Waste Management for Hog Farms* - Review -

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ABSTRACT : The planning and application of new developments in management of wastes in hog farming is required to minimise the gaseous emissions from wastes and pollution of the aquatic environment. These strategies are enveloped in the "Farm Waste Management Plan" which identifies areas of the waste assets in form of plant nutrient and considers optimal manure collecting and storing procedures. The storage volumes for environmentally acceptable manure treatments and application methods are suggested. Good Waste Management Planning together with appropriate system design will ensure safe, reliable and effective waste handling. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 2 : 295-304)*

Key Words : Wastes, Hog Farming, Pollution, Manure Treatments, Waste Handling

INTRODUCTION

The hog farmers of small and large farms have to resolve a number of challenges associated with the effects on the environment and human population. Hog excrements contribute in majority of cases to these challenges. Not all of them are negative; the fertilising value of slurries or farm yard manure (FYM) (table 1) should be recognised in order to minimise the input of inorganic fertiliser to the arable or grass producing farm.

Table 1. Characteristics of hog slurry (Svoboda 1995)

Param	TS	COD	BOD_5	Tot-N	Org-N	Amm-N	PO_3^{3-}	K_2O
$g.l^{-1}$	100	134	35	8	4	4	4.5	3.4

Param .... Parameter.
Org-N .... Organic nitrogen.
TS .... Totalsolids.
Amm-N .... Ammoniacal nitrogen.
COD .... Chemical oxygen demand.
PO_3^{3-} .... Phosphate.
BOD_5 .... Biochemical oxygen demand.
K_2O .... Potash.
Tot-N .... Total nitrogen.

Although this benefit is acknowledged, the collection, storage and application of manures is linked to the emissions of odour, ammonia and other gasses, pollution of ground and surface water with organic matter, nitrogen, phosphorus and pathogens and similarly to the pollution of soil. They can be minimised, if not completely eliminated, by the correct management of the farm and livestock wastes and, by relatively new development in minimising hog feed nutrient input in a form of enzymatic additives promoting digestion of plant phytin-phosphorus (Hoppe et al., 1993) or supplementation of protein/nitrogen input by properly balancing the diet synthetic amino acids (Mordenti *et al.*, 1993). The degree of complexity of the management processes involved will depend on the farming intensity and the relative stress on the environment recognised by the neighbouring community and the country or the state regulatory requirements. What can be a healthy country odour for a farmer may be an odour nuisance for the neighbour and as such it has to be considered. Since there are not two farms the same the management of wastes on each farm should be assessed individually and not assume "what is good for one farm has to be good for the other farm too".

THE WASTE MANAGEMENT PLAN

Waste Management Planning in intensive agriculture, as in other industries, can reduce the risk of pollution. It can help evolve a sensible and practical approach to handling on sites where considerable development and investment is taking place.

It can ensure facilities for collection, storage, treatment and distribution of wastes are appropriate and effective. It takes account of waste characteristics for handling systems and available nutrients for timeliness of application to land with reference to crop uptake.

Planning can also be used to appraise and improve the use of existing facilities allowing continuation of a viable production unit, but reducing risk of pollution with the minimal necessary investment.

In the course of compliance with current regulations and Codes of Practice (MAFF, 1991; SOAEFD, 1997), many farms must now invest heavily in systems of collection, storage and land application. It is apparent that the industry is becoming more aware of the environmental pressures it is now subject to, and many farmers now require the safe and effective use of 'wastes'. Land application of both agricultural and imported wastes is an issue farmers must take more control over.

In order to provide timeliness of application, minimise land damage and obtain maximum nutrient use, storage of waste is inevitable. In many countries at

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present, where any storage development is being considered, there is a legal requirement for a viable Waste Management Plan to be produced. In some cases minimum storage periods must be provided to ensure wastes are not disposed of in unsuitable conditions but are utilised effectively and nutrients recycled for crop use. It is suggested in many Codes of Practice that all farms should produce a Waste Management Plan. The Codes are mostly voluntary at present although components of it are controlled by legislation. Legislation varies depending on the sensitivity of the area and potential effect.

The Waste Management Plan provides an audit of wastes, identifying sources, volumes and times of production. It must include similar details of any wastes produced on and imported to the farm. Consideration is given to alternative management strategies which can reduce the volumes of some effluents considerably, while increasing the effective value of the portion to be handled.

The Plan can provide a storage specification with consideration to waste production and land application in accordance with relevant Codes of Practice and farm management requirements. It should provide a viable spreading schedule and a full system specification, taking account of sustainable practice.

Manure collection

The piggeries, and especially those collecting slurry rather FYM, can be source of air borne ammonia and odour. Ammonia originates mostly from urine degraded by the ever present bacteria urease enzyme. The slower breakdown of the remaining undigested protein produces ammonia too, together with organic acids some of which are already excreted as a result of the animal metabolism of feed. The arrangement of slurry collection and storage within the piggery can therefore greatly affect the ammonia and odour emissions from the piggery ventilation systems. Since about 70% of ammonia emanates from the slurry surface (Monteny, 1994), considerable attention has been given to the slurry removal from the building and surfaces by flushing with the separated and treated slurry (van Gastel et al., 1995) (figure 1).

By flushing the underslat channels with nitrified separated slurry, ammonia emission was reduced between 50 to 70% compared with traditional housing. Although environmental conditions in the piggery were considerably improved the high energy requirement made this system expensive.

The opposite view was adopted when piggery waste was collected in the form of solid composted manure using the technique of deep litter bedding which originated in Far East countries. Wood shavings and sawdust or straw in a deep layer can absorb urine and faeces after incorporation and this bedding would compost. The heat evolved from the composting process increases the reaction rate of the waste degradation but can also aid ammonia emissions and through nitrification and denitrification of nitrogen it can produce nitrous oxide (N_2O), a powerful greenhouse effect gas (Voorburg, 1994). This system, although producing relatively small volumes of composted manure, would be suitable only for small farms mainly due to its intensive labour requirement.

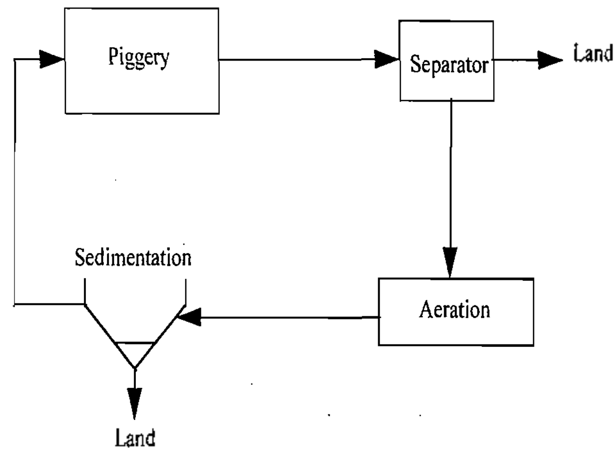

Figure 1. Diagram of slurry management for flushing the piggery

In the UK over 25% of breeding sow production is raised in outdoor breeding systems (Watson and Edwards, 1997). Although the welfare of pigs seems to improve by keeping them in a more natural environment with no requirement for excrement management, the high nitrogen depositions together with the vegetative cover being stripped by sows can have adverse environmental effect in form of nitrogen losses into the drainage and ammonia emissions from patches of concentrated urine and faecal deposits.

The most commonly used in house waste management systems are based on the fully or a partially slatted floor with slurry regularly removed by scrapers or siphoning systems. Minimal bedding systems with straw intake by the hogs activity is gaining on popularity namely for its effect on the animal welfare and production of waste in the form of compostable FYM rather than slurry.

Manure storage

Hog excrements can be stored inside the building in the space underneath the slats or, and more often, outside the piggery in above ground stores or lagoons. Middens are used when the waste is collected as FYM. The storage systems, when correctly designed and maintained, are rarely the cause of pollution of aquatic environment except in cases of mismanagement when stores overflow or due to the poor store maintenance which results in the escape of waste through damaged walls. Emissions of offensive odour and ammonia from stores of waste were recently in the focus of attention (Voorburg, 1994). They can be relatively large and can affect, similarly as emissions from piggery buildings, the land cover (forest, crop) in the vicinity of the farm. It was estimated (Voorburg, 1994) that the ammonia emissions from the tanks storing hog slurry were 200 to 600mg.$m^{-2}.h^{-1}$ during winter and summer respectively. Together with odour emissions, they can be reduced considerably (70 to 90%) using floating or tent covers respectively. Similarly the emanation of the offensive odour from stores was reduced by up to 35% using floating or tent covers.

Procedure for waste management planning

Current SAC procedures for carrying out a *Waste Management Plan* can be summarised as follows:

1) A full waste audit is carried out to determine type, characteristics volumes and times of production or import of waste.
2) An appraisal of available facilities and equipment is made together with an assessment of present and attainable management practices.
3) A land availability schedule is completed. Consideration is given to stock and cropping situations, type of waste and inference on management. Regard is given to soil type, rainfall, frost, slope, proximity to water courses, drainage and access. Field areas are identified with reference to time and expected volume of application.
4) With consideration to the land availability schedule, potential handling rates and specific management requirements, a full system specification can be proposed.

Strategies in land application

Handling rates during field application can have a significant effect on storage requirement and timeliness. The rates can be modified with alternative application systems. Using the management plan it is possible to evaluate the effects of changing the application system on storage and management requirements.

In response to the requirement for timeliness of application, together with more storage being installed on many farms, alternative application systems are being investigated and further developed.

Handling rate and storage requirement can be significantly effected by the transport and application system. Table 2 shows a typical effect on annual handling capacity and storage requirement of the system. Increasing the handling rate allows land application to take place at selected times with reduced storage requirement.

Changes to distribution systems on tankers are taking place to improve effectiveness both with regard to nutrient utilisation and reducing emissions.

Stored manures (slurries and FYM) can be applied onto land by several techniques. The liquid raw or separated slurry had been, until some 5 to 7 ears ago, mostly applied by the wide broadcast or high trajectory technique (figure 2), employing a tanker with a splash plate. Since the more stringent regulations for the environment and human population protection are being implemented, other, usually more expensive techniques to reduce odour and ammonia emissions were developed.

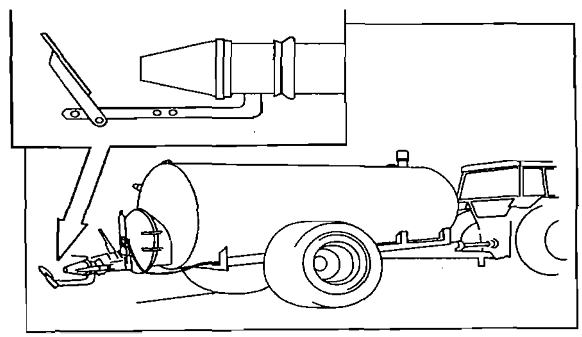

Figure 2. A slurry tanker with a splash-plate (MAFF, 1992)

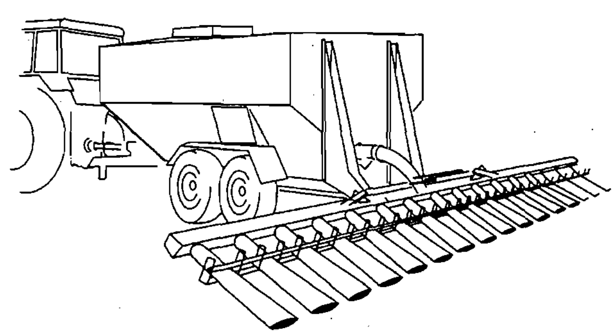

Figure 3. A slurry tanker with flat trailing hoses (MAFF, 1992)

A low level drag and a high application rate delivery system uses trailing hoses (figure 3) so that

Table 2. Effect of handling rates on spread capacity and storage requirement

Spreading programme	Handling rate $m^3.hr^{-1}$	Slurry produced $m^3.yr^{-1}$	Spreading capacity $m^3.yr^{-1}$	Store size Required m^3
All year round spreading	50	6,200	10,600	2,200
No spreading Oct, Nov, Dec, April, May	50	6,200	7,100	3,649
No spreading Oct, Nov, Dec, April, May	100	6,200	14,200	2,770

slurry is applied in form of bands 15 to 40 cm apart and slurry is directly applied onto the soil under the plant canopy or on grass.

A system with drag shoes applies slurry behind the shoes which spread open the canopy of plants or the grass cover so the slurry comes in the direct contact with soil. The reduction of odour and ammonia is higher than with trailing hoses (table 3).

Table 3. Reduction of ammonia and odour emissions from hog slurry using various application techniques, compared with splash-plate application.(Adapted from Manure Management, 1997 and Pain, 1994)

Application technique	% ammonia reduction	% odour reduction
Ploughing in	Not available	84
Deep injection	98	73
Shallow injection	90	53
Drag shoe	73	Not available
Drag hose	31	Not available

Slurry injection is a method which, if properly applied, would prevent most of odour and ammonia emissions (table 3). Slurry can be injected (figure 4) in deep slots of about 150mm or shallow grooves and when rolled over to close the openings maximum contact with soil and minimal with air, reduces the emissions. There are however some drawbacks using this type of implement. Mainly it is an increased capital cost comparing with the splash plate distribution system, higher cost for energy required to drag the shoe or even to slit the ground before injection and, in the case of slurry injection to grassland, especially with winged tines and distances of 150mm between the slits, the mechanical damage to sward can lead to 15% reduction of the herbage yield (Pain, 1994).

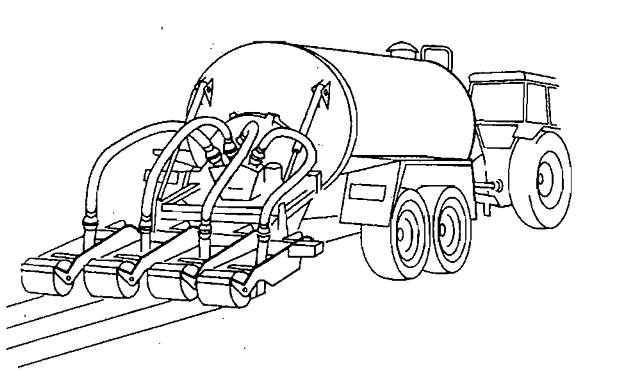

Figure 4. A slurry tanker with injection attachment (MAFF, 1992)

Treatment techniques

For farms where the Farm Waste Management Plan identified that the storage and application techniques of raw waste would be inadequate for the prevention of the environmental pollution, some form of treatment to alleviate the negative effects on environment would be required.

Mechanical separation

Reduction of the solids content in slurries may increase the manageability of the waste as well as to reduce the environmental impact. Slurry flushing systems (van Gastel et al., 1995) incorporate a mechanical screening to decrease the energy input into minimising the ware of the moving parts of pumps and aerators. Similarly, the oxygen demand for aeration of screened slurry was lower than for the whole slurry and the storage time of treated slurry was extended as demonstrated by Williams et al. (1989). The mechanical separation step is not usually included before anaerobic digestion of livestock slurries in order to maximize the biogas production, but in cases when the mixing of the reactor contents could be compromised or when a anaerobic filtration process is used than the separation of solids would be required (CRPA 1996). Separation after the digestion process can provide certain benefits, together with these already mentioned above, commonly exploited in separation of raw slurries:

* Decreased storage volume for the liquid fraction.
* Increased homogeneity of the liquid thus providing more even distribution of slurry fertilising components (N, P, K) for land spreading.
* Prevention of sediments and floating layers in the storage tank.

Pumping and distribution of the separated liquid phase becomes easier with lower occurrence of blockages. The application on grass presents less problems with smothering by solids which can contaminate silage when rain is scarce between the slurry application and grass cutting. Faster infiltration of the separated liquid into the soil minimised the ammonia and odour emission by 34% (Pain, 1994).

Manure management which includes the use of a separator should always be carefully assessed. The cost of the separator and its installation may be far higher than the benefits listed above and those which may results from selling the composted solids fraction. The benefits to the environment, sometimes very difficult to judge, can be tangible when the solids fraction, containing a large part of phosphorus and nitrogen (table 4), can be exported out with the areas which may be already overloaded with these two elements.

Biological processes

Raw livestock slurries contain undigested and partially digested food and metabolites including urine. The dissolved products of protein namely mercaptans, volatile fatty acids (VFA), phenols and indols (TIP) and hydrogen sulphide are the source of offensive odour which is associated with the typical smell of hog excrements. Odour increases with the storage of slurry till it reaches the point when the uncontrolled digestion starts reducing the odorous compounds. This turning point depends on the slurry solids concentration and the storage temperature. Although the odour reduction using this method seems quite attractive the storage intervals may exceed a year or more in the temperate climates. The requirement for very large storage capacities can be satisfied only in places with a large available land area for construction of earth lagoons. A higher evaporation rate than rain precipitation is advantageous for volume decrease and being associated with high ambient temperatures a high biological reaction rate degrades the odorous compounds faster (Bicudo et al., 1996).

Table 4. Performance of livestock manure separators (Manure management, 1997)

	Belt press	Sieve drum	Screw press	Decanter centrifuge
Flow rate ($m^3.h^{-1}$)	3.3	8-20	4-18	5-15
Separation efficiency (%)				
Dry Matter	56	20-62	20-65	54-68
Nitrogen	32	10-25	5-28	20-40
Phosphorus	29	10-26	7-33	52-78
Potassium	27	17	5-18	5-20
Volume reduction (%)	29	10-25	5-20	13-29
Specific energy ($kWh.m^{-3}$)	0.7	1.0	0.5-2.0	2.0-5.3

* Reduction of organic pollution potential (BOD)
* Reduction of solid material
* Partial reduction of pathogens and weed seeds
* Generation of energy

The treatment system usually consists of the parts indicated in the figure 5, although many variations are available, mainly on the side of further storage and use of treated slurry and the utilisation of biogas, with preference to direct use for heat generation in smaller plants.

The objectives outlined above are achieved in a 15 day treatment time for hog slurry and 20 days for cattle slurry at 35℃. The production of biogas, normally consisting of 35% CO_2 and 65% methane, varies with the manure digested and in average 450 litres are produced from one kilogram of volatile solids from hog slurry and 250 litres from cattle slurry (Werner et al., 1986).

The use of AD varies through Europe. The economy of the temperature controlled digestor on a single hog farm, unless the farm is relatively large with more than 5000 hogs, (Parsons, 1984) cannot be justified. Thus the trend of using AD as a viable slurry treatment system in Europe varies with climate and the ability of farmers to create co-operative systems. In Italy and Portugal the

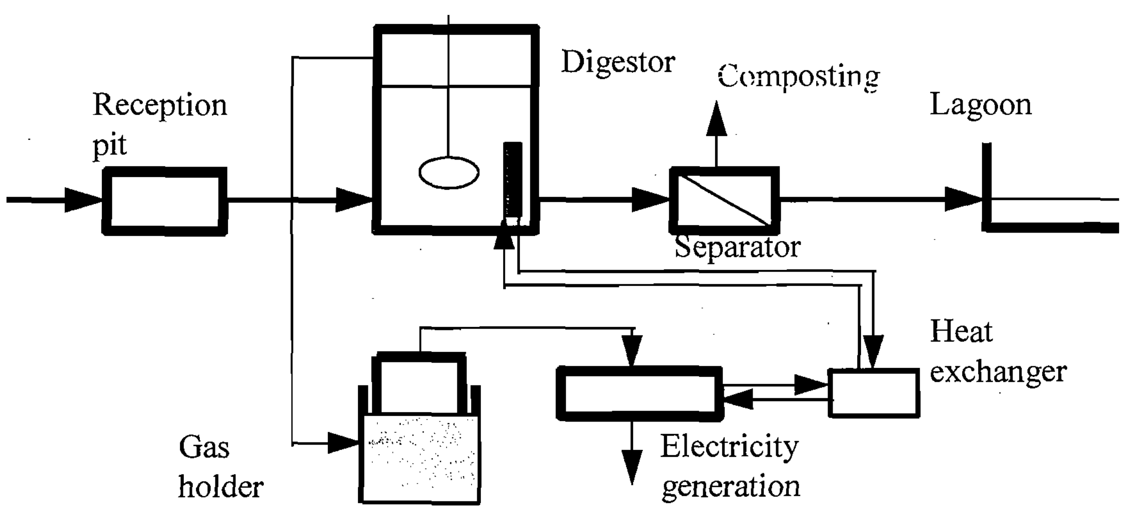

Figure 5. A schematic description of anaerobic digestion system for treatment of piggery slurry

Anaerobic Treatment (AD)

A controlled anaerobic digestion achieves the objectives of manure treatment much faster than the uncontrolled cold digestion in lagoons. Livestock slurry can be treated to various degrees depending on the local requirements and the environmental protective measures. Objectives of these requirements which can be accomplished by anaerobic treatment are usually formulated as follows:

* Reduction of offensive odour

warm weather conditions allow to use unheated AD systems with the main aim of reducing pollution potential and odour from hog slurry (Bicudo et al., 1996, Piccinini, 1996). In Denmark a few co-operative digestion plants were established. They digest waste from local farmers who created the co-operatives. The digested livestock slurry is distributed to local or private storage tanks and applied during 3 months onto the land (Holm-Nielsen et al., 1993), thus optimising the application rates of NPK, minimising the pollution of aquatic environment and utilising the biogás either for electrical energy generation or for heating local houses. Anaerobic digestion requires a relatively long time (hog slurry 15 days, cattle slurry 20 days) to achieve slurry characteristics which are compatible with pollution control requirements. The use of aerobic systems for slurry improvement can be much faster.

The suspended solids are degraded much more slowly therefore the slurry total BOD_5 even after the treatment, will remain relatively high with levels routinely exceeding 1000 mg/l. Slurry treated in such a way therefore has to be applied onto land and not discharged into the water stream.

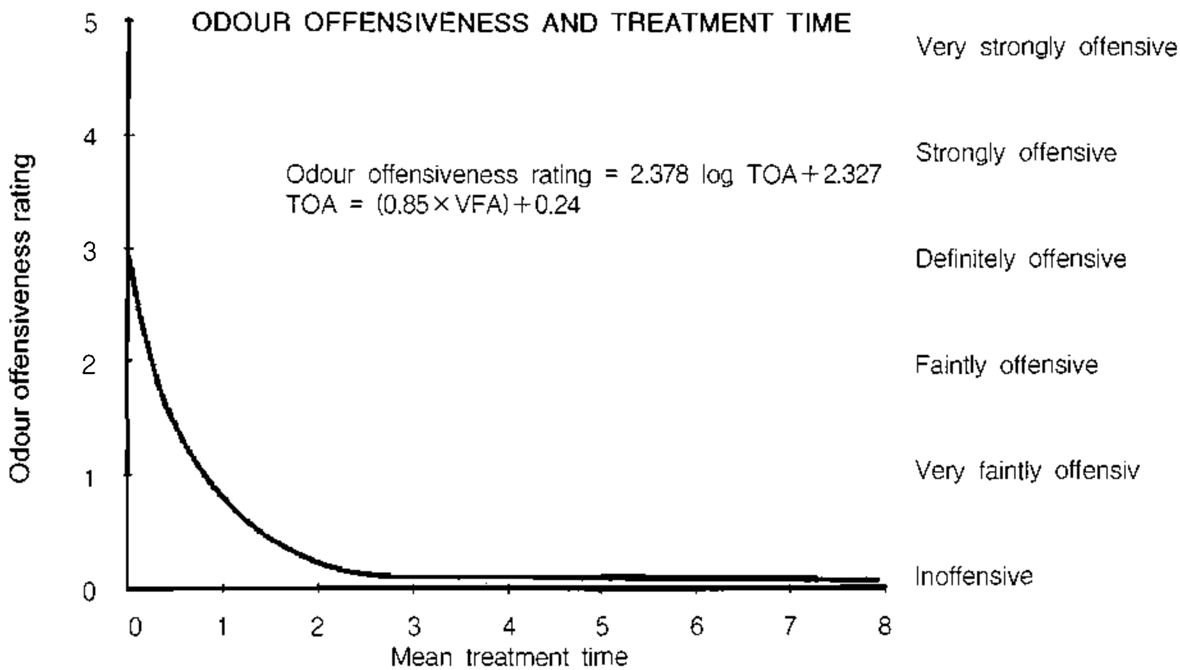

Figure 6. A graphical description of a change of hog slurry odour offensiveness during the slurry aerobic treatment

AEROBIC TREATMENT

Aerobic treatment of hog slurry is, similarly as AD, a natural biological degradation and stabilisation process. The biodegradation is accelerated by both, optimising supply of oxygen for micro-organisms within the slurry and increasing temperature of treated slurry arising from the exothermic treatment process. Elevation of temperature during aerobic treatment process, up to 40 to 60°C can be achieved in insulated reactors or in lagoons. The secondary objective of treatment, namely utilisation of the large quantity of heat energy, can be accomplished, thereby offsetting to a large extent the treatment costs.

Initially the micro-organisms in slurry metabolise the dissolved components. These components (organic acids, phenols, indoles, sulphur compounds and low molecular proteins etc.) are the cause of offensive odour and their concentrations are reflected in high BOD_5 of the liquid slurry phase (supernatant) with levels reaching 10,000 mg/l.

With aerobic treatment this BOD_5 can be decreased to approximately 100mg/l. The continuous treatment system removes offensive odour from hog slurry within three days as was demonstrated by Thacker and Evans (1985) (figure 6).

Table 5. Equations for caculation of residual COD, BOD_5 and BOD_5 of supernatant ($g.l^{-1}$) of treated slurry at treatment temperatures 25 to 45°C and 50°C, where TS_f, TSS_f, COD_f and BOD_f are concentrations of fresh slurry and R the mean treatment time

Parameter	Temperature 25 to 45°C	Temperature 50°C
TS	[0.262/(1+0.4R) +0.744] TS_f	[0.450/(1+0.7R) +0.579] TS_f
TSS	[0.282/(1+0.4R) +0.696] TSS_f	[0.405/(1+0.7R) +0.563] TSS_f
COD	[0.333/(1+0.4R) +0.535] COD_f	[0.429/(1+0.7R) +0.445] COD_f
BOD_5	1.568/R +0.152 BOD_f	1.568/R+0.152 BOD_f
$BOD_{5(sup)}$	0.11/R	0.0427/R+0.007 $BOD_{f(sup)}$

TS .... Total solids.
TSS .... Total suspended solids.
COD .... Chemical oxygen demand.
BOD_5 .... Biochemical oxygen demand (5 days).
$BOD_{5(sup)}$ .... Biochemical oxygen demand of supernatant.

Aerobic treatment of hog slurry was accomplished in many laboratories, pilot-scale and full-scale systems

(Fenlon and Mills, 1980; Gobel, 1891). The characteristics of hog slurry treated by a continuous culture system at temperature from 15 to 50°C, high and low dissolved oxygen (DO) concentrations and treatment time from 0.5 day to 15 were described by Evans et al. (1983, 1986a, 1986b). Treated slurry parameters including total solids, suspended solids, COD, BOD of the whole and filtered slurry were expressed as functions of temperature and treatment time. These equations (table 5) derived from the results of laboratory experiments were evaluated using pilot and full scale treatment systems (Williams et al., 1989; Svoboda, 1993). Therefore these equations provide a sound base for assessment of oxygen requirement for achieving a degree of slurry treatment. This can vary from farm to farm, depending on the environmental restrictions.

Aerobic treatment can effectively control the nature and the quantity of nitrogen. Depending upon operating conditions, nitrogen can be conserved as ammoniacal nitrogen, lost via ammonia stripping, oxidised to nitrate and conserved, or lost via denitrification (Evans et al., 1986b; Bortone and Piccinini, 1991) (figure 7).

Nitrification of ammonia nitrogen can be described by a two step reaction as follows (Sharma and Ahlert, 1977):

$NH_4^+ + 1.5\ O_2 \longrightarrow 2H^+ + H_2O + NO_2^- + 58$ to 84kcal (1)

$NO_2 + 0.5O_2 \longrightarrow NO_3 +$ 15.4 to 20.9kcal (2)

The control of nitrogen speciation during and after the aerobic treatment has environmental implications. Nitrified slurry can be stored for an extended time with the nitrate acting as an oxygen donor and the odour regeneration is therefore avoided prior to land spreading. When simultaneous nitrification and denitrification is controlled in the reactor up to 70% of total slurry nitrogen can be lost as nitrogen gas (Svoboda, 1995). Such slurry can be then safely applied in nitrogen sensitive areas.

Farm scale aerobic treatment plant

Hog slurry is usually aerated after a mechanical separator removes husk, hair and particles of food and faeces to minimise the energy requirement for mixing and aeration (Sneath et al., 1990). Treatment of whole slurry with up to 10% dry matter was demonstrated on a farm scale aerobic treatment plant (Svoboda and Fallowfield, 1989). The integrated system consisted of removal and collection facilities for slurry, reactor for aerobic treatment with heat recovery and utilisation system and a High Rate Algal Pond (HRAP) (figure 8). Slurry was supplied from a piggery with 300 fattening hogs and 200 weaning hogs, it was scraped on a daily basis and 1/24 of the daily volume was pumped hourly into the reactor. The above ground 24m^3 reactor was insulated to conserve heat and covered with a gastight lid. Aeration was provided by a floating subsurface aerator (figure 9). The level of DO concentration in treated slurry was maintained at predetermined level by blowing fresh air into the space between the lid and slurry level from where the aerator sucked it and dispersed it into the slurry. Treatment temperature was controlled by heat extraction with a stainless steel

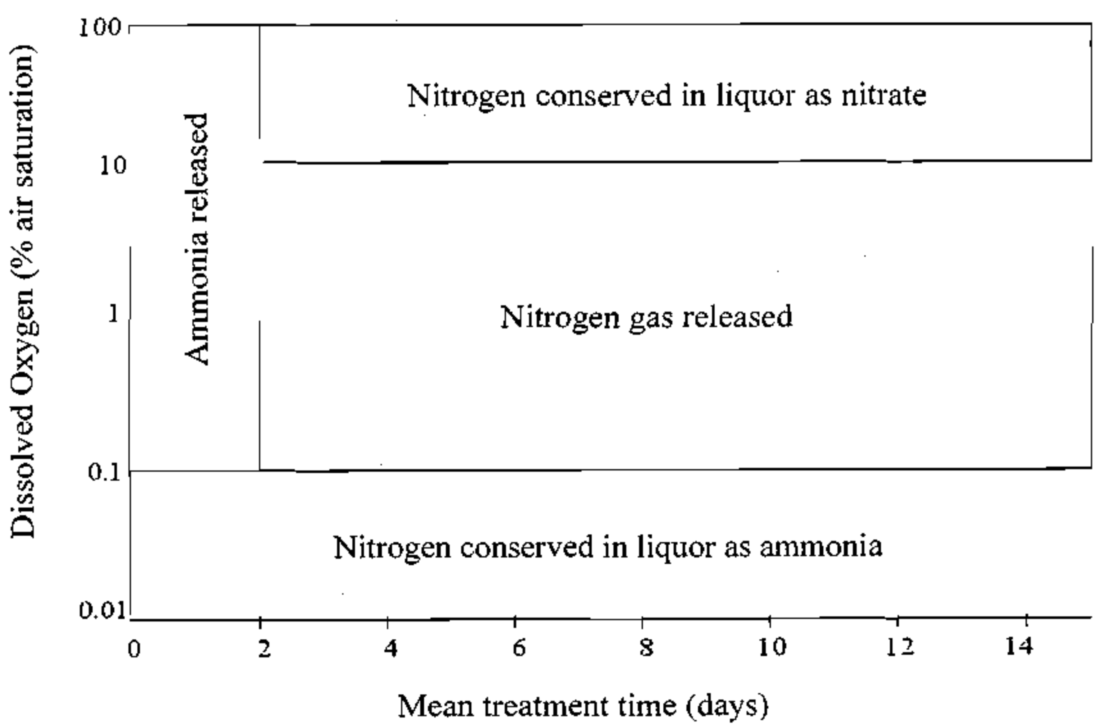

Figure 7. Effect of dissolved oxygen concentration and treatment time on nitrogen speciation in treated hog slurry

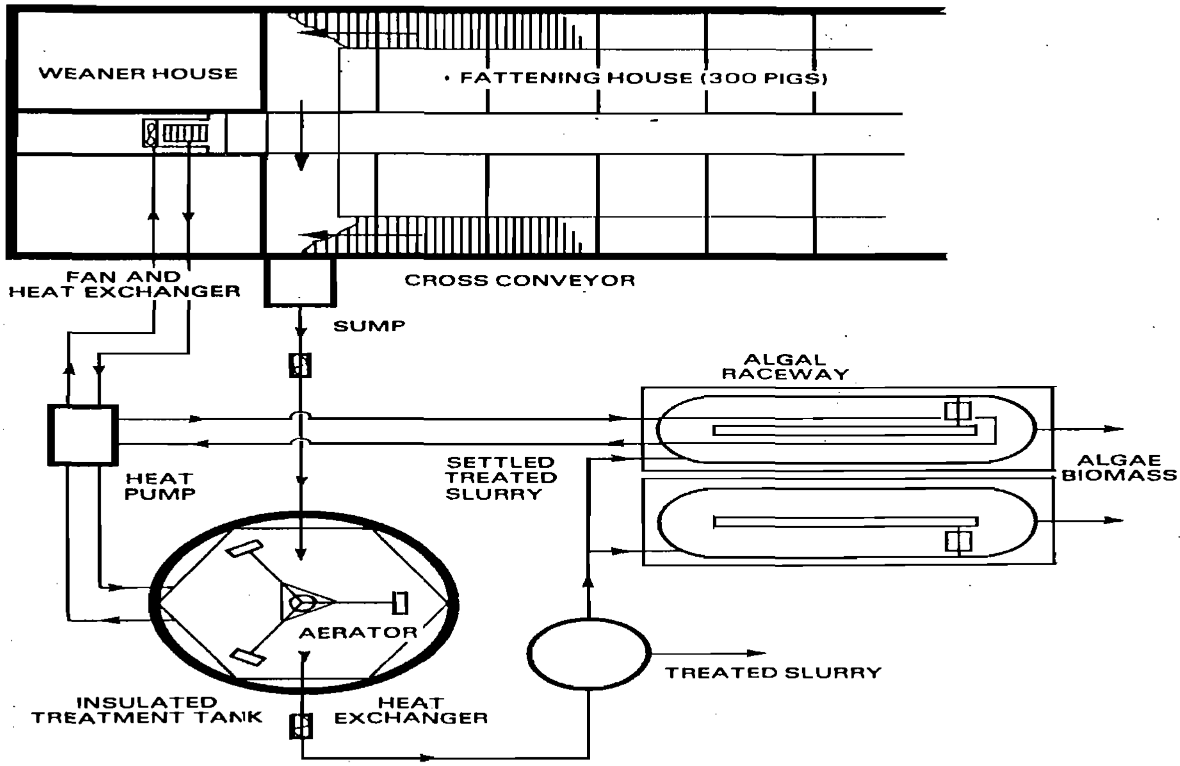

Figure 8. The piggery with the slurry aerobic treatment plant, heat recovery and a high rate algal pond

tubular heat exchanger. Hot water was used directly at treatment temperature of 50℃ or indirectly through a heat pump for treatment temperature of 35℃ for heating the weaner houses or the HRAP.

Solids from treated slurry were removed by mechanical separation and sedimentation and the liquid phase after dilution was further treated in HRAP for nitrogen, phosphorus and BOD removal.

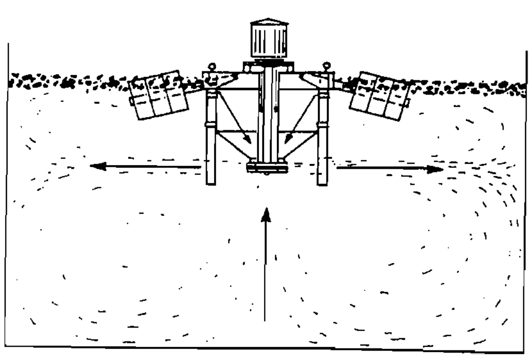

Figure 9. A mechanical subsurface aerator

Two experiments described here were controlled to provide nitrification of available nitrogen at mezophilic temperature (Exp.1) and ammonification of slurry at thermophilic temperature (Exp.2). To obtain nitrate in the treated slurry, high DO levels were maintained (table 6) while for ammonification low levels of DO were sufficient and a more effective control by measuring Redox potential was used.

Table 6. Mean values of the operational parameters of Experiments 1 and 2

Exp.	Treatment time days	DO conc. % of saturation	Redox potential mV E_{cal}	Treatment temp. ℃
1.	11.8	24	Not available	36.8
2.	4.0	3	-37	49.5

The characteristics of raw and treated slurry (table 7) indicate the effectiveness of treatment especially in the decrease of soluble BOD5 which reflects the reduction of offensive odour. Nitrification occurring during the first experiment oxidised all ammonia to nitrate thus any ammonia emission during the subsequent land application of treated slurry was eliminated, but the 61% loss of total nitrogen decreased the slurry fertilising value. This would be beneficial in nitrogen vulnerable zones. Low losses of nitrogen during thermophilic treatment (Exp. 2) resulted from ammonia stripping.

The amount of oxygen required for aeration varied with the length of treatment time, treatment temperature and increased when additional oxygen was used for nitrification (table 8).

The quantity of heat energy recovered from the system in the form of hot water varied depending on the heat losses, treatment temperature and the type and

Table 7. Mean values of raw and treated slurry characteristics and their percentage of reduction resulting from the treatment

Exp. & slurry	TS $g.l^{-1}$	COD $g.l^{-1}$	BOD_5 $g.l^{-1}$	$BOD_{5(sup)}$ $g.l^{-1}$	Tot-N $g.l^{-1}$	Amm.-N $g.l^{-1}$	Nitr.-N $g.l^{-1}$
1. raw	74.1	84.6	22.8	10.1	6.4	3.4	0.0
1. treat.	57.3	48.8	2.5	0.03	2.5	0.03	0.44
% red.	22.7	42.4	89.0	99.7	61.0	99.1	-
2. raw	62.8	72.7	15.6	6.6	7.7	4.2	0.0
2. treat.	47.0	44.3	3.8	0.25	6.9	3.6	0.0
% red.	25.2	39.1	75.6	96.2	10.4	14.3	-

Tot-N: Total nitrogen; Amm.-N: Ammoniacal nitrogen; Nitr.-N: Nitrate nitrogen.

efficiency of the aeration system (Svoboda and Evans, 1987). In both experiments the daily extracted heat energy exceeded the energy required for aeration when the average aeration efficiency was 1 $kgO_2.kWh^{-1}$ (table 8).

Table 8. Oxygen requirement and heat energy extracted during Experiments 1 and 2

Experiment	Oxygen req. $kgO_2.d^{-1}$	Oxygen req. $kgO_2.m^{-3}.d^{-1}$	Extracted heat $kWh.d^{-1}$	Extracted heat $kWh.m^{-3}.d^{-1}$
1.	37.9	47.3	101	126
2.	57.7	34.1	67.5	40

The HRAP system removed from the diluted liquid phase of treated slurry further 95% of BOD_5, 75% of total nitrogen and 35% of phosphorus with N and P incorporated in the algal biomass (Svoboda et al., 1991).

CONCLUSIONS

Hog excrements collected and stored on a hog farm are in reality a valuable fertiliser and soil improver. Although this manure can cause pollution of air and water when its management is neglected, it can be turned into a useful commodity by using modern approaches to the environment protection and manure utilisation. As a rule, the manures and other wastes collected on the farm should be assessed with regard to environmentally friendly use. The farm waste management plan should forward this assessment in a realistic and most effective way by suggesting processes with minimal use of energy for collection and manure application, by optimising manure storage and by planning land application to prevent environmental pollution. In the case of shortage of land available for raw manure application, the next most economical options should be exploited, i.e. export of manure to the neighbouring farms. Although the manures offensive odour may be controlled preferably by the simplest methods (aeration, composting), the treatment of manures to the level of standards for discharge to a water recipient should be considered as a last possible option. It is not only very expensive to build and run and requiring skilled labour, but the discharge standards are hardly achieved and fines by the water quality controlling authority would follow.

Good management of manure on hog farms therefore prevents pollution of the environment, minimises the requirement for the crop fertilisers and helps to maintain a good relationship between the farmer and his neighbours.

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