A PIG SLURRY PURIFICATION OPTION: CONSTRUCTED WETLAND.

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1 INTRODUCTION

Nowadays pig slurry management is a very important environmental issue, because pig industry has turned into an intensive production with pig confinement without soil contact. The most traditional way for slurry removal is its application as soil amendment (Villar et al., 2004). Unfortunately, most of the farmers do not have enough arable land near their farms to apply that residue in the proper environmentally sustainable doses according to the water and soil protection EU directives.

As a result, it is essential to find technologies able to recycle this waste, solving pig slurry management problems. In this sense, constructed wetlands systems are among the most proven low cost wastewater treatment (Kadlec and Knight, 1996). At the moment good efficiencies in purification have been obtained treating domestic wastewater (Asuman et al., 2004) and dairy parlor wastewater (Mantovi et al., 2002), which are wastes with lower organic and pollutant charge than pig slurry. Therefore, if certain construction and operation modifications are included, wetlands result in an excellent system for pig slurry treatment. With this system it is possible to get an odourless supernatant similar to horin and suitable to use as fertilizer in arid areas.

The construction of artificial systems with emergent plant species to treat sewage has its origin during the fifties in Germany, where most of the development of this kind of treatment has been carried out. Nevertheless, over the last decade, countries such as Great Britain, U.S. and Australia are making great efforts to research into this field (Pérez-Olmedilla and Rojo, 2000). In fact, the use of these constructed wetlands as natural purifiers is widespread throughout the territory of Great Britain (Griffin and Upton, 1999). In developing countries as India or the Czech Republic (Vymazal, 1996) have recently proliferated of this kind of wastewater treatment due to their effectiveness and low cost compared to conventional ones. It is also important to consider the number of recent investigations in China (Zhang et al., 2009).

In this context, the objective of this study were i) to evaluate the depurating efficiency of pig slurry in an artificial wetland system, built according to the parameters considered as optimal, based on several previous research (Caballero et al., 2009); ii) to find out the optimum hydraulic retention time (HRT) for these processes; and iii) to reduce nutrients, solids, ions, bacteria and pollutants in pig slurry, obtaining a suitable liquid for use in fertilization.

2 MATERIALS AND METHODS

This study was developed in an experimental farm located in La Hoya (Lorca), a high productive pig industry area (Murcia- southeast Spain), which also suffers from water deficit. The mean annual temperature is 16.8 ºC, the mean annual precipitation is 238 mm and the potential evapotranspiration surpasses 1100 mm per year. This farm is located in a vulnerable zone for nitrogen fertilization (Directive 91/676/CE).

Pig slurry wastewater from a close farm was treated using a set of technical treatments as follows: 1) Raw pig slurry is stored in a underground pit of 150 m^3 of capacity. 2) Raw pig slurry goes to a mechanical separator which removes the solid phase with the highest particle size. 3) This solid phasel is dried-out and used directly as fertilizer. 4) Filtered liquid phase goes to a thicken sludge system, where the sludge obtained is dried-out too and the filtered wastewater obtained is disposed into a main tank (20 m^3) during several days. During this time more solid material sediments in the bottom of the tank. 5) Depending on HRT, wastewater from main tank (income slurry) is conducted to three horizontal flow subsurface constructed wetlands (HSFCW). *Phragmites australis* was recently planted there (April 2009) with a density of 10 plants per m^3. HRTs were 2, 3 and 4 weeks in HSFCW1, HSFCW2 and HSFCW3 respectively. All of them are same-sized (27x2.5x1 meters), have a cm 20 cm surface sand layer and a 80 subsurface gravel layer. These characteristics make them able to treat 8 m^3 of pig slurry per charge. 6) Purified wastewater from each HSFCW is disposed in a tank under anaerobic conditions. After 17 months of operation, the amount of pig slurry treated was 780 m^3.

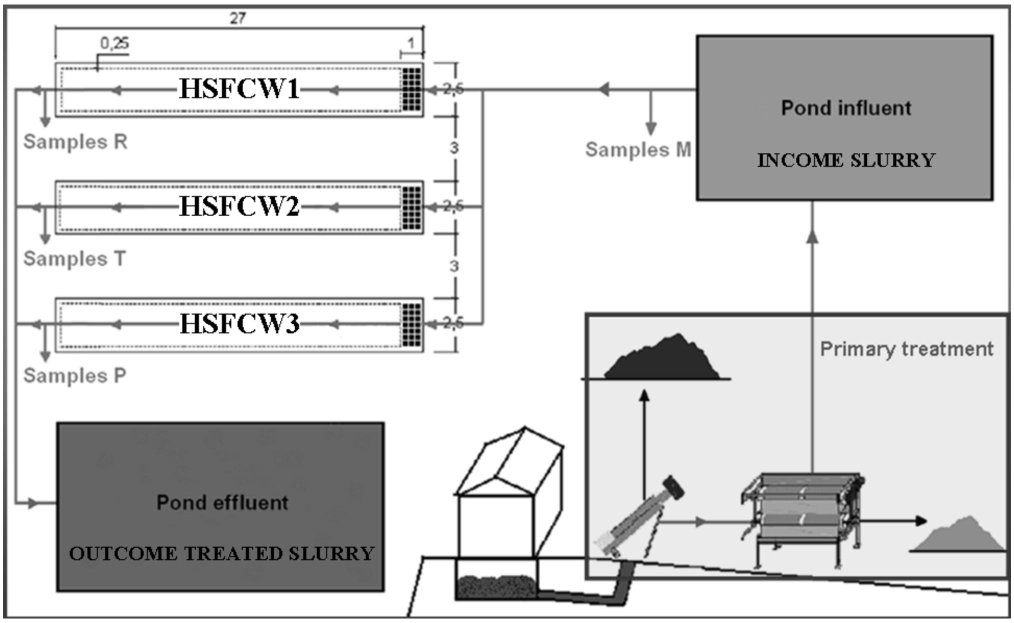

FIGURE 1 **Diagram of the set of technical pig slurry treatments.**

To evaluate the efficiency of the system, physic-chemical analyses (Table 1) were carried out on the different HSFCW income and outcome flows, depending on the different HRT, according to APHA (1998) and DIN (1980). Purifying efficiency (E) was calculated by the percentage of the difference between income and outcome values.

Statistical analyses were performed using the software SPSS 17.0. No normality was assured for any analyzed variable. Thus, for each analytical set of 189 samples and for each HRT a Kruskal-Wallis test and a U Mann-Whitney multiple comparisons test were performed, to show significant differences between each HRT.

3 RESULTS AND DISCUSSION

Table 1 shows the mean values and standard deviation of pig slurry income to the HSFCW, the mean values of the outcome treated slurry and the treatment efficiency, for the different HRT.

Using all data, the HRT effect has been evaluated (2, 3 and 4 weeks) on the studied parameters (variables) to assess the purifying efficiency. Thus, it is possible to distinguish 3 different parameters groups, depending on their removal over the time:

- Group 1: Variables not significantly different depending on HRT. That is, HRT is not a factor that affects the studied variables. They appear in table 1 with square-chi ns: TSS and SS.
- Group 2: Variables which show moderate mean differences among HRT. That is, time affects moderately the purification efficiency. They appear in table 1 with **: COD, all species of nitrogen and Phosphorous.
- Group 3: Variables which show high mean differences, depending on HRT. That is, time is important in purification efficiency of the system. They appear in table 1 with ***: Eh, pH, EC, TDS and BOD.

As it is shown in Table 1, in HSFCW 3 (HRT 4 weeks) is achieved the best purification efficiency in all the parameters. So, this HRT is considered as the optimum balance between purified volume per unit of time and elements removal efficiency. As a consequence, all the following data discussion will be referred to HSFCW 3.

Regarding analyzed parameters in Table 1, outcome treated slurry shows negative values of redox potential, which indicate reducing and anaerobic conditions. The pH is ranged from 7.0 to 7.9, so is according to the range of 6.5-8.4 from irrigation water quality FAO Guidelines (1987). Electrical conductivity after the set of treatments was 15.7 dS m^{-1} (17% of removal), which is higher than the limit value of 3 dS m^{-1} recommended by the FAO Guidelines. Total dissolved solids after the treatments was 12581 mg L^{-1} (E=17%). Results obtained show important removals of total suspended solid (E=77%), sedimentable solids (E=almost 100%), biochemical oxygen demand (E=72%) and total phosphorus (E=33%).

Regarding to nitrogen, the maximum fertilizer amount that can be applied in a vulnerable zone is 170 kg N ha^{-1} $year^{-1}$ (Directive 91/676/CE). Assuming a pig slurry with a mean value of 4.5 kg N m^{-3}, the maximum amount which could be used for fertilization is 38 m^3 per ha and year. In this research, nitrogen decreased to 1371.3 mg L^{-1} (1.37 kg N m^{-3}) (E=42%), so the maximum amount of the outcome treated slurry applied to soil is 124 m^3 per ha and year. Therefore, these treatments let farmers use a higher amount of this effluent for fertilization, decreasing the environmental problems caused by raw pig slurry application. On the other hand, nitrate nitrogen decreased from 38 to 19 mg L^{-1}, which is according to 50 mg L^{-1} limit value for irrigation water quality FAO Guidelines (1987).

TABLE 1 **Mean values and standard deviation of different proprieties of income and outcome pig slurry, and depuration efficiency – E (%) of different proprieties of outcome treated pig slurry in each HSFCW.**

Parameters	Income pig slurry	Outcome treated pig slurry						Square-chi
		HSFCW 1	E	HSFCW 2	E	HSFCW 3	E	
Potential redox - Eh (mV)	-383 ± 103	-331± 87 a	15	-319 ± 96 a	11	-269 ± 80 b	21	13.16**
pH	7.45 ± 0.25	7.35 ± 0.32 a	1	7.52 ± 0.38 b	-1	7.44 ± 0.41 b	0	11.2**
Electrical conductivity - EC (dS m^{-1})	19.1 ± 3.4	18.4 ± 3.6 a	3	16.6 ± 4.1 b	9	15.7 ± 4.1 b	17	11.66**
Total suspended solids-TSS (mg L^{-1})	28244 ± 26829	9754 ± 8189	57	8642 ± 6628	66	5489 ± 4007	77	5.18 ns
Sedimentable solids - SS (mL L^{-1})	mud	7.9 ± 32.3	≈ 99	3.3 ± 11.2 b	≈ 99	0.2 ± 0.5	≈ 99	0.18 ns
Total dissolved solids - TDS (mgL^{-1})	15258 ± 2744	14680 ± 2914 a	3	13271 ± 3288 b	9	12581 ± 3292 b	17	11.66**
Biochemical oxygen demand – BOD (mg L^{-1})	8543 ± 4158	4789 ± 3191 a	41	2869 ± 2134 b	61	2336 ± 1484 b	72	11.53**
Chemical oxygen demand – COD (mg L^{-1})	11656 ± 3352	9752 ± 3807 a	18	7192 ± 3246 b	33	6778 ± 3513 b	40	16.29***
Total phosphorus - TP (mg L^{-1})	30.5 ± 11.5	28.4 ± 6.3 a	3	21.8± 5.0 b	26	19.0 ± 6.0 b	33	37.19***
Kjeldahl N. - NK (mg L^{-1})	2629.0 ± 1405.2	1991.2 ± 697.3 a	17	1640.1 ± 640.8 b	31	1371.3 ± 520.7 c	42	19.68***
Ammonium N.- N-NH_4^+ (mg L^{-1})	2028.4 ± 857.0	1546.3 ± 509.9 a	18	1352.4 ± 477.5 ab	26	1212.8 ± 436.5 b	35	10.79**
Organic N. - ON (mg L^{-1})	759.9 ± 589.9	445.0 ± 256.3 a	37	371.2 ± 312.6 a	47	158.5 ± 120.6 b	75	26.49***
Nitrate N. - N-NO_3^{--} (mg L^{-1})	39 ± 8	28 ± 8 a	28	25 ± 10 a	35	19 ± 6 b	49	19.62***
Number of samples	72	54		36		27		

Square-chi. *, ** and *** indicate significance at $P<0.05$, $P<0.01$ and $P<0.001$, respectively. ns: non significant. “a”, “b” and “c” indicate the existence of significant differences ($P<0.05$) among HSFCW mean values after U Mann-Whitney multiple comparisons test. The same letters indicate no significant differences among HSFCW mean values. Means with no letter are not significantly different ($P>0.05$).

4 CONCLUSIONS

We conclude that the system is getting a high efficiency in solid, nutrients and organic matter removal. In addition, good results in other parameters monitored like microbiology and removal of heavy metals have been obtained. In this sense, we consider this effluent suitable to use for fertirrigation in properly doses according to legislation and crop requirements. However, it was not possible to significantly decrease the electrical conductivity, therefore, we suppose that the system is not efficient enough yet, so the outcome treated slurry obtained is not purified enough and might produce salinization of soils. It is expected to get better efficiency regarding electrical conductivity in further growth stages of *P.australis,* according to other research that show that the purification capacity of the system depends on the roots rhizosphere (Gersberg et al., 1983; Peterson and Teal, 1995; Brix, 1997).

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