PIG SLURRY SEPARATION AND FILTRATION EFFICIENCY FOR ON-FARM WATER REUSE

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1 INTRODUCTION

The main problem of livestock waste, in particular pig slurry, is the concentration of its production in certain geographic areas overcoming the absorption capacity of the local environment. The excessive application of livestock waste into the soil contributes to water pollution. In addition, the high presence of nutrients contributes to the contamination of soil. It is also important to highlight the impact caused on the atmosphere such as the production of unpleasant smells, gaseous emissions of NH_3, H_2S, NO_x and volatile organic compounds, which contribute to acid rain and greenhouse effect, and of methane, one of the most important gases on climate change.
Most of the pig farms in the Spanish Valencian Region are small and medium sized (MAP, 2002). At the same time, the scarcity of water resources combined with the seasonal nature of torrential rainfall, classify Valencia as a semiarid region that fully justifies the adoption of slurry management systems that, in addition to being environmentally friendly and economically feasible, provide available water. One of the most important benefits to be gained promoting a slurry management in a sustainable manner is to recover valuable products from slurry compared to its elimination. Physical solid-liquid separation has usually been used as a complementary treatment for biological digestion, thermal dehydration, or for the reuse of the effluent. It has been reported some physical systems for slurry treatment, such as centrifuges and screw presses, known as mechanical separators, which produce an effluent able to be spread on arable lands or to be reused at the farm (Melse and Verdoes, 2005).
The general aim of this work is to develop and evaluate a slurry treatment system based on the solid-liquid separation consisting of a screw press and a decanter centrifuge in addition to a slow sand filter as a means to produce a suitable liquid effluent for on-farm reuse.

2 MATERIALS AND METHODS

Figure 1 shows a diagram of the system of solid-liquid separation (S/L) and filtration installed on the experimental farm of IVIA. Two separation devices have been tested and evaluated: a screw press (5.5 kW and mesh 0.5 mm) and a decanter centrifuge (5500 rpm and regulation rings of 146 mm diameter). The resulting liquid effluent is pumped to a sedimentation tank of 1000 L, from which is conveyed through a regulation tank that feeds the sand filters tested. The regulation tank is an upflow of 36 cm of gravel (55 cm diameter and 115 cm depth), and it serves as prefilter.

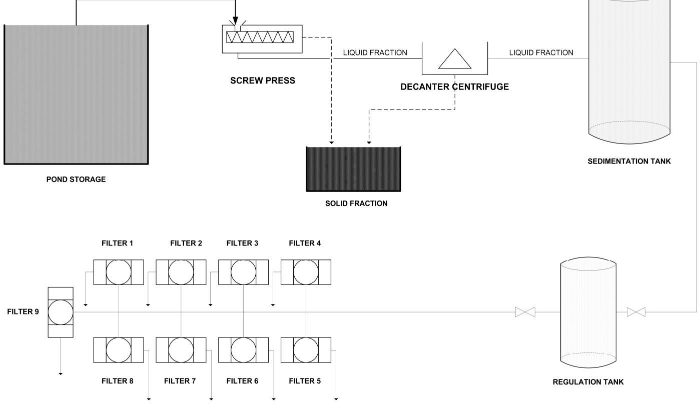


FIGURE 1 **Outline of the solid-liquid separation and filtration process tested**

To characterize the type of the pig slurry (Table 1), physical and chemical analyses before performing the treatments (raw manure) have been realised according to the official methods of analysis of the Ministry of Agriculture, Fisheries and Food (1999), the standard methods UNE and ISO, and the standard practices of analysis (NTP) accredited by the ENAC (Spanish National Accreditation Entity).

TABLE 1 **Characterization analysis of the raw manure conducted in four samples**

Sample	BOD_5 mg O_2/L	COD mg O_2/L	N_{TK} mg/L	N_A mg/L	NO_3^- mg/L	P_T %	PO_4^{3-} mg/L	TS %	SS mg/L	VS %
1	32000	77700	4900	3400	12	1.70	1630	4.2	26000	44
2	29000	79300	4700	3200	<10	1.00	800	4.0	28000	68
3	29000	43500	4800	3100	<10	2.63	1970	3.8	28000	67
4	31700	55100	4800	3000	<10	2.24	1830	4.9	39000	72
Mean	**30425**	**63900**	**4800**	**3175**	**<10**	**1.89**	**1558**	**4.2**	**30250**	**63**

From this characterization of the raw manure it can be pointed out that it does not correspond to any of the individual characterizations according to the different categories of farms (production of piglets, feedlots, etc.) since it is an experimental farm in which they all coexist. In this case, the relationship BOD/COD is almost 0.5, then it can be concluded that the slurry presents a satisfactory degree of biodegradability.

In order to evaluate the solid-liquid separation effectiveness samples were analyzed for total solids, volatile solids, suspended solids, BOD_5, COD, total Kjeldahl nitrogen, ammonia nitrogen, total phosphorus and nitrates; they were analyzed according to the methods specified in MAPA (1999), UNE, ISO and NTP.

Moreover, to assess the efficiency of the mechanical separation equipment, the energy consumption and the time invested to separate a volume of slurry of 1500 L were measured. Two modes of work in each separator and their combinations were considered resulting in the six treatments listed below:

- T1: Screw Press (60 kg pressure on the cap).
- T2: Screw Press + Centrifuge at 50% maximum flow rate (1.25 L s-1).
- T3: Screw Press + Centrifuge at 100% maximum flow rate (2.08 L s-1).
- T4: Screw Press with overpressure (23 kg extra pressure on the cap).
- T5: Screw Press with overpressure + Centrifuge at 50% maximum flow rate (0.9 L s-1).
- T6: Screw Press with overpressure + Centrifuge at 100% maximum flow rate (2.08 L s-1).

To study the effect of granular media on the effectiveness of the filtration treatment it has been designed Treatment 7. It has been built 9 filter columns (30 cm diameter and 100 cm depth), and they were filled with sand from different effective sizes to a height of 60 cm, according to the recommendations of the USA Environmental Protection Agency (USEPA, 1999). Treatment 7 was divided into three treatments corresponding to the three different types of sand sizes evaluated: Treatment 7 (T7): Treatment 6 + sand filters. T7.1: 0.7 mm, T7.2: 0.4-0.8 mm, T7.3: 1.4-2.5 mm. Each one of these columns receives a daily load of 14.4 L of pretreated effluent in twelve doses.

The behaviour of each type of column has been characterised analysing the output effluent of each one of the column filters. In each sample was measured pH and EC (APHA *et al.*, 2005). It has also been obtained the particle size distributions with a series of sieves of decreasing size (Moller *et al.*, 2002).

3 RESULTS AND CONCLUSIONS

Table 2 presents a summary of energy consumption, energy efficiency and the elimination of dry matter for each one of the treatments. Figure 2 shows the granulometry analysis carried out in the raw manure and the effluent from all treatments.

In view of these data one can deduce that the screw press is much more efficient with more pressure on the cap (T4 compared with T1). However, it is interesting to note that in the case of T4 the raw slurry contained more total solids, moreover this amount of solids corresponded to the larger ones (Figure 2), which are the ones that this separator remove from the liquid fraction (0.5 mm mesh).

TABLE 2 **Energy efficiency of the treatment of the solid-liquid separation treatments**

Treatment	Energy consumption (kWh/Tm)	Time	Dry matter (ST %)	Dry matter eliminated (g/kg)	Energy efficiency (kg/kWh)	Energy efficiency in each stage (kg/kWh)
Raw manure			4.00			
T1	0.22	6' 40"	3.70	3.0	13.43	13.43
T2	1.39	20' 9"	2.95	10.5	7.54	6.41
T3	1.33	14' 40"	3.05	9.5	7.16	5.89
Raw manure			4.45			
T4	0.18	6' 12"	3.95	5.0	27.27	27.27
T5	1.88	24' 48"	2.75	17.0	9.04	7.07
T6	1.81	14' 12"	2.90	15.5	8.56	6.45

Treatments T5 and T6 eliminated more solids than T2 and T3 did, with an energy consumption that is only slightly higher. These treatments are therefore more energy-efficient. One might think that the great efficiency of T4 (27.27 kg kW^{-1} h^{-1}) has favourably conditioned the efficiencies of treatments T5 and T6. It has then been considered the efficiencies of the second stage of the solid-liquid separation process independently (Energy Efficiency in each Stage in Table 2). It is noted that the second stage of the treatment, that's to say the decanter centrifuge, it is still more efficient in T5 and T6 treatments, which can be explained by the greater amount of total solids and their size distribution or granulometry of the effluent used. These data also show that the decanter centrifuge is more efficient when working at 50% flow rate (T2 and T5) than working at maximum flow rate (T3 and T6).

Table 3 shows the reduction percentages obtained for the parameters analyzed in each treatment. As can be seen the removal of nitrogen in all treatments is not high, which limits the amount of manure that can be spread out to the natural environment.

TABLE 3 **Percentages of reduction of the parameters analysed**

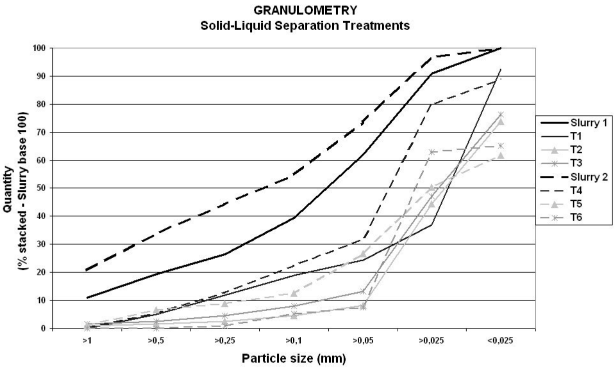
Treatment	BOD_5 %	COD %	N_{TK} %	N_A %	P_T %	TS %	SS %	VS %
T1	9.4	3.9	4.1	11.8	--	16.7	3.6	0.0
T2	6.9	14.9	2.1	3.3	73.3	14.3	37.0	1.5
T3	34.5	21.4	4.3	6.7	26.7	8.6	37.0	1.5
T4	9.1	16.8	--	0.0	2.7	20.4	30.8	--
T5	--	21.2	27.6	31.9	59.8	28.2	37.0	2.9
T6	16.0	19.7	24.1	36.2	46.1	20.5	25.9	1.5

The decanter centrifuge is more effective than the screw press in the elimination of most parameters. There are differences in the reduction of parameters when the screw press works with more or less pressure, obtaining greater reductions in nitrogen when the machine is working at lower pressure.

As for the decanter centrifuge, the proportion of total solids reduction is similar to that established by Zhang and Westerman (1997). Moreover, the separation efficiency of nutrients (nitrogen and phosphorus) and the COD is similar to that collected in the literature (Zhang and Westerman, 1997; Flotats *et al.*, 2004), especially when the screw press works in overpressure conditions and the flow rate of the decanter centrifuge is restricted.

Figure 3 presents the granulometry of the sand filtration treatment obtained from effluent after T6. There is a clear trend towards reduction of solids diameter as effluent receives the different treatments. There are no major differences between the three types of sand, but a significant reduction in the size of solids in all sand filters with respect to the input effluent. This figure clearly manifests the effective separation of solids from the screw press, the decanter centrifuge and the slow sand filters. The complete separation treatment applied can be summed up in the screw press removes grossest solids, mainly till 0.5 and 0.25 mm, the decanter centrifuge eliminates intermediate solids, up to 0.05 mm, and sand filters produce a fine separation, eliminating almost all remaining solids over 0.025 mm , and most of the solids under 0.025 mm.

These results indicate that the effluent, once filtered using this type of treatment, could be used to irrigate crops. Therefore, results obtained for each sand filter treatment are as: T7.1 (pH = 7.99 EC = 13.65 dSm^{-1}), T7.2 (pH = 8.10 EC = 2.24 dS m^{-1}), T7.3 (pH = 8.17 EC = 19.52 dS m^{-1}). According to the criteria established by Ayers and Westcot (1985) for irrigation, all pH values are within the "normal" range. In contrast, looking at electrical conductivity values only effluent obtained in the treatment T7.2 is suitable for crop irrigation. However, they are only rough values due to the short period of time that sand filters are operating.



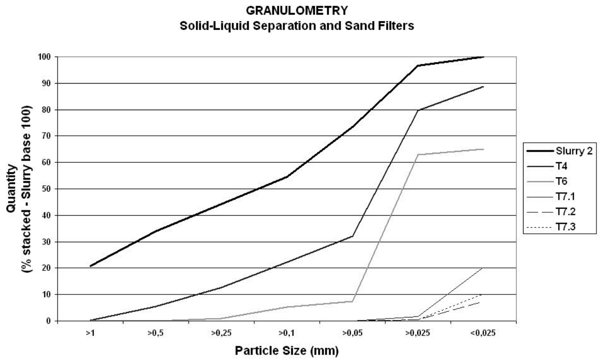


FIGURE 2 **Particle size distributions: (A) Soli-liquid separation treatments and (B) Plus sand filtering**

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