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Using covered anaerobic ponds to treat abattoir wastewater, reduce greenhouse gases and generate bio energy

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Contents

1 Introduction

Wastewater treatment ponds are the preferred method for treating rural municipal wastewater and agricultural wastewater in Australia due to their simplicity to build and operate (Laginestra and van-Oorschot 2009). Pond design consists of a series of facultative and polishing ponds, with the inclusion of a primary treatment anaerobic pond for wastewater with high solids content. The pond surface area required for treatment can be reduced if physical and/or mechanical methods such as baffles, recirculation and subsurface mixing are used to manage the sludge.

Wastewater from meat processing plants has a high influent Biochemical Oxygen Demand (BOD) of around 2,000 mg/L, requiring treatment in an anaerobic pond prior to stabilisation in facultative and aerobic ponds in series (Green 1992). A typical meatworks effluent analysis includes a high total solids content, and a high total fat content (Husband 1992, Table 1.1). Screens and/or dissolved air flotation systems are often used as a primary pre-treatment in meat processing plants to remove fat and solids that might otherwise overload wastewater treatment ponds. In contrast to many other wastewater treatment influents, the temperature of wastewater from abattoirs is high, of the order of 35 to 37^{0}C. This can be an advantage for anaerobic treatment, as biogas production rates increase with temperature (Chynoweth et al 1998).

Parameter	Typical Value for Abattoir Wastewater Stream	Operational Recommendations for Anaerobic lagoons
pH	7.3	6.8 – 7.2
BOD_5	2,000 mg/L	500 – 800 g/m^3/day
Total Solids	3,500 mg/L	600 – 1,600 g/m^3
Suspended Solids	2,000 mg/L	
Settleable Solids	40 mg/L	
Total Fat	1,700 mg/L	

Table 1.1: Typical analysis of Australian abattoir wastewater (Husband 1992), and generic guidelines for influent entering an anaerobic lagoon (Tchobanoglous et al 1993, Laginestra and van-Oorschot 2009)

The efficiency of anaerobic ponds in reducing the BOD and organic solids content depends on the loading rate of the wastewater being less than or equal to the design capacity of the anaerobic pond (Chynoweth et al 1998). In the meat industry, the potential for fat and grease to blind screens, reducing the efficiency primary treatment, and the inevitability of changes in blood collection and the size of production runs increases the likelihood that the design capacity of anaerobic ponds is exceeded (Green 1992). Under such conditions, the anticipated lifespan of wastewater treatment ponds may be substantially reduced. Understanding how changes in the loading rate of fat and grease, and suspended solids and volatile solids affect the biochemical methane potential of the sludge within an anaerobic pond, will assist in improving the design and performance of wastewater treatment ponds for abattoirs.

2 Traditional anaerobic pond design

The surface loading approach for waste stabilisation ponds is the most widely accepted design specification (Pearson et al 1995). Examples of generic design guidelines for anaerobic lagoons include the American Society for Agricultural Engineers (1985) Engineering Practice 403: Design of Anaerobic Lagoons for Agricultural Waste Management; Mara D and Pearson H (1998) Design Manual for Waste Stabilisation Ponds in Mediterranean Countries. European Investment Bank, Lagoon Technology International Ltd.; and Tchoboanoglous G, Theisen H, and Vigil S (1993) Integrated Solid Waste Management: Engineering Principles and Management Issues. McGraw-Hill Inc. Recommended design parameters for abattoir anaerobic ponds in Australia (Meat Technology Update 4/10, October 2010) specify:

- Loading rate of 500 to 800 g BOD/m^3/day
- Hydraulic retention time of 20 to 40 days
- Depth of 3 to 5 metres
- Length to breadth ratio of 3:1
- Minimum freeboard of 0.5 metres
- Internal slope of 2 to 3:1 depending on the soil type

Anaerobic ponds require high volume lagoons to process organic wastes with a solids concentration within the range of 4 to 8% (Tchobanoglous et al 1993). The low solids fermentation system converts volatile solids to gas, reducing the BOD and the solids content of the water. The BOD of meatworks wastewater is of the order of 2 g/L BOD and a pond volume sufficiently large to retain seven days of effluent production is necessary to reduce the BOD by 90% (EnviroFacts 1995). The effective lifespan of an anaerobic pond is ten to fifteen years, depending on the efficiency of pre-treatment to remove fat and other solids. Two anaerobic ponds operating in parallel are recommended, to halve the loading rate and to improve the flexibility of the system. Traditionally the development of an insoluble crust was considered an advantage, acting as a biofilter to reduce odour. Treated effluent from the anaerobic pond flows into a facultative and/or aerated pond in series, followed by one or two settling ponds (Figure 1.1).

Key factors affecting the efficiency of low solids anaerobic digestion of municipal wastewater (Tchobanoglous et al 1993) are:

- Particle size and solids concentration (4 to 8%) of the influent
- Distribution of the solids and mixing to maintain microbial activity in the sludge (in unmixed ponds only the first third of the floor surface is active)
- Hydraulic and mean cell residence time (3 to 4 days and 10 to 20 days respectively is recommended)
- Loading rate (600 to 1600 g/m^3 depending on the parameters listed above)
- Temperature (mesophilic 30 to 38^{0}C, or thermophilic 55 to 60 ^{0}C)

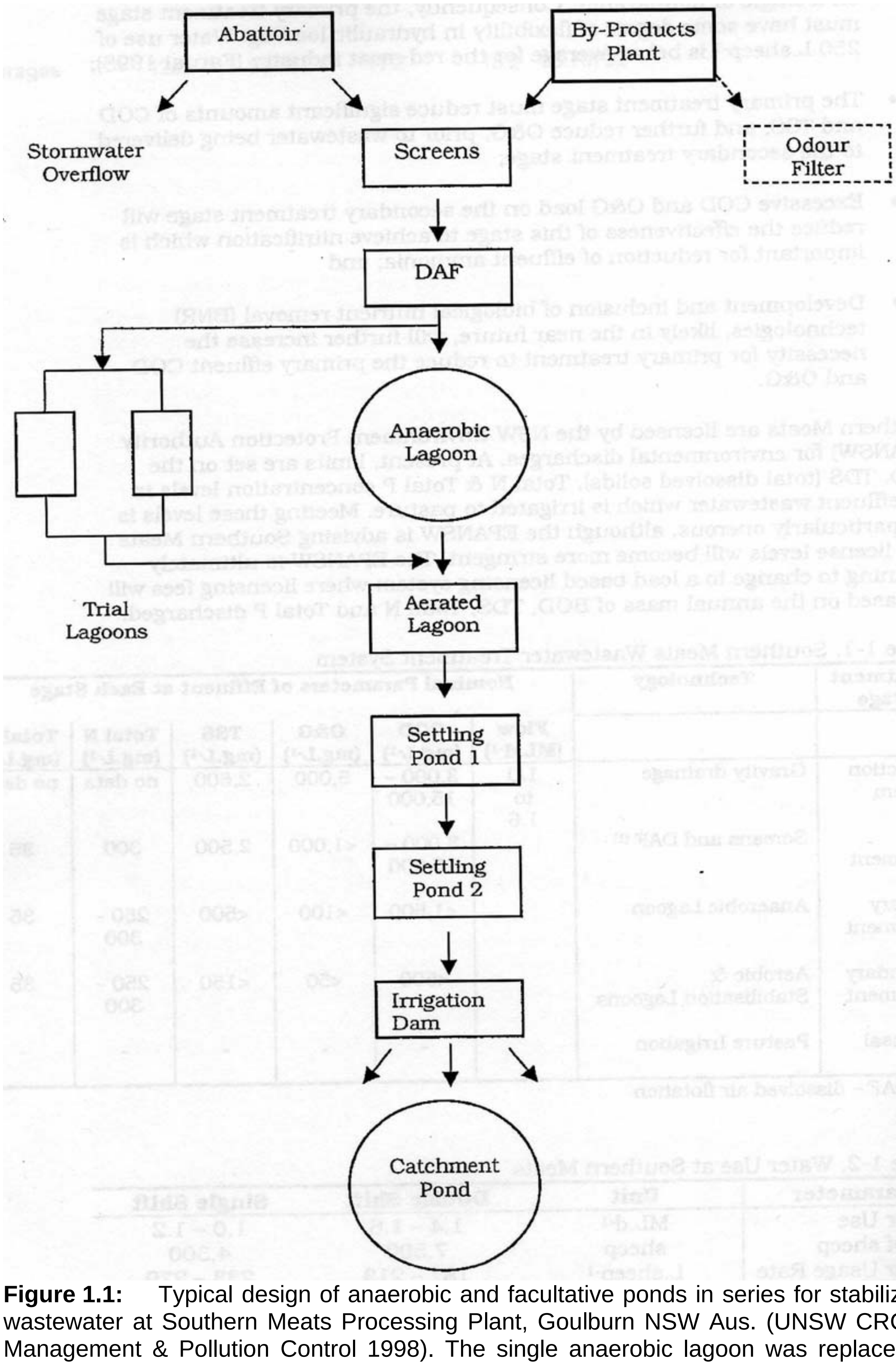

Figure 1.1: Typical design of anaerobic and facultative ponds in series for stabilizing abattoir wastewater at Southern Meats Processing Plant, Goulburn NSW Aus. (UNSW CRC for Waste Management & Pollution Control 1998). The single anaerobic lagoon was replaced by paired anaerobic lagoons in parallel to improve operational flexibility.

Equivalent criteria have been developed from research on the performance of piggery and cattle anaerobic lagoons (Tables 1.2 and 1.3), which lack the abattoir complications of high concentrations of fat and grease, and changes in BOD associated with variations in blood collection (Green 1992). Pond failure is due to lack of methanogenic activity, responsible for the conversion of solids to gas. Sludge builds up at a faster rate than expected, incurring the costs of excessive odour generation, and de-sludging.

The first step in the anaerobic digestion process is the microbial hydrolysis of larger polymeric molecules into smaller, monomeric molecules (Enbom and Huijbregsen 1995). During this process, the COD of the sludge does not change. The dissolved monomers are converted into volatile fatty acids (mainly formic, acetic, propionic, isobutyric and isovaleric acids), hydrogen and carbon dioxide. This process proceeds rapidly, with the decrease in COD proportional to the production of hydrogen and the reduction in suspended solids due to sedimentation (usually less than a 10% reduction). The COD of the liquid also decreases during acetogenesis (the conversion of the long chain fatty acids to acetic acid and hydrogen).

The greatest reduction in COD occurs when methanogens convert hydrogen, formic acid, methanol, methylamine and acetic acid into methane and carbon dioxide (a COD decrease of 70 to 90%). Poor conversion rates at any one of the steps in methanogenesis will result either in the accumulation of solids, and/or no reduction in the COD of the effluent. Inhibition occurs if the concentration of ammonia is greater than 3,000 mg/L ,or if the total volatile organic acids (VOA) concentration is greater than 2,000 mg/L, or if the VOA to alkalinity ratio exceeds 0.5 (Chynoweth et al 1998). Organic waste with a high carbon to nitrogen ratio may also adversely affect methanogenesis if the concentration of ammonia in the pond exceeds 3,000 mg/L. However, when managed appropriately, BOD (COD) removal efficiencies of 40 to 90% can be achieved (Tables 1.2 and 1.3).

2.1 Operating and performance parameters

Generic efficiency parameters for low solids anaerobic digestion systems (Tchobanoglous et al 1993) are:

- 60 to 80% destruction of volatile solids
- 40 to 60% reduction of total solids
- gas production of 0.5 to 0.75 m^3 per kg of volatile solids destroyed.

The main factors affecting organic loading removal efficiencies are temperature, retention time, and volumetric loading (Alexiou & Mara 2003, Table 1.2). Pond design is based on a generic maximum loading rate of 300 g BOD per unit volume of pond per day, for anaerobic ponds with a depth of 3 to 5 m, and a length to width ratio of 3 to 5:1 (Laginestra and van-Oorschot 2009). Suspended solids need to be retained within the lagoon for 20 to 40 days in warm climates.

Modifications to the influent inlet such as the addition of diffusers or horizontal pipes or the incorporation of baffles (Laginestra and van-Oorschot 2009), solids recycle or subsurface agitation avoids short-circuiting (Chynoweth et al 1998). Sludge circulation also enhances the interaction between feed and microbial cells, and minimizes the build-up of inhibitory metabolic products.

Climatic zone and reference	**Loading rate g BOD/m^3/day**	**Physical dimensions and retention time**	**Source material & Removal efficiency**
Mediterranean climate Mara & Pearson (in Alexiou & Mara 2003)	300g for summer, 100g for temperatures < 10^{0}C To avoid odour, < 400 g, with SO_4 < 500 mg/L, with a recirculating flow 1.5 to 2.5 of inlet flow	L to W ratio 2:1 or 3:1, effluent take-off 300 cm below the surface. 1/3 of pond volume designed for sludge accumulation, retention time 5.1 days	Generic guidelines Total BOD 40-60%
Australia MSW anaerobic pond ((Laginestra and van-Oorschot 2009)	Waste > 2,000 mg/L. Cool climate 40 to 60 g BOD per m^3 per day Warm climate 50 to 80 g BOD per m^3 per day	3 to 5 m depth length to breadth 2:1 Cool climate 30 to 50 days retention, Warm climate 20 to 40 days	Industrial municipal wastewater ponds 50 to 90% BOD depending on loading rate and recirculation
Southeastern Spain (Alexiou & Mara 2003)	Designed for 1,650 g, but operated at 3,500 – 5,600 g, with SO_4 400 – 1,100 mg/L	Volumetric loading 180-200 g BOD/m^3/day	Sewage & fruit processing Total BOD 46-49%
Nairobi Kenya (Alexiou & Mara 2003)	240 g		Sewage Total BOD 82%
Nairobi Kenya (Alexiou & Mara 2003)	Designed for 380 g, operated at 400-1800 g at 17^{o}C SO_4 350 mg/L	4 m depth, Designed for a retention time of 1.2 days, but operated at 0.6 days	Sewage and tanneries Total COD 46%
Sana'a, Yemen (Alexiou & Mara 2003)	340 g, air temperature 13.5-23.5^{o}C, ammonia (NH_3) 150-200 mg/L, SO_4 30-40 mg/L	2.0 m depth Influent BOD 800 mg/L, COD 1600 mg/L	Sewage Total BOD 80%
Generic piggery lagoon (Chynoweth et al 1998)	Mesophilic temperature 30 – 40^{0}C	5 m depth Solids concentration 3-10% with a retention time >15 days	Generic Piggery Volatile solids reduction of 50%

Table 1.2 Design criteria and operational specifications for anaerobic ponds treating municipal solid waste water in different climatic regions, and generic specifications for the treatment of piggery waste water. High solids reduction performance is achieved with ponds that receive less than or equal to the design loading rate and that meet the design retention time.

Climatic zone and reference	Loading rate g BOD/m^3/day	Physical dimensions and retention time	Source material & Removal efficiency
USA (in Safley & Westerman 1988)	Digester temp 35^{o}C 3,400 g VS/m^3/day		Beef cattle feedlot Biogas productivity 1.02 m^3 per m^3 of pond per day, 61% CH_4
USA (in Safley & Westerman 1988)	Water temp varied from 14 -27.5^{o+}C for the swine lagoon	Design volume 0.09 and 0.10 m^3 per kg of live animal weight of swine and cattle respectively	Piggery and cattle feedlot lagoons. Biogas production for swine lagoon at 27.5^{o+}C was 0.055 m^3 per m^2 per day
USA California Chandler et al (in Safley & Westerman 1988)	Water temp 11 to 22^{o}C, loading rate 1,100 g VS/m^3/day	1070 m^2 floating cover, pond depth 6.1 m	Biogas yield in covered portion of lagoon 0.11-0.15 m^3 per m^2 per day
USA North Carolina (Safley & Westerman 1988)	Water temp 24-30^{o}C Loading rate 50 g VS/m^3/day	Pond depth 0.8-3.7 m	Piggery lagoon covered 1.5m^{2+} gas collector, biogas 0.04 m^3 per m^2 per day (5-8% CO_2)
USA North Carolina (Safley & Westerman 1988)	Water temp 27-33^{0}C Loading rate 20 g VS/m^3/day	Pond depth 1.8-3.7 m	Dairy cattle lagoon covered 9 m^{2+} gas collector, biogas 0.07 m^3 per m^2 per day (18-20% CO_2)
USA North Carolina (Safley & Westerman 1992)	Sludge temp range 4-28^{0}C, very similar to temp under the cover. COD of influent 16 g/L, COD in lagoon 2.1g/L, loading rate of 41 g VS/m^3/day	Pretreatment of solids separation basin and vibrating screen. Pond 85.9x58.2m and 2.6 m deep.	Dairy cattle lagoon floating cover 7.3x21.3m sitting 5-10 cm above water 80-90% reduction in COD. Biogas production 0.218 m^3 per m^2 per day (18-20% CO_2)
New Zealand (NIWA 2008)	Loading rate 300 g VS/m^3/day.	Pond depth 6 m, Length to width ratio 3:1, retention time of 51 days	Piggery lagoon floating cover. Biogas production 0.26 to 0.38 m^3 per kg of volatile solids added (55-70% CH_4, 30-40% CO_2)
New Zealand (Heubeck and Craggs 2010)	Loading rate 12.5 g VS/m^3/day, total solids	Pond depth 3 m, 28 m width ad 90 m length (capacity 7,200 m^3).	Piggery lagoon floating cover, TS reduction 73%, biogas 0.263 per kg of volatile solids added (67% CH_4, 30% CO_2)

Table 1.3: A comparison of volatile solids loading rates and methane generation in covered ponds receiving effluent from either piggeries or cattle feedlots (beef and dairy cattle). The two North Carolina dairy lagoons have very similar design and volatile solids loading rates, but very different methane generation rates. The pre-treatment of solids via screening and sedimentation may explain the higher methane yield in the second pond.

2.2 Key issues

Anaerobic pond design and operation vary according to the climatic zone in which they are constructed (Table 1.2). As the operating temperature increases, loading rates can be increased and the hydraulic retention time can be decreased. However, the best removal efficiencies are achieved when the pond operating loading rates are below the design loading rates (Alexiou & Mara 2003).

Increasing the length to breadth ratio of ponds to passively increase the bulk flow along the longitudinal axis does not appear to improve performance (Pearson et al 1995). The positioning and depth of the inlet and outlet, and the vertical stratification or lamination of the water column may have a greater impact on treatment efficiency than pond shape or depth.

3 Covered anaerobic pond (CAP) technology

Covered anaerobic ponds are in widespread use in Europe and the USA but their use has received an indifferent introduction to Australia. Current examples of the application of covered pond technology in Australia are Ingham's, Murarrie; Throsby's, Singleton; and A J Bush at Beaudesert.

Despite higher initial infrastructure costs when compared to uncovered anaerobic ponds, covered anaerobic ponds offer significant advantages such as odour control, intensification of the decomposition process and BOD removal, an increase in feed rate and the potential for capturing methane-rich gas as a fuel source for bio energy and the reduction in greenhouse gas emissions (GHGs). Covered anaerobic ponds are also low tech and relatively robust in nature, requiring minimal operation or monitoring. In cooler climates, pond covers may also insulate and heat ponds, via the absorption of solar radiation (Heubeck and Craggs 2010).

3.1 Design features and key performance criteria for CAP

Biogas production increases with temperature as long as the total organic acid concentration remains high. However, organic acid levels above 2,000 mg/L and a pH of less than 6 inhibit methanogenesis (Chynoweth et al 1998). Efficient methane generation at low temperature ($<35^oC$) requires a longer hydraulic retention time (Safley & Westerman 1988). Biogas quality in a covered lagoon study in the USA was high, with CO_2 varying from 5 to 30%. H_2S levels in this study varied from 30-850 mg/L (Table 1.4). The authors attributed the low CO_2 concentration to the relatively high solubility of CO_2 in the lagoon liquid at the lower water temperature 'scrubbing out' the gas.

This may not be the case where there is a large headspace under the cover, and the water temperature is higher. The Safley cover sat at only 5-10 cm above the pond surface. In other biogas capture systems the cover is submerged, for example in a facultative pond, above a deeper anaerobic pit (Green et al 1995).

Organic Component in Piggery Waste Water	Concentration in Influent	Anaerobic Digestion Removal Efficiency %
Total solids %	6.9	52%
Volatile Solids (% of total solids)	82.6	60%
Chemical Oxygen Demand	73.8	58%
g/L	3.9	-
Total N g/L	19.3	47%
Protein (% of total solids)	20.1	65%
Hemicellulose (% total solids)	12.4	64%
Cellulose (% total solids)	14.8	69%
Lipids	1.6	94%
Starch	4.4	3%
Lignin		

Table 1.4: Relative biodegradability of different organic fractions typically present in piggery wastewater. Table is reproduced from Chynoweth et al (1998).

Sludge management is also critical for efficient biogas production. Methane production is highest where a large population of methanogenic bacteria is maintained, on submerged media or as semi-inert solids (Oswald et al 1994). An inoculum to feed ratio of 2:1 and organic particles within the size range of 1-8 mm improves the potential for methane generation (Chynoweth et al 1993). The buffer capacity (alkalinity) of the lagoon must be maintained, with the pH within the range of 6.8 to 7.2. The concentration of highly oxidized compounds (negative redox potential) such as NO_2-, NO_3- and SO_4- must also be reduced.

The rate of biogas production must be consistently high across the pond subsurface (Safley and Westerman 1988). Under suitably low loading rates, pond depth does not appear to affect removal efficiency or biogas production efficiency in piggery and cattle feedlot anaerobic lagoons (Table 1.3). High rates of biogas production are achieved with higher volatile solids loading rates. Poor solids removal performance is most commonly associated with exceeding the designed loading rate of the pond, and with reducing the hydraulic retention time (Table 1.2).

The organic composition of waste water is also critical for achieving high biogas production rates. Lignin is recalcitrant to anaerobic decomposition, and lignin cellulosic complexes such as pine wood, or eucalypt wood containing methanogen inhibitors further reduce BOD removal efficiencies (Chynoweth et al 1998, Table 1.4).

3.2 Solids removal efficiency and biogas generation from CAP

Biodegradability is most commonly expressed as the concentration of methane produced per kg of volatile solids (VS). Carbohydrates are the most readily degraded substrates, followed by proteins, lipids and lignin (Table 1.4). The feed rations of monogastric animals such as pigs contain low concentrations of lignin, whereas feed rations for ruminants such as cattle typically contain higher concentrations. The higher methane generation rate in the North Carolina dairy lagoon receiving effluent pre-treated with screening and sedimentation (Table 1.3) may be due to the removal of larger, more recalcitrant solids that might otherwise inhibit methane generation.

Abattoir waste processing provides the following challenges (Johns 1995):

- Insoluble nature of and high concentrations of fat, oil and grease slows the rate of degradation (increasing volatile organic acid concentration > 2,000 mg/L or reducing pH <6), and forms a scum at the air-water interface (interfering with biogas capture in floating covers).

- Compared with other food processing wastes the BOD (TVS) concentration of abattoir waste is relatively low for high rate methane generation (recommended BOD > 10g/L)

The higher concentration of fat and grease in abattoir waste reduces solids removal efficiency rates due to the insoluble nature of the fats (Battimelli et al 2009). Fats are less dense than water, limiting the physical mass transfer from the solid to the liquid phase, and/or the presence of some of long chain fatty acids may inhibit some methanogenic organisms (Rinzema et al 1994). Pre-treatment such as the removal of fat and grease using screens or dissolved air flotation (Arvanitoyannis and Ladas 2008), or the saponification or exposure to low frequency ultrasound (Erden et al 2010) may assist in solubilising otherwise recalcitrant organics.

However, if well managed, removal efficiencies of up to 90% can be achieved for abattoir wastewater (Table 1.5). Anaerobic baffle reactors improve the efficiency of typical lagoon systems by diverting the flow of influent over and under several baffles placed in series at right angles to the influent flow, improving sludge distribution and mixing. Recirculating the effluent also improves sludge mixing and the increases the hydraulic retention time (Polprassert et al 1992, and Figure 1.2). Baffles have also been added to anaerobic ponds close to the inlet, to reduce the velocity of the flow (Wood et al 1995). Modifying pond flow overcomes the stagnant area that otherwise develops behind the inflow jet. Submerged baffles also increase the surface area available for biofilm formation (Polprassert and Agarwalla 1995). Fibrous physical carriers have also been added to increase biofilm formation and the retention time of microbes (Qi Peishi et al 1993). Microbial biofilms attached to the carriers were also more resilient to shock loading during high intensity storms. Presumably, biofilm attachment increased the stability of the microbial biomass, with attached microbes less prone to being washed out during shock loading.

Climatic zone and reference	Loading rate g BOD/m^3/day	Physical dimensions and retention time	Source material & Removal efficiency
USA Dague et al. in Johns (1995)	Design loading rate BOD 330 g/m^3/day, actual rate 100 g/m^3/day.	Design HRT 8.8 days, actual rate 12-14 days	Pork abattoir Covered, BOD removal 85-90%, methane 0.51 m^3 per kg BOD removed.
Thailand, laboratory scale (Polprassert et al 1992)	COD g/L/day 0.67-2.14 (670-2140 g/m^3/day)	Laboratory-scale baffle reactor HRT 2.5 to 26.4 hr	Abattoir waste, pretreated with DAF. COD removal 67-90%, CH_4 gas yield 0.11-0.19 L per g COD applied
Goulburn, Victoria Aus. (UNSW CRC for Waste Management & Pollution Control 1998)	COD 160-530 g/m^3/day Lagoon water temperature 15-28^{0}C Inflow of 80-260 m^3/day	29x39 m, depth 6 m. with x1 flexible, internal baffle 1m above floor, with recycled sludge. HRT 11.5 to 37.5 days	Abattoir waste, covered, pretreated with DAF and screens. COD removal 79-87%
Australia, mild climate (Laginestra and van-Oorschot 2009)	Design rate not specified: Actual loading rate Case 1 BOD 150 g/m^3/day Case 2 BOD 190 g/m^3/day	Case 1 retention 24 days, Case 2 retention 7 days	Abattoir waste, uncovered, aerated Case 1 64% BOD removal Case 2 79% removal

Table 1.5: Solids removal efficiency rate and methane yield for anaerobic ponds receiving abattoir effluent. The highest efficiency rates are in ponds that receive up to or less than the design loading rate. No design loading rates are specified for the Australian ponds, but the actual loading rates are very similar. Unexpectedly, the Australian pond with the substantially lower retention time recorded the highest BOD removal. In the absence of data on actual methane yield, it is difficult to determine if the reduction in BOD is due to biogas production or solids sedimentation.

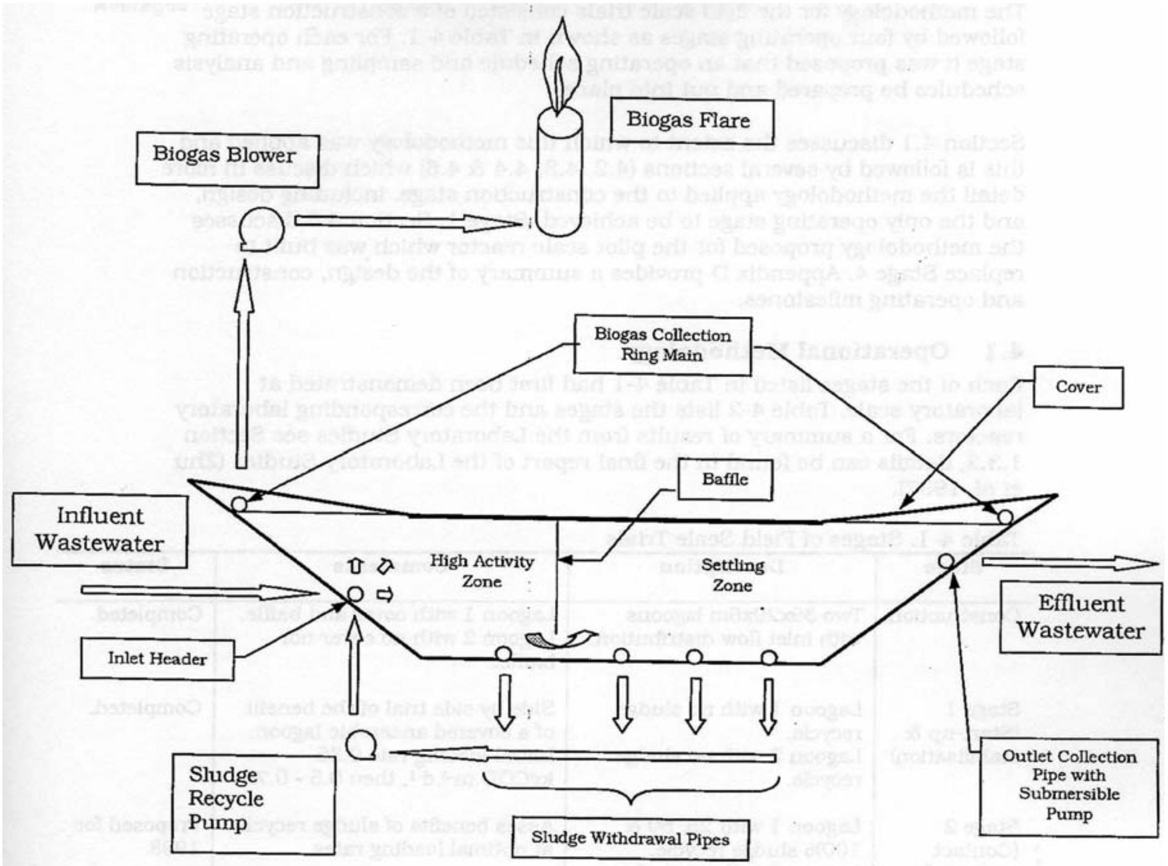

Figure 1.2: Design of a covered anaerobic lagoon for processing abattoir effluent constructed at Southern Meats Processing Plant, Goulburn NSW Aus. (UNSW CRC for Waste Management & Pollution Control 1998). The dimensions of the pond were 29x39 m, with a depth of 6 m and included x1 flexible, internal baffle perpendicular to the influent flow and 1m above the pond floor. Sludge was recycled, and the hydraulic retention time was 11.5 to 37.5 days.

The wastewater was pre-treated using screens and dissolved air flotation. The inlet header was located at half the total depth of the pond, with the effluent pipe located closer to the surface. COD removal efficiency was 79 to 87%. Data is not available for methane gas production due to problems with lagoon management and gas capture.

For feeds with a high cellulose and lignin content, the installation of baffles or solids recycling (effluent recirculation) is necessary to maximize the retention of feed solids and microorganisms (Fannin and Biljetina 1987). Settling (sedimentation) is the traditional method for increasing residence time, but the accumulation of toxic metabolites may produce inactive zones, reducing the efficiency of solids reduction (Chynoweth et al 1998).

Increasing the solids concentration of feed above 32% slows methane production, especially for feed with a high concentration of particulate solids (Fannin and Biljetina 1987). For example, methane gas production from woody biomass is highest at 10-15% total solids, with a biodegradable fraction of 30 to 60% of total volatile solids. Paunch and manure from beef cattle contain a higher proportion of total solids and lignin that may require a longer retention time for removal efficiency and methane gas production. Alternatively, sedimentation or screening may be required to reduce the proportion of larger particles and recalcitrant solids (refer Table 1.3).

3.3 Design Criteria Used for Churchill Abattoir Ponds

Recommended design parameters for abattoir anaerobic ponds in Australia (Meat Technology Update 4/10, October 2010) specify:

- Loading rate of 500 to 800 g BOD/m^3/day
- Hydraulic retention time of 20 to 40 days
- Depth of 3 to 5 metres
- Length to breadth ratio of 3:1
- Minimum freeboard of 0.5 metres
- Internal slope of 2 to 3:1 depending on the soil type

The BOD of meatworks wastewater is of the order of 2 g/L BOD and a pond volume sufficiently large to retain seven days of effluent production is necessary to reduce the BOD by 90% (EnviroFacts 1995). The effective lifespan of an anaerobic pond is ten to fifteen years, depending on the efficiency of pre-treatment to remove fat and other solids. Two anaerobic ponds operating in parallel are recommended, to halve the loading rate and to improve the flexibility of the system. Traditionally the development of an insoluble crust was considered an advantage, acting as a biofilter to reduce odour. Treated effluent from the anaerobic pond flows into a facultative and/or aerated pond in series, followed by one or two settling ponds (Figure 1.1).

Designs for the conventional anaerobic pond constructed at Churchill Abattoir in 2000 were based on a BOD loading of 300 g per m^3 per day, with a 20 day hydraulic retention time (M Spence personal communication 2010). The anaerobic pond was 5 m deep, with a capacity of 10 ML. Effluent from the anaerobic pond flowed into a facultative pond (5 m depth, 10 ML capacity) and an aerobic pond (2 m depth, 16 ML capacity) in series. The anticipated lifespan of the system was 10 to 15 years. However, within 5 years of construction, the ponds had failed. A comparison of the average BOD loading of raw influent and pond 1 effluent over 10 years of operation indicates a removal efficiency of 91%, but presumably this represents sedimentation, not biogas production. Desludging was attempted in 2006, but the presence of a hardened crust (1 m thick) and the viscous nature of the sludge below made the task difficult.

Factors that could be considered to improve the performance of the ponds may include:

1. Pre-treating the influent to reduce the fat and grease loading if sludge monitoring indicates the concentration of total volatile organic acids exceeds 2,000 mg/L, or the Volatile Organic Acid to alkalinity ratio exceeds 0.5, or the pH is less than 6.2, or the Biochemical Methane Potential assay indicates that long chain fatty acids are inhibiting methanogens.

2. Pre-treating the influent to reduce the particle size and to increase the proportion of volatile solids if the particle size distribution contains a high proportion of particles closer to or exceeding 8 mm in diameter, or if the proportion of volatile solids is low.

3. Modifying the influent pipe or adding deflectors, or baffles, or physical biofilm carriers, or recirculating effluent to improve sludge mixing and the uniformity of high rates of methane generation across the entire subsurface floor of the pond.

The monitoring phase of the project will indicate which of the options above may be the most promising option for optimising the performance of the smaller, covered ponds at the Churchill abattoir.

Abbreviations

BOD	Biochemical oxygen demand
°C	Degrees Celsius
CAP	Covered anaerobic ponds
cm	Centimetres
COD	Chemical oxygen demand
DAF	Dissolved air flotation
g	Grams
HDPE	High density polyethylene
L	Litres
m	Metres
mg	Milligrams
ML	Megalitre
MLA	Meat & Livestock Australia
TVS	Total volatile solids
USA	United States of America
VOA	Volatile organic acids
VS	Volatile solids

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