Piggery Wastewater Characteristics Associated with Particle Size and Settling Time.

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Abstract

Solid-liquid separation is used widely as a waste treatment process. A wide range of solid-liquid separators have been applied to agriculture overseas, but their application in New Zealand has been limited.

This study has determined levels of pollution parameters associated with particle size and settling time for wastewater from a New Zealand piggery. This information has been used to compare the effectiveness of sieving and settling on separating solids from piggery wastewaters.

It was found that a high proportion (75-90 %) of COD, TS, VS and TP were associated with filtrable solids, and therefore indicate that some form of solid-liquid separation can remove high levels of these parameters. Only low levels of TKN were associated with filtrable solids so their removal by solid-liquid separation is limited.

The study revealed that removal of particles in the 500-2000 um range will not remove high levels of COD, TS, VS, TP or TKN and to to remove substantial levels of the first four parameters, particles less than 500 um need to be removed.

Settling tests demonstrated that high levels of COD, TS and VS were removed in a short time period (5 minutes), and that substantial levels of all parameters were settled in longer time periods.

Comparison of the two trials reveals that very small aperture

sieves would be required to achieve a similar removal of all parameters, compared with a five minute sedimentation period. Sedimentation appears to be an effective waste treatment option for piggery wastewater. Further research is required to quantify performance in the field and find practical methods of disposal or utilization for the separated sediment.

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Abbreviations

BOD = Biochemical Oxygen Demand

CI = Confidence Interval

COD = Chemical Oxygen Demand

CH = Methane

C:N Ratio = Carbon: Nitrogen Ratio

Cu = copper

DDT = 1,1-bis(p-chlorophenyl)-2,2,2-trichloroethene

DO = Dissolved Oxygen

DM = Dry Matter

Ha = Hectare

kg = kilogramme

l = litre

log = logarithm base 10

ln = natural logarithm

ml = millilitre

mg = milligramme

MJ = Megajoule

mm = millimetre

NPS = non-point source

PE = population equivalent

ppm = parts per million

PS = point source

t = tonne

TKN = Total Kjeldahl Nitrogen

TP = Total Phosphorus

TS = Total Solids

um = micrometre (micron)

VS = Volatile Solids

1. Introduction

1.1 Agricultural Wastes.

The constituents of agricultural wastes which can affect water quality include organic matter, nutrients, suspended solids, toxic substances, waste heat and pathogens (Hickey and Rutherford,1986). Several problems are associated with these constituents. Organic matter stimulates microbial respiration, and may cause deoxygenation (which affects aquatic insects and fish), and it may cause the growth of sewage fungus (which can aggravate dissolved oxygen (DO) depletion and can smother benthic invertebrate habitats) (Hickey and Rutherford, 1986). Nutrients, especially nitrogen and phosphorus, can increase the growth rate and the biomass of aquatic plants. These plants can clog channels, and cause aesthetic problems and diurnal DO variation (Hickey and Rutherford, 1986). Suspended solids can reduce the aesthetic water quality and light infiltration, as well as blocking water channels, possibly smothering benthic invertebrate habitats (McColl,1982). Toxic substances can cause disturbed function and possibly death in plants and animals (Hellawell, 1986). In addition some potentially toxic substances such as DDT and mercury can be accumulated to toxic levels. Heat can reduce the DO levels of fresh waters by raising the temperature and increasing the rate of biochemical reactions (some of which require oxygen), and reducing the level of oxygen held in a saturated solution. The discharge of pathogens into water cause problems of possible disease in other organisms and so restrict further use of that water.

The main methods used in agriculture to measure the physical, chemical and biological characteristics of wastewaters are:

(a) Solids, these can be total solids or any fraction of interest such as suspended or volatile solids.

(b) Turbidity and colour, which can relate to the solids concentration in waters, and may impart undesirable visual effects on receiving waters.

(c) Chemical characteristics are broken into inorganic and organic constituents. Biochemical and chemical oxygen demand (BOD, COD) are the two most commonly used measures of organic contamination.

(d) Biological characteristics of waste waters can include the estimation of numbers of any living organisms. Estimating the presence of a specific pathogen can be difficult and so the more simple measure of faecal coliforms is used to predict the possibility of the presence of pathogenic organisims.

The range of tests used to assess the characteristics of agricultural wastewater will vary depending upon the specific waste and the methods of treatment and disposal.

1.2 Agricultural Pollution in New Zealand.

In New Zealand, agricultural point source waste discharges contribute significantly to total point source discharges to fresh waters, (Dakers and Painter, 1982; Ferrier and Marks, 1982; Hickey and Rutherford, 1986). Agricultural point source discharges emanate mainly from cowsheds and piggeries. Estimates by Hickey and Rutherford (1986) state that agricultural point source discharges to fresh waters total 0.7-2.0 million population equivalents (P.E.) (see table 1.1) compared with 0.2 - 0.7 million P.E. for sewage discharge. It would appear that although sewage waste accounts for the greatest potential organic and nutrient load (nitrogen and phosphorus), its effect on natural waters is minimised for the following reasons: (a) the number of sewage systems discharging to fresh waters is only about 49% of total discharges (Hickey and Rutherford, 1986), and (b) that in 1986 all communities with populations greater than 1000 persons operated satisfactory sewage disposal systems (Fitzmaurice, 1987). In addition Hickey and Rutherford, (1986) stated that although the meat and dairy processing industries potentially produce large volumes of waste, modernisation programmes have resulted in fewer, larger factories, which have improved waste treatment facilities.

It would appear from the research of Hickey and Rutherford, (1986) that the treatment of agricultural point source discharges has the ability to significantly reduce the levels of potentially polluting discharges to rivers. In fact, it would appear that the level of pollution caused by the discharges from cowsheds and piggeries may be greater than that estimated previously by Hickey and Rutherford (1986), as Wilcock (1986) emphasised that small point source discharges such as from piggeries and dairies are often difficult to identify, and may be included as non-point source (NPS) in estimates of loads to receiving waters.

Table 1.1 shows that even though there is significantly more cowsheds than piggeries discharging wastes to rivers in New Zealand (7850 cf. 220 respectively), piggeries are still discharging 25%, 36%, and 44% of the total BOD, N and P load attributable to PS discharges, respectively. This point was supported by Dakers and Painter (1982), and would indicate that a greater reduction in polluting load from agricultural PS discharges could more easily be achieved by improving piggery waste treatment methods than dairy waste treatment methods. Since implementation of improved waste treatment would be required on much fewer properties. In addition the conclusions reached by Hickey and Rutherford,(1986) do not highlight the fact that piggery wastes are more concentrated than cowshed wastes, and that agricultural wastes are more concentrated than municipal wastes (Moore et al, 1975). Although the concentration of flushed cowshed and piggery wastes, and domestic wastes vary considerably the following information in table 1.2 (Tchobanoglous and Schroeder, 1985; Vanderholm et al, 1984) indicates the relative concentrations of each.

Table 1.1

Summary of Point Source Discharges to New Zealand Rivers in 1984.

(Hickey and Rutherford, 1986).

	Total Produced[1]				Discharged to Rivers			
	No.	BOD	N	P	No.	BOD	N	P
Sewage	197[2]	4	4	4	96[2]	0.2	0.6	0.7
Cowsheds	14317	1.8	1.7	1.6	~7850	0.6	0.7	1.0
Dairy Factories	50	2	0.4	0.7	23	0.3	0.1	0.2
Meatworks	39	3[3]	2[3]	1.3[3]	18	0.7	0.6	0.6
Pulp and Paper	7	0.7	0.4	0.3	6	0.3	0.2	0.1
Piggeries	503	0.6	0.9	1.8	~220	0.2	0.4	0.8

Notes: [1]BOD, N and P figures are population equivalents x 1/1000000, where 1 PE= 77g (BOD)/Cap/day, 11g(N)/cap/day and 1.8g (P)/cap/day.

[2]Populations greater than 1000, include some industry.

[3]After primary treatment.

Table 1.2

Relative Concentrations of Various Wastewaters.

	Cowshed(flushed)	Piggery(flushed)	[1]Domestic
BOD average	1500 mg/l	------	272.5 mg/l
range	1000-4500	2880-12,800	-----
COD average	6600	------	443
range	5000-11,000	7000-32,800	-----
Total N average	208	1738	42
range	100-325	1075-2500	-----
Total P average	35.2	537	11.4
range	10-?	109-950	-----

[1]These figures are averages of four indusrialized countries, not including New Zealand (USA, UK, Japan and F.R.of Germany)

1.3 Solid-Liquid Separation in Agriculture.

Solid-liquid separation may be practiced for three main reasons:

(a)to reduce total solids which may cause blockages in pumps, pipes and waste reticulation components,

(b)to reduce the organic load on subsequent waste treatment processes,and

(c)to concentrate or recover waste components for further digestion or utilization.

Solid liquid separation is a common primary treatment process used to reduce total solids and organic loading on secondary municipal and industrial wastewater treatment systems in New Zealand (Ferrier and Marks, 1982; Moore el al, 1975). Although it is not widely practiced in pig farming, where it is applied separation is more commonly achieved with large aperture wedgewire screens (0.5-1.5mm) (Dakers and Painter 1982) and gravitational settling is seldom used. Conversely in municipal and industrial wastewater treatment gravitational sedimentation for solid separation is commonly practiced and in addition more efficient setting is commonly acieved by the use of chemical coagulants (Ferrier and Marks,1982).

More use could be made of solid-liquid separation as a unit process in the treatment of high concentration piggery wastewaters. Wall et al (1987) state that there is a lack of design information suitable for the above objective and that there is a further need to quantify the reduction in organic loading due to solid-liquid separation in piggery wastewaters. This is backed up by Dakers and Painter (1982), who state that there is a need for better quantitative information on solid-liquid separation devices to enable them to be designed with greater confidence. They also state that lagoons are becoming a popular agricultural waste treatment method. However there are several problems with their use:(a)some piggeries may be limited by the land area available for disposal, and (b) more research is required on sludge accumulation and desludging techniques. Both these problems can be
reduced to a certain extent if primary treatment is practiced prior to lagoon disposal, thus reducing the organic load, the land area reqired, and minimising sludge accummulation.

It would appear that the screens used in piggery solid-liquid separation may satisfactorily remove suspended solids which are likely to cause blockages in the waste treatment system, but do not necessarily reduce organic load to any significant extent.In contrast to this sedimentation has been shown to significantly reduce total solids and organic load in several animal wastewaters (Moore et al, 1975). It would also be of use to quantify the level of nitrogen and phosphorus removed by any solid-liquid separation process for the following reasons:

(a)eutrophication in natural waters is most commonly limited by the absence of nitrogen and phosphorus (Vollenweider 1968). Consequently quantification of the reduction in nitrogen and phosphorus content due to solid-liquid separation is useful in waste treatment systems designed to minimise eutrophication.

(b)nitrogen and phosphorus are commonly required as soil fertilizers, and their concentration into a solid or slurry fraction could be applied to soils and contribute to soil fertility without the associated waste liquid. The latter (liqiud) dilutes the nutrient concentration, and may limit application during wet periods throughout the year.

1.4 Statement of Problem.

To date solid-liquid peparation has been used in piggeries to prevent mechanical blockages of pumps, pipelines and irrigation systems. There are now situations where solid-liquid separation is being considered by pig farmers in New Zealand to reduce organic loading on waste treatment systems such as lagoons, and also to retrieve waste components for further utilization, such as nutrients which can be applied as fertiliser to the land.

In New Zealand the design of solid-liquid separation systems to achieve particular objectives is difficult, since it is unclear what particle sizes must be removed to achieve a significant reduction in organic loading or retention of utilizable components.

In addition methods not commonly used in agricultural waste treatment for solid-liquid separation may be worthy of consideration. Lessons can be learnt from municipal and industrial waste treatment, especially in the area of sedimentation, but because of differences in waste characteristics, plant scale and management expertise these are not necessarily directly transferable to piggeries without further research.