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Efficiencies of solid-liquid separators applied to pig farm slurry

(Kecekapan alat pengasing pepejal-cecair yang digunakan untuk air buangan ladang ternakan khinzir)

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Key words: solid-liquid separators, efficiency, pig slurry

Abstract

Protection of the environment demands that the tremendous quantity of manure in today's intensive livestock farms be managed properly. In the Malaysian context, the most sensitive problem is in pig farms, where manures are turned into slurries due to farmers' practice of washing barns daily. The slurry formed would eventually find their way into the country's waterways, treated or otherwise.

One of the problems in treating and handling pig slurry is the accumulation of solids. The accumulated solids often cause stratification and short-circuiting problems during treatment. This could be partly overcome by separating it into a solid and a liquid component. The solid fraction, composed of undigested grain, roughages, hair and bedding materials, is readily stabilized by composting. The separated liquid is less voluminous and more easily pumped. Besides it does not form crusts. Mechanical separators are employed for this purpose.

This paper reports on the efficiencies of two types of separator applied to pig farm slurry, namely a screw-press separator and an inclined-screen separator. Efficiency was measured in terms of reductions in total solids (TTS), total volatile solids (TVS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN) and total phosphorus (TTP) after mechanical separation.

Removal efficiencies of the screw-press were found to be 54, 46, 58, 21, 36, 33 and 31%, for TTS, TVS, TSS, BOD, COD, TKN and TTP, respectively. In the case of inclined-screen separator, removal efficiencies were 33, 44, 41, 20, 35, 25 and 21%, respectively. The throughputs were 5.2 and 13.9 m^3/h; and the dry matter of separated solids was 28.7% and 18.5% for screw-press and inclined-screen separator respectively. The advantages and disadvantages of solid separation are discussed.

Introduction

Effluent from pig farms in Malaysia is typically in the form of slurry or wastewater, with a low solid content of only a few percent. This is due to the traditional practice of hosing down pig manure daily with plenty of water. The mean discharge of slurry is in the region of 30 litres/pig/day (Teoh et al. 1988).

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Size requirement for treatment facilities, storage tanks or lagoons are tremendous, leading to very high capital cost. Although solids are low in the slurry, they accumulate and gradually reduce the effective volume of treatment system or storage basin. Furthermore, the accumulation of solids in these facilities causes problems of stratification and short-circuiting (Ong 1998).

While reduction in water usage is effective in decreasing the volume of wastewater discharged, it has not been well received by the farming community whose priority is the cleanliness of the pig barns. The next best option for the reduction of wastewater volume or increasing the effective volume appears to be the removal of solids in the treatment vessel or storage basin.

Under the Environmental Quality Acts 1974 (Sewage and Industrial Effluents Regulations, 1979), the limits on total suspended solids (TSS) in the effluent are 50 and 100 mg/litre for areas within and outside of water catchments respectively. The use of solid-liquid separators to regularly remove solids would slow down the rate of solid accumulation and thus lengthen the desludging interval. Alternatively, it can be deemed as the removal of water from the solids, since solid-liquid separating machines are used for dewatering. This paper reports on the efficiencies of two types of solid separator (screw-press type and inclined screen type) used in commercial farms.

Materials and methods

Data were collected from two commercial pig farms operating two separate units of solid-liquid separator applied to the slurry of each farm. The two separators were based on different principles of operation, with differing specifications. One was a screw-press type while the other was inclined screen vacuum type. Thus, this paper reports a case study involving the use of solid-liquid separators applied to pig farm slurry.

The screw-press type had the following specifications: weight, 350 kg; length, 2 070 mm; height, 975 mm; width, 525 mm; body material, cast iron; gear motor, 4 kw; vibrator, 0.15 kw; screen, stainless steel; screen diameter, 260 mm; screen slots, 1.0 mm; auger material, stainless steel; auger length, 800 mm; flight pitch, 200 mm; influent pump, 10 hp; effluent pump, 8 hp.

The inclined screen vacuum type had the following specifications: length, 1 300 mm; width, 730 mm; height, 2 500 mm; inlet diameter, 76 mm; outlet diameter, 142 mm; length of screen, 1 330 mm; influent pump, 1 hp; water suck-back pump, 4 hp; screen slots, 1.0 mm.

Each of the separators was installed at the first pond of the farms holding the slurry. In each case, the slurry separated had been retained in the pond for 5–7 days. The screw-press and inclined screen separators are shown in *Plate 1*.

Data on performance of each separator were collected once a month for 6 months. The throughput in terms of cubic metres per hour of slurry pumped from the storage pond was recorded. Efficiency was monitored in terms of percentage removals of total solids (TTS), total volatile solids (TVS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN) and total phosphorus (TTP). Analyses of these parameters were carried out according to the methods described in APHA (1985), except TTP for which conventional acid digestion was carried out followed by analysis using atomic absorption spectrometer (graphite furnace). To express removals in terms of percentages, the mass of each parameter before and after separation was recorded (Pain et al. 1978). Slurry generation rate was estimated by determining the flow rate of slurry over a length of a drain leading to the first pond, as well as the cross-sectional area of the drain.

Plate 1. Screw-press separator (left) and inclined screen separator (right)

Results and discussion

In each of the farms, waste stabilization ponds already existed before the introduction of the separators. The first pond appeared to be ideal to site the separators since it is the first point of solid accumulation, and it is nearer to the farm structures with power supply. The hydraulic retention times of the ponds in Farm 1 and Farm 2 were estimated at 7 days and 5 days respectively and the original depths of the ponds were 2.5 m and 1.8 m respectively.

The influents were pumped from the 'bottom' of the ponds, with the depth of accumulated solids being undetermined. It is acknowledged that stratification and settling were already occurring in the first pond with differing degrees of biological 'treatment', which would have also given rise to differences in influent parameters. Thus, the influents pumped from the first pond were not the same as the raw slurry generated in the barns.

Removal of total solids was higher in the case of screw-press (54%), compared with that of the inclined screen separator (33%) (*Table 1*). Since the screw-press separated more solids from the influent, it is expected that the TSS in the effluent would be less than that of the inclined screen separator, giving a higher removal efficiency (58%) compared with 41% in the case of inclined screen separator.

In terms of removal of TVS, there was not much difference, since by its analytical definition, TVS is a measure of its volatility at 550 ^{o}C. At this temperature, the organic fraction would be oxidized and be driven off as gas. It is a measure of the biological stability of the waste. The inorganic fraction remained behind as ash. The difference of about 2% would be attributable to the differences in feed composition.

Data obtained also showed that removal efficiencies of BOD and COD were similar in both cases. Both parameters measure the organic content of the slurry. The BOD determined was 5-day BOD, involving the measurement of dissolved oxygen used by microorganisms in the

Table 1. Removal efficiencies of solid-liquid separators applied to pig slurry

	BOD	COD	TTS	TVS	TSS	TKN	TTP
Screw-press							
Influent (kg)	2 988	4 728	5 357	4 486	3 773	302	267
Effluent (kg)	2 360	3 026	2 464	2 422	1 585	202	184
% Removal	21	36	54	46	58	33	31
Inclined screen							
Influent (kg)	2 467	6 290	6 059	4 921	4 725	339	294
Effluent (kg)	1 974	4 088	4 060	2 755	2 788	254	232
% Removal	20	35	33	44	41	25	21

biochemical oxidation of organic matter. It is the primary parameter used by regulatory authorities to determine compliance to national effluent standard.

In the case of COD, the oxygen equivalent of the organic matter that can be oxidized is measured by a strong chemical oxidizing agent (potassium dichromate) in an acidic medium. The data shows that solid separation could only remove BOD by about 20%. As the name of the machine implies, it primarily removes solids from the slurry, whereas large proportions of microorganisms and dissolved nutrients remain in the liquid. The primary means of reducing BOD is biological treatment, be it anaerobic or aerobic.

The COD/BOD ratios of the influent and effluent before and after separation were 1.6 and 1.3 respectively in Farm 1, whereas those in Farm 2 were 2.6 and 2.1 respectively. It is postulated that in Farm 1, nitrification might have already occurred during BOD determination, since the retention time of influent in the pond there was longer than that of Farm 2. This would have happened during hydrolysis of proteins, producing ammonia. The oxidation of ammonia to nitrate would have exerted a nitrogenous BOD leading to increased BOD measurement. Suppression of nitrification reaction during the BOD test was not carried out in both cases. It is understood that in the 17th edition of the Standard Methods (APHA 1989), suppression of nitrification is listed as a standard procedure.

Another factor contributing to the discrepancies in COD/BOD ratio could be the differences in the composition of ‘feed additive’. A case in point is the use of copper sulphate as animal ‘growth promotant’, which is a common practice in the industry. However, the dosage given ranged from 50–250 ppm, which could have affected microbial population in the slurry, since excess copper is mostly excreted. It is noted that in both farms, the source of wash water was rain-fed pond water (water storage ponds and not waste ponds), each with different soil and microbial profiles. It could explain the large amounts of wash water used, since the water source was plentiful and free of charge.

The generation of raw slurry in Farm 1 and Farm 2 was 32 and 38 litres/head/day respectively *(Table 2)*, both larger than that reported by Teoh et al. (1988). The quality of wash water, which was not determined in this case study, would have contributed to the differences in influent quality. When the COD/BOD ratio is more than 2 in the final effluent, it would mean that compliance to COD limit would not be achieved even if compliance to BOD limit were achieved, since the ratio in the legal standard (Standard B) is 2.0, i.e. COD, 100 mg/litre; BOD, 50 mg/litre (Environmental Quality Act 1974, Sewage and Industrial Effluents Regulations, 1979).

The removal efficiencies of TKN were 33% and 25%, for screw-press and inclined screen separators, respectively. The nitrogen

Table 2. Throughput and separation characteristics of solid-liquid separators*

Separator	Slurry generation from farm (litres/animal/day)	Throughput (m^3/h)	Daily wet wt of separated solids (kg)	Dry matter of separated solids (%)	Daily dry wt of separated solids (kg)
Screw-press	32	5.2	2 246	28.7	645
Inclined screen	38	13.9	3 670	18.5	679

*Based on pumping of 8 h/day at solid separation efficiencies shown in *Table 1*, with 1% total solids in influent

originates from protein feeds in animal diets. The common protein ingredients used in the farms were milk powder, fish meal, meat meal, soybean meal, leaf meal and groundnut meal, with N contents of 5.4, 9.6, 9.6, 8.6, 2.7 and 7.2, respectively, and apparent digestibilities of 84.0, 84.4, 75.3, 79.8, 42.6 and 85.1, respectively (Anon. 1989). The analysis of TKN does not include nitrite nitrogen (NO_2) and nitrate nitrogen (NO_3).

In the solid fraction, organic nitrogen in animal waste is in the form of complex molecules associated with digested feeds. In the liquid fraction, it is mostly in the form of urea. The organic nitrogen is generally converted to ammonia via mineralization. In an adequate supply of other nutrients, particularly phosphorus, nitrate nitrogen promotes algal blooms in water bodies. Currently the Environmental Quality Act 1974 (Sewage and Industrial Effluent, 1979) does not include nutrients like nitrogen and phosphorus.

The data obtained from this case study showed that with solid separation, TKN could be concurrently removed by about a quarter and a third, using inclined screen and screw-press separators, respectively. An ideal situation would be the prevention of excess nitrogen going into the waste. This can be achieved by optimal feeding of protein sources with high digestibilities and balanced amino acid composition. Nitrogenous excretion would be decreased with reduction of dietary crude protein coupled with use of free amino acids as well as enzymes. Such nutritional manipulations help to reduce nitrogenous waste, which is the major contributor of malodour, particularly under anaerobic conditions. Thus feed formulation has a direct role in reducing nitrogenous waste. The use of digestible amino acids, rather than crude protein levels in diet formulation is a step forward in this effort.

In the case of total phosphorus, the removal efficiencies were found to be 31% and 21% for screw-press and inclined screen separators, respectively. It is possible that a large proportion of the total phosphorus is fixed in the solid fraction, such that an increase in solid removal efficiency would lead to an increase in TTP removal as well. It has been found that 25, 33, 9 and 33% of local farmers use supplemental phosphorus in the form of tricalcium phosphate, dicalcium phosphate, mono-calcium phosphate and mono-dicalcium phosphate, respectively, each with a digestibility of 48, 66, 81, and 73%, respectively (Ong et al. 1999). Again, ultimate reduction in excess phosphate would lie in optimal feeding at source. Avoiding over-specification in feed formulation, using phosphorus sources of high availability and using phytase in feed would go a long way in reducing TTP in wastes.

It was found that the throughput in terms of volume per hour was higher in the case of inclined screen separator (13.9 m^3/h) compared with that of screw-press (5.2 m^3/h) *(Table 2)*. However, the dry matter content of separated solids was higher for the screw-press (28.7%) compared with the inclined screen (18.5%). With such a differing pumping rate and dry matter content of separated solids, it was found that the daily amounts of dry separated solids were similar, with a difference of about 5%. This was based on the assumption that both separators were operated at 8 h per day, with the influent having a solids content of only 1%. About 650 kg of dry solids could be expected daily. These would need to be further stabilized prior to disposal or utilization. On the other hand, removal of this amount of solids on a daily basis would extend the working life of the waste treatment ponds and lengthen the desludging intervals.

Based on the same pumping rate and the respective slurry generation rate, it would seem that the screw-press and the inclined screen separators could handle standing animal population of 1 300 and 2 900 respectively. However, the handling capacity would depend on many other factors such as maintenance. The solids content of 1% is extremely low. The data of Pain et al. (1978) showed that solid removal efficiency increases with increase in the dry matter content of input slurry. However, the separators were different, namely rotary press, vibrating screen, rotary screen and flat belt separator. For the rotary screen separator, solid removal efficiency ranged from 45% for input slurry of 6% TTS to 55% for input slurry of 9% TTS (Pain et al. 1978).

Further study on the solid removal efficiency at local conditions with input slurry of higher TTS is warranted. Huijsmans and Lindley (1984) reported TTS removal efficiency of 25% with an inclined screen separator using input slurry of 11% TTS, resulting in a separated solid fraction of 22% dry matter. When a pressure roller was added to the system, the dry matter of the separated solids increased to 31.3%.

The farmer should recognize that solids separation is just one of the unit operations in the management of waste. A solid separator does not treat the waste per se. It can be considered as a pre- or post-treatment process depending on its placement in the treatment operation.

There are several advantages with its use. If it is used as a pre-treatment unit operation, the volume of the treatment vessel be it a tank or a lagoon, could be made smaller compared with treating the whole slurry. Furthermore, the fibrous residues, which are less easily degradable, are mostly removed, thus making the treatment more efficient.

Total suspended solids in the effluent could be reduced. The separated solids could be bagged for transporting elsewhere or further processed into a soil conditioner. The separated liquid is more readily pumpable compared with whole slurry and has fewer tendencies to form crusts in storage basins.

However, depending on the point of view, there are disadvantages with the use of solid separators. First of all, it is not energy efficient, since manure is turned into slurry before the solids are in turn recovered from the slurry. There is also the associated capital and operational cost, both of which must be weighed against the cost of having to build a larger treatment system, if solids are not separated. These costs are higher in the case of screw-press type compared with the inclined screen type, due to bigger pumps being used in the screw-press. In addition, the separated solids are not stable unless treated, and should not be indiscriminately dumped.

The use of unstable solids would lead to unhygienic conditions such as fly infestation and malodour emission. These solids could be readily stabilized by aerobic composting (Ong et al. 1994), and could be a source of organic fertilizer if the market accepts them. However, the fertilizer value of separated solids is less than that obtained from whole manure.

If biogas were desired as a by-product of anaerobic treatment, there would be a reduction in gas production using separated liquid compared with whole slurry (Ong et al. 1995). The total solids level should be sufficiently high to get reasonable methane production because methane production is primarily dependent on the amount of volatile solids fed into the digester, and the volatile solids are directly related to the solids content. However, there would be problems in material handling if the total solid content exceeds 10% (Lo et al. 1983).

Conclusion

The throughput in the screw-press was lower than that of the inclined screen separator, being 5.2 and 13.9 m^3/h respectively. Both machines exhibited similar removal efficiencies in terms of BOD and COD. However, for TTS, TVS, TSS, TKN and TTP, the screw-press showed higher removal efficiencies. Dry matter contents of separated solids were 28.7% and 18.5% for the screw-press and inclined screen separators respectively.

The advantages of using a separator: a) reduction in volume of treatment vessel, b) reduction in solid content in effluent, c) increase in pumping efficiency of separated liquid, and d) reduction in stratification leading to increased treatment efficiency.

The disadvantages of using a solid separator: a) it is not energy-efficient, b) there would be additional operational cost, c) further treatment of separated solids is still required and d) there would be a reduction in biogas production if gas were desired.

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Abstrak
Perlindungan alam sekitar memerlukan pengurusan najis yang wajar di ladang ternakan. Dalam konteks Malaysia, masalah yang paling sensitif ialah najis dari ternakan khinzir yang telah dijadikan air buangan disebabkan oleh penggunaan air untuk cucian kandang setiap hari. Air buangan yang terjadi akan mengalir ke sungai sama ada diberi pengolahan atau tidak. Salah satu daripada masalah pengolahan air buangan di ladang ternakan khinzir ialah penambahan kandungan pepejal. Kandungan pepejal yang terlalu tinggi dalam air buangan akan menimbulkan beberapa masalah dalam pengolahan air buangan, seperti stratifikasi dan 'short-circuiting'. Masalah ini dapat diatasi dengan menggunakan mesin yang mengasingkan pepejal daripada cecair supaya air buangan lebih mudah dipam dan tidak meninggalkan kerak.

Artikel ini melaporkan kecekapan dua jenis mesin pengasing pepejal, iaitu mesin skru tekan dan mesin skrin condong yang telah digunakan dalam pengurusan air buangan di dua buah ladang ternakan khinzir. Kecekapan pengasingan diukur sebagai peratus penghapusan jumlah pepejal (TTS), jumlah pepejal mudah ruap (TVS), jumlah pepejal terampai (TTS), keperluan oksigen biokimia (BOD), keperluan oksigen kimia (COD), jumlah nitrogen Kjeldahl (TKN) dan jumlah fosforus (TTP).

Bagi mesin skru tekan, peratus penghapusan TTS, TVS, TSS, BOD, COD, TKN dan TTP masing-masing ialah 54, 46, 58, 21, 36, 33 dan 31%. Bagi mesin skrin condong, peratus penghapusan TTS, TVS, TSS, BOD, COD, TKN dan TTP masing-masing ialah 33, 44, 41, 20, 35, 25 dan 21%. Daya keterpaman ialah 5.2 dan 13.9 m^3/jam, dan berat kering bagi pepejal yang diasingkan ialah 28.7% dan 18.5% masing-masing bagi mesin skru tekan dan skrin condong. Kebaikan dan keburukan penggunaan mesin pengasing dibincangkan.

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