removals significantly decreased during period II, which was in part due to a sudden decrease in influent concentration together with a higher effluent TSS concentration.

Table 2. Surface loading rate and removal efficiency for different operational periods

			SLR (g/m^2·d)		
Period (days)	TSS	TCOD	BOD_5	NH_3-N	TKN
I (0–74)	14.7	70.3	6.3	0.8	3.4
II (75–156)	4.0	19.5	3.2	0.3	1.7
III (157–205)	9.2	17.9	4.8	1.1	1.6
Overall	8.8	36.2	4.6	0.6	2.1
			Removal efficiency (%)		
Period (days)	TSS	TCOD	BOD_5	NH_3-N	TKN
I (0–74)	99.1	97.8	99.1	97.1	98.7
II (75–156)	74.6	78.2	98.6	99.3	90.6
III (157–205)	98.6	93.2	99.2	96.6	92.0
Overall	95.5	94.1	99.0	97.0	94.0

Figure 2-left shows a typical effluent flow profile (obtained at day 29 of operation) for the main operational conditions applied (dosing of about 360 L during a short time of about 15 minutes and a cycle time of 6 hours). A maximum flow value of about 6 L/min was reached at about 30 minutes after the dosing started. Figure 2-rigth shows the evolution of the maximum "after dosing" effluent flow through the operation time. After day 138 (period II), the infiltration capability of the gravel bed progressively decreased as indicated by the reduction of the maximum effluent flow. At about day 165 (period III) the system was clogged and large pounding on bed surface was observed. On day 172, the system was subjected to a resting period of 2 weeks, and restarted again. The infiltration capability was recovered but partial pounding rapidly appeared, although the high treatment efficiency was maintained during this period (III). The permanent presence of partial pounding suggests that intermittent operation with treatment and resting alternating periods could be necessary.

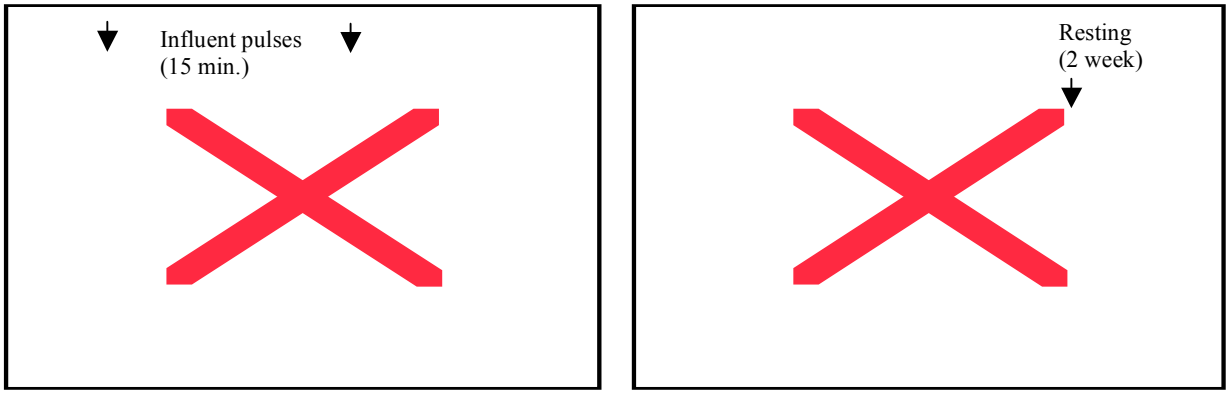

Figure 2. Typical effluent flow profile (left) and maximum effluent flow after dosing (right).

CONCLUSIONS

A vertical flow CW provided with effluent recycling allowed a high percent contaminant removal from high strength swine wastewater and a high quality effluent. However, applying high surface hydraulic organic and nitrogen loading rates without clogging will require previous TSS removal or the intermittent operation with treatment and resting alternating periods.