final report

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Continuous anaerobic pond desludging

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EXECUTIVE SUMMARY

Theoretical Considerations

Anaerobic ponds comprise a cost effective method of reducing chemical oxygen demand (COD) and five day biochemical oxygen demand (BOD_5) concentrations in meat process wastewater prior to release to aerobic wastewater treatment operations. Theoretically, anaerobic systems should generate lesser amounts of sludge compared to aerobic systems, however, in practice in the Australian meat process industry, anaerobic ponds frequently fill rapidly with solids.

Desludging of anaerobic ponds is often difficult due to the presence of a thick crust on top of the pond. More recent technology involves covering the anaerobic pond with a synthetic plastic membrane, permitting capture of energy-rich biogas and odours. In these systems, desludging is even more difficult since the membrane is readily damaged if removed for desludging operations.

Existing pond desludging technologies are difficult to apply to existing anaerobic ponds when crust or membrane covered. The development of low cost continuous or semi-continuous methods of desludging of anaerobic ponds is therefore of significant economic benefit to the Australian Meat Industry.

The effective design and operation of anaerobic ponds is reliant on introducing sufficient biodegradable organic load based on the surface area available to greatly exceed the oxygen transfer by natural diffusion. This permits the formation of a stable crust to subsequently eliminate all oxygen diffusion. Thus many ponds at start up suffer from odour generation prior to formation of the crust.

It is therefore desirable during sludge withdrawal to maintain the surface crust to minimise the potential for odour generation upon reinstatement of the pond or during continuing operation whilst carrying out sludge withdrawal.

Desludging Considerations

Anaerobic ponds are not well suited to utilising the more common methods of desludging such as dredging or pontoon mounted pumps due to the need to preserve the surface covering. Mechanical sludge conveying can not be employed due to the large spans involved and high capital cost. Steeply sloping sides are precluded due to the large depths required and the steep wall angles required that are unsuitable in earthen basins. Permanent pipework for sludge draw-off can suffer from blockages through a number of mechanisms.

It is also critical to the successful operation of anaerobic ponds that an active sludge layer be maintained within the pond to provide a continuous supply of methane forming bacteria. It is for this reason that many anaerobic ponds at start-up suffer from severe odour generation until an active settled sludge layer is established.

Based on microbiological considerations, complete desludging of the anaerobic pond is undesirable. More regular, partial draw-off of the settled sludge is therefore more desirable.

Small, frequent sludge withdrawal will minimise changes in the bacterial biomass providing treatment thus ensuring more stable performance. The quantity of sludge requiring dewatering and disposal at any one time is also reduced. This will reduce the potential for odour generation problems. The quantity of dewatered sludge requiring disposal at any one time will be reduced and more regular supply to end users can be provided in comparison to identifying large reuse markets once every 20 to 25 years.

Attention-causing problems are avoided through small frequent sludge withdrawal. Experience would suggest in most cases that the need to desludge is only considered necessary when there is a problem. By that stage, the neighbours and the regulatory authorities are also aware of the problem. Typically the problems can be attributed to excessive sludge accumulation resulting in decreased treatment efficiency and overload of downstream treatment units or discharge of inadequately treated effluent. The desludging operation then typically involves removal of massive volumes of sludge that can present additional problems of odour generation and logistics.

Sludge that has been permitted to accumulate for an excessive period of time will also tend to consolidate. This will increase its resistance to flow and make draw-off more difficult.

Pretreatment Simplifies Sludge Draw-Off

The amount of grit and non-biodegradable material discharged to the anaerobic ponds should be minimised. This minimises both the amount of sludge generated and the transport velocities required for the withdrawal of the settled sludge layer.

Deep Ponds Offer Significant Advantages

Grading of the base of the anaerobic pond to a single or several locations can be carried out. Anaerobic ponds with a slope back to the inlet end where the majority of the sludge accumulation occurs can be constructed. Alternatively, slopes to the sides of the lagoon for simplified draw off pipework could be provided.

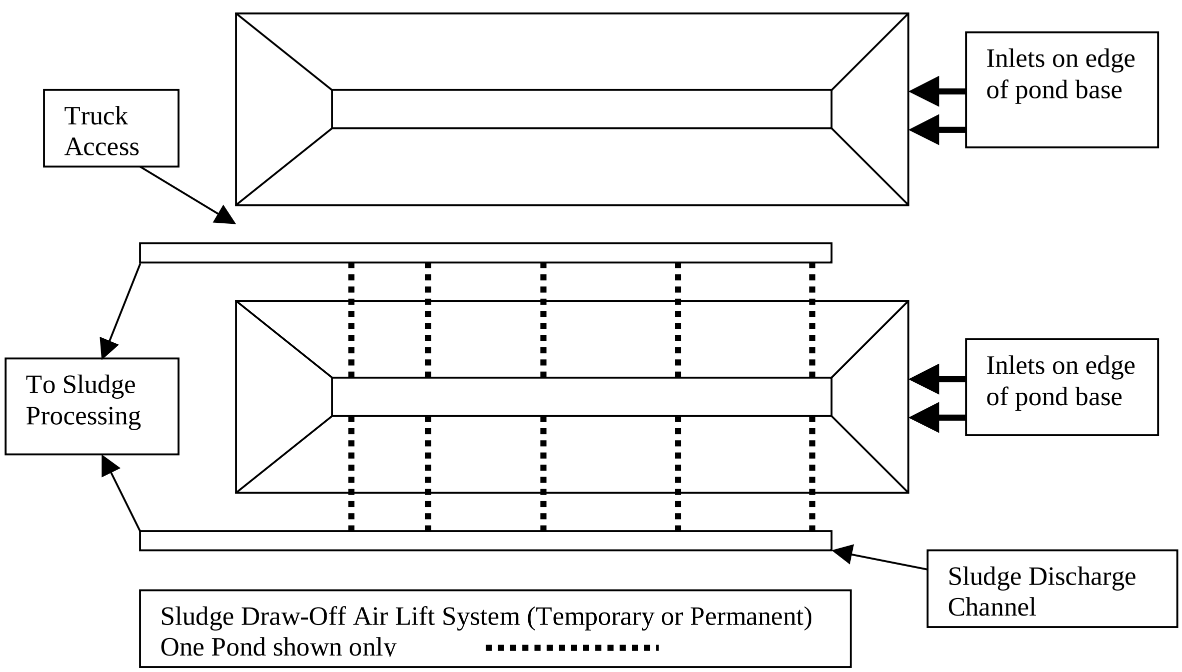
The review of the problems encountered in the draw-off and pumping of sludge from anaerobic ponds has demonstrated that there are considerable advantages to constructing deep ponds. The benefits of the use of deep ponds of approximately 6 m depth include;

- Increased sludge accumulation volume
- Less draw-off points required
- Larger sludge draw-off volumes before "rat-holing" occurs.
- Permits the use of mixers to transport sludge to draw-off point

The review of the microbiology of the treatment process has demonstrated that the increased detention time in deeper lagoons will not have any detrimental impact on the treatment process. The volumetric organic loading has no impact on anaerobic conditions. The key factor for anaerobic conditions is the surface organic loading rate as this must exceed the oxygen transfer capacity through the surface of the pond.

The use of deep ponds permits the use of simple airlift pumps for sludge draw-off. These simple and low cost pumps can be provided as permanent fixtures with either a reticulated air supply or a relocatable blower used for air supply.

Desirable Features of Anaerobic Pond Layout.



Small, frequent desludging operations have less environmental and logistical problems. Odour generation is reduced as are sludge drying, cartage and disposal requirements.

Operation of the Ponds can be Improved to Improve Desludging

With the provision of the air-lift pump system for sludge draw-off, operating procedures can be implemented to assist in achieving routine and regular effective sludge draw-off. These procedures are aimed at not only maintaining the settled sludge in a fluid state, but may also assist in maximising treatment within the anaerobic pond.

Anaerobic ponds without a synthetic cover and reliant on a surface crust can be periodically air sparged at approximately weekly intervals resulting in air mixing at the bottom of the lagoon. Benefits achieved by this procedure include;

- Prevents consolidation of the settled sludge therefore maintaining the sludge in a more fluid state and promoting better flow of the sludge.
- Mixes anaerobic organisms back into the water column and improving contact with substrate to achieve improved treatment
- Releases accumulated anaerobic gases regularly thus minimising periodic large odorous gas eruptions
- Releases accumulated anaerobic gases regularly thus minimising generation of toxic conditions such as pH and inhibitory concentrations of gaseous by-products
- May prevent very low oxidation reduction potential conditions that increase hydrogen sulphide generation.

Adoption of periodic mixing of the sludge layer therefore will improve the overall digestion process in addition to maintaining the settled sludge in a more fluid condition. As the facilities required for the mixing (the air lift pumps) have already been installed, it is clearly a relatively simple matter to gain the maximum benefit from these facilities. The entire process can be fully automated through the use of solenoid valves on the air supply line to each air-lift pump.

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1.0 INTRODUCTION

Anaerobic ponds comprise a cost effective method of reducing chemical oxygen demand (COD) and five day biochemical oxygen demand (BOD_5) concentrations in meat process wastewater prior to release to aerobic wastewater treatment operations. Theoretically, anaerobic systems should generate lesser amounts of sludge compared to aerobic systems, however, in practice in the Australian meat process industry, anaerobic ponds frequently fill rapidly with solids.

Desludging of anaerobic ponds is often difficult due to the presence of a thick crust on top of the pond. More recent technology involves covering the anaerobic pond with a synthetic plastic membrane, permitting capture of energy-rich biogas and odours. In these systems, desludging is even more difficult since the membrane is readily damaged if removed for desludging operations.

Existing pond desludging technologies are difficult to apply to existing anaerobic ponds when crust or membrane covered. The first stage of this project is to evaluate existing technologies and ways in which they can be modified to allow continuous/batch desludging of the pond without impairing its performance or generating environmental problems. Alternatively, superior, novel technologies are to be developed to achieve desludging. In a subsequent stage of this project, the recommended desludging technology will be trialled at a site to demonstrate its usefulness and operability.

Benefits to processors due to the development of modified or revised desludging systems would include:

- Availability of a new desludging technology able to complement existing and new anaerobic ponds;
- Ability to operate anaerobic ponds under current design parameters and operating environment without interruptions due to desludging operations
- Ability to desludge anaerobic ponds continuously and under controlled conditions in a manner that maximises their operational efficiency

Benefits to the community due to improved desludging technology would include;

- Limiting the possibility of odour generation, wastewater treatment failures and the need for disposal of large quantities of unstable anaerobic sludge
- Maintaining the economic viability and environmental sustainability of the Australian meat process industry through the continued use of cost-effective modern anaerobic technology for the treatment of its wastewater.

This report presents the findings of the investigation into anaerobic ponds in the Australian processing industry and the development of desludging technologies to meet the requirements of the stated project aims.

2.0 WASTE LOADS GENERATED IN THE MEAT PROCESSING INDUSTRY

2.1 Sources of Wastes from Meat Processing Plants.

The Australian meat processing industry generates a broad range of wastes subject to the actual site operations. Sources of wastes can include;

- Animal pens and holding yards
- Kill Floors
- Evisceration
- Paunch removal
- Boning rooms

Various by-products processing operations can also be carried out including;

- Blood processing
- Offal processing
- Inedible rendering
- Edible rendering
- Hide/skin preservation

All of these processes can generate wastewater streams containing wastes requiring separation and treatment prior to reuse or discharge. Selection of the optimum treatment for each of these streams requires consideration of the characteristics of the actual stream generated and the effectiveness of the treatment processes employed in separating or degrading the wastes.

2.2 Pretreatment Processes Employed at Meat Processing Plants.

A number of pretreatment processes are employed at meat processing plants. Some systems are provided on combined waste streams whereas others are used on specific streams to achieve either separation of waste components or by-product recovery. Typical pretreatment systems for specific streams include;

- Manure Traps on animal pens
- Screening of paunch
- Blood recovery
- Product separation for rendering

General pretreatment facilities for the main waste stream or a number of combined streams include;

- Gross solids traps
- Savealls
- Dissolved air flotation

Some or all of these processes can be employed at meat processing plants. This can have significant impact on the loads and characteristics of the wastes discharged to the subsequent anaerobic pond treatment system. This in turn determines the sludge generation rates and much of the characteristics of the sludge draw-off requirements.

2.3 Waste Load Generation Rates from Meat Processing Plants.

The Australian meat processing industry is diverse in nature with a range of animals processed. Some plants are dedicated to a specific product range whilst others process a number of different types of animals. The type and degree of pretreatment and product recovery will also vary from plant to plant. The combination of these factors results in a broad range of waste loads and waste components discharged to the anaerobic ponds. This has been demonstrated in the industry survey carried out. This has demonstrated a broad range of BOD_5 concentrations in the influent to the anaerobic ponds. Typically the influent BOD_5 concentration varied form 2000 mg/L to 6,000 mg/L.

Determination of exact waste loads discharged to anaerobic pond systems is further made difficult by the limited degree of monitoring carried out. As there are no control parameters that can be adjusted in the anaerobic pond system, there is no benefit to be gained in carrying out extensive monitoring. Thus, in order to minimise costs, influent monitoring is usually restricted to compliance with statutory obligations. It appears that little if any monitoring is carried out of individual waste streams within the processing plant.

A review of the literature on meat processing wastes has confirmed this highly variable nature in the loads generated. The loads can be evaluated on a "live weight kill" basis as presented in the following table.

Table 2.1 Waste Loads Reported for Meat Processing Plants

Component	Maximum Load kg/1000 kg LWK	Minimum Load kg/1000 kg LWK	Average Load kg/1000 kg LWK
BOD_5	21.6	6.5	14.6
Suspended Solids	21.7	4.6	12.0
Nitrogen	2.67	0.79	1.7
Grease	6.0	0.27	1.63

As demonstrated in the table, the organic (BOD_5) and suspended solids loads can vary over a very broad range. This reflects the products processed, the extent of processing carried out, the extent of by-product recovery and the extent of pretreatment carried out. The monitored grease loads also demonstrate significant variation reflecting variations in by-product recovery and pretreatment carried out. The nitrogen loads demonstrate significantly less variation as nitrogen is removed from the wastes predominantly through by-product (blood) recovery and is not significantly removed during pretreatment.

With the wide range of waste loads experienced and the lack of data on the individual waste stream components, estimation of sludge generation rates within the anaerobic ponds cannot be accurately determined. Site specific factors will result in the variations reported in the literature being experienced. Therefore, in order to develop a general approach to sludge generation and the characteristics of the sludge accumulating in the anaerobic ponds, it is necessary to consider the components of the wastes as viewed by the microorganisms undertaking the treatment.

3.0 DESIGN PRINCIPLES AND OPERATION OF ANAEROBIC PONDS

3.1 Characteristics of Organic Wastes Streams Requiring Treatment

Organic wastes can generally be classified into the following four categories;

- Non-biodegradable soluble wastes
- Non-biodegradable particulate wastes
- Biodegradable soluble wastes
- Biodegradable particulate wastes

The non-biodegradable soluble wastes are unable to be treated and pass through the treatment system relatively unchanged. These compounds do not exert any oxygen demand in the receiving waters as they are non-biodegradable and therefore have a BOD_5 of zero. These wastes therefore do not require any treatment under current licensing conditions.

Non-biodegradable particulate wastes may be organic or inorganic. The inorganic particulate wastes are by definition non-biodegradable. Typically this fraction of the wastes comprises grit and other similar material primarily generated in the animal pens and holding yards. This material has a specific gravity of 2.3 or more and settles rapidly. Discharge of this material to anaerobic ponds will result in a dense settled layer of grit that is resistant to flow and transport out of the pond. This material should be removed prior to discharge to anaerobic ponds to prevent unnecessary solids accumulation.

Biodegradable soluble wastes are either directly consumed by bacteria within the anaerobic ponds to form methane, hydrogen and carbon dioxide. More complex, soluble components need to be hydrolysed by bacteria to simpler compounds prior to conversion to organic acids and then methane, hydrogen, water and carbon dioxide. As a result of the biological processes carried out, bacterial growth occurs resulting in the conversion of some of the soluble components to particulate material.

The particulate biodegradable material present in the wastes are large compounds and must first be hydrolysed to simple compounds prior to generation of organic acids and then methane, hydrogen, water and carbon dioxide. During the hydrolysis process, the acid formation process and the methane formation process, additional bacterial growth occurs adding to the total biomass within the system.

In summary, the wastes generated can be broadly categorised into the following groups;

- Non-biodegradable soluble components that pass straight through the treatment system

- Non-biodegradable particulate material that will settle out and accumulate if discharged to the biodegradable system.
- Biodegradable material that is converted to water, gaseous products and biomass with the biomass formed settling out and undergoing further degradation.

During decomposition of the bacterial cells carrying out the treatment, not all of the cell can be degraded. The remaining material is termed endogenous residue and accumulates in the settled sludge along with non-biodegradable particulate material. Ultimately these settled components accumulate to the point where desludging is required.

3.2 Design and Operation of Treatment Ponds

The fundamental requirement of an anaerobic pond is that it is in fact anaerobic. Treatment ponds may also be designed to be aerobic, facultative or anaerobic. The operation of each of these types of lagoons is briefly reviewed to demonstrate the operational requirements of anaerobic ponds both during normal operation and desludging.

Aerobic ponds achieve treatment of biological wastes through consumption of organic wastes by aerobic bacteria. Protozoa then prey on the aerobic bacteria and themselves undergo death and lysis. The lysis products released upon death of the protozoa are in turn consumed by the bacteria and the cycle is repeated. During each step of the cycle, a small amount of non-biodegradable particulate endogenous residue is generated. This material settles out in the pond and accumulates as a settled sludge layer in the pond. In order for the pond to remain aerobic, the oxygen diffusing into the surface layer of the pond must exceed the oxygen demand exerted by the bacteria consuming the wastes and the protozoa consuming the bacteria. The oxygen transfer from the atmosphere to the liquid phase is encouraged by wave action on the surface of the pond. Where the aeration demand exceeds that possible by natural diffusion, mechanical surface aerators or diffused air systems can be provided to increase oxygen transfer.

Facultative lagoons are in fact a combination of aerobic and anaerobic processes. The surface layer of the facultative lagoon is aerobic and the settled sludge layer is anaerobic. The lagoon must be sufficiently deep to permit odorous soluble and gaseous components released from the anaerobic settled sludge layer to be oxidised by the aerobic bacteria in the upper layer. Again, the limitation of the system is the amount of oxygen that can diffuse from the atmosphere through the surface of the lagoon.

Anaerobic ponds, to function correctly, must establish a population of hydrolysing anaerobic bacteria, acid forming bacteria and methane forming bacteria. The hydrolysing bacteria break down the complex biodegradable organic material to simpler compounds that are then transformed to short chain fatty acids by the acid forming bacteria. These short chain fatty acids then serve as food or substrate for the methane forming bacteria.

The methane bacteria are extremely sensitive to dissolved oxygen. Thus, for satisfactory operation of the anaerobic pond, it is essential that either oxygen diffusing into the surface of the pond is rapidly scavenged or the surface of the pond is covered to prevent oxygen diffusion. Rapid scavenging of diffused oxygen can be achieved by ensuring that the biodegradable organic load discharged to the pond is extremely high. Prevention of oxygen diffusion can be achieved by permitting a stable crust to form on the surface of the pond or provision of an artificial cover for the pond.

The classification of the different types of ponds is therefore based largely on the proportion of the incoming biodegradable organic load that is satisfied by the oxygen diffusing from the atmosphere through the surface layer of the pond. Aerobic ponds have almost all of the oxygen demand of the influent waste satisfied aerobically, facultative ponds have part of the oxygen demand of the influent waste satisfied aerobically and anaerobic ponds only have a very small proportion of the influent potential oxygen demand satisfied aerobically. As the amount of oxygen diffusing into the surface of the pond is relatively constant in the absence of natural or artificial covers, the proportion of the influent oxygen demand satisfied is a function of the influent biodegradable organic load. With higher loads a smaller proportion of the total load is satisfied aerobically. As loads increase, the pond will become anaerobic and generate a smooth pond surface with minimal oxygen transfer due to surface tension effects generated by the intermediate treatment products.

Typical biodegradable organic loading rates for the various types of ponds are summarised in the following table. These loading rates will vary with ambient temperature and prevailing wind conditions. However, the purpose is to primarily demonstrate the difference between aerobic or partially aerobic ponds and anaerobic ponds.

Table 3.1 Treatment Pond Loading Rates

POND TYPE	ORGANIC LOADING RATE
Aerobic	<15 kg BOD_5/ha.d
Facultative	<45 kg BOD_5/ha.d
Anaerobic	>400 kg BOD_5/ha.d

Based on the values presented and allowing for some conservatism in the design parameters, it can be approximated that the total oxygen demand exerted by 20 kg BOD_5/ha.d can be fully satisfied by the oxygen diffusing through the surface of the pond. Thus, in a facultative pond, approximately half of the potential oxygen demand is satisfied aerobically with the remaining half satisfied anaerobically. Within the anaerobic ponds, theoretically 5% of the influent potential oxygen demand is satisfied aerobically. However, the anaerobic ponds either develop a crust that effectively excludes oxygen diffusion or develops a high surface tension on the surface of the pond due to products released by anaerobic break down of the complex organics. The quantity of products released by the break down of the complex organics exceeds the amount that can be treated aerobically and thus they accumulate giving a flat sheen to the surface of the pond. Wave action is eliminated significantly reducing the oxygen transfer achieved and providing almost completely anaerobic conditions.

Minimisation of oxygen diffusion either by formation of surface tension, formation of a surface crust or use of an artificial cover, is essential to prevent oxygen damage of the methane forming bacteria. Damage to the methane forming bacteria will result in reduced conversion of the short chain fatty acids and emission of some of these compounds as odours. Characteristic odours include acetic acid (vinegar type odour) and butyric acid (rancid type odour). The release of hydrogen sulphide will also occur with the characteristic "rotten egg" gas smell.

Some texts provide design criteria for anaerobic ponds based on the volumetric organic loading rate. Although there is a minimum organic loading rate that will generate anaerobic conditions, as demonstrated here, the surface-loading rate is the more critical loading parameter to ensure effective operation. Two ponds of identical surface area and differing depths can both operate anaerobically whilst exhibiting differing detention times and volumetric loading rates.

Effective design and operation of anaerobic ponds is therefore reliant on introducing sufficient biodegradable organic load based on the surface area available to greatly exceed the oxygen transfer by natural diffusion and form a stable crust to subsequently eliminate oxygen diffusion. Thus many ponds at start up suffer from odour generation prior to formation of the crust.

Therefore, during sludge withdrawal, it is desirable to maintain the surface crust to minimise the potential for odour generation upon reinstatement of the pond or during continuing operation whilst carrying out sludge withdrawal.

3.3 Microbiological Requirements of Anaerobic Ponds

Anaerobic ponds rely primarily on three groups of bacteria. The anaerobic hydrolysing bacteria grow rapidly and thus relatively short detention times are required to develop a stable population to treat the incoming waste loads. Similarly, the acid forming bacteria also grow relatively fast. By comparison, the methane forming bacteria exhibit a relatively slow growth rate and require considerably longer detention times. Theoretically, the methane forming bacteria require a detention in excess of 25 days at 20^0C to prevent washout. Longer detention times would be required at lower temperatures.

Many anaerobic pond systems do however, successfully operate at lower detention times than that theoretically required. This can be attributed to the role of the settled sludge layer in providing a continuous supply of methane forming bacteria to the liquid phase. The settled sludge layer therefore provides a continual store of methane forming bacteria for reseeding of the water column. This permits lower detention times to be used in the anaerobic pond without risk of washing out of the methane forming bacteria.

It is therefore critical to the successful operation of anaerobic ponds that an active sludge layer be maintained within the pond to provide a continuous supply of methane forming bacteria. It is for this reason that many anaerobic ponds at start-up suffer from severe odour generation until an active settled sludge layer is established.

Based on these microbiological considerations, it can be seen that complete desludging of the anaerobic pond is undesirable. More regular, partial draw off of the settled sludge is therefore more desirable.

4.0 CONSIDERATIONS ASSOCIATED WITH SLUDGE DRAW OFF SYSTEMS FOR ANAEROBIC POND SYSTEMS

4.1 Preservation of Surface Covering of Anaerobic Pond

The essential need to maintain a surface cover for anaerobic ponds has been highlighted. Failure to achieve a surface cover may result in oxygen diffusion into the pond and damage to the methane forming bacterial population. This in turn may result in odour release and reduced effectiveness of treatment.

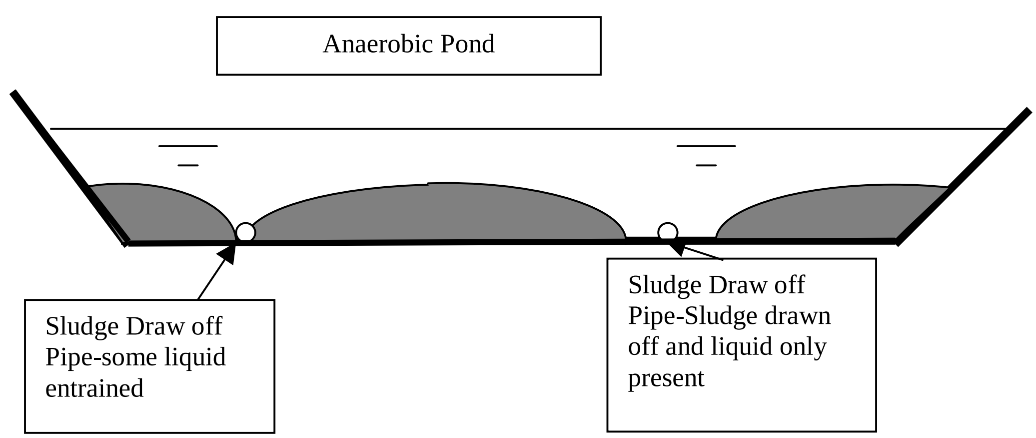
The need to preserve a surface cover over the pond therefore precludes the use of sludge draw-off systems that rely on regular relocation of the draw-off system around the pond. The commonly used systems relying on this principle include pontoon mounted pump and mixer systems and dredges. These systems, when used, require the use of multiple, parallel ponds to permit an individual pond to be taken off-line for desludging. The pond may need to be taken off-line for a period of time prior to desludging to permit further stabilisation of fresh sludge thus minimising odour generation during the desludging process. A re-establishment period may be required for the pond following desludging. During this period, problems of odour and reduced treatment performance may be experienced.

4.2 Submerged Sludge Draw-Off Systems

The major problem encountered with the draw-off of settled sludge from anaerobic ponds is the large area covered by the ponds and the poor flow characteristics of the settled sludge. These two problems combine to cause severe difficulties in sludge draw off.

The problems confronted can be demonstrated graphically as shown in the following drawing.

Figure 4.1 Typical Sludge Draw-Off Problems from Anaerobic Ponds



As demonstrated in the sketch, the sludge flow properties are such that multiple draw-off points are required to achieve substantial draw-off of settled sludge. Partial entrainment of liquid is a common occurrence resulting in discharge of dilute sludge and subsequent added difficulties during dewatering or drying.

Effective sludge draw-off systems have been developed for other unit processes achieving settlement of influent solids such as primary sedimentation tanks and Imhoff tanks. The primary sedimentation tanks incorporate mechanical scrapers to transport the sludge to the sludge draw-off locations. Provision of mechanical scrapers on anaerobic ponds is not practical due to the large spans involved.

Imhoff tanks achieve sludge transport through the provision of steeply sloping sides. This method of construction is not suitable for anaerobic ponds due to the excessive depths for the sloping walls that would be required. Anaerobic ponds are also usually of earthen construction that prohibits the construction of even multiple, low depth steep sludge collection hoppers.

4.3 Pumping or Gravity Flow of Sludge

It is the aim of any pond sludge draw-off system to remove the sludge with the thickest consistency possible. This minimises subsequent sludge dewatering and drying requirements. Typically a solids concentration of between 2% and 8% w/w solids will be experienced. At this solids content, the sludge is extremely viscous and requires a large static head of the order of two metres to achieve reasonable flow rates. Suction draw off is extremely difficult if long suction lines are used. Pumped systems must therefore utilise very short suction lines or reliance must be made on the static head of the lagoon to induce sludge flow from the settled sludge layer.

4.4 Sludge Draw-Off Pipework

Anaerobic ponds can encourage the formation of struvite (magnesium ammonium phosphate) and other compounds that can form scale deposits on the inside of the sludge draw-off pipework. This restricts the flow rate that can be achieved in the pipe and this in turn restricts the entrainment velocity that can be developed at the pipe inlet to draw in the sludge. In some instances, complete blockage of the pipework can occur.

Floor mounted pipework in anaerobic ponds can suffer from grit accumulation. The accumulated grit can “cement” around the inlet of the pipe and within the pipe itself causing complete blockage of the pipe.

4.5 Summary of Problems for Sludge Draw-Off for Anaerobic Ponds

Anaerobic ponds are not well suited to utilising the more common methods of desludging such as dredging or pontoon mounted pumps due to the need to preserve the surface covering. Mechanical sludge conveying can not be employed due to the large spans involved and high capital cost. Steeply sloping sides are precluded due to the large depths required and the steep wall angles required that are unsuitable in earthen basins. Permanent pipework for sludge draw-off can suffer from blockages through a number of mechanisms.

5.0 CONSIDERATIONS IN DEVELOPING CONTINUOUS DESLUDGING SYSTEMS

5.1 Design and Operation Considerations

The evaluation of the operation of the anaerobic pond system has demonstrated that several key factors must be observed during desludging in order to maintain the treatment integrity of the system and prevent odour generation either during desludging or following reinstatement of the pond into operation. These factors include;

- Maintenance of the surface crust, where present, to exclude oxygen diffusion
- Maintenance of some settled sludge within the pond to provide seeding of methane forming bacteria back into the water column.

The maintenance of the surface crust to maintain anaerobic conditions and the need to maintain some settled sludge in the pond as a seed sludge, demonstrates that complete removal of <u>all</u> sludge from the pond is not only unnecessary but is also undesirable.

Small, frequent sludge withdrawal will minimise changes in the bacterial biomass providing treatment thus ensuring more stable performance. The quantity of sludge requiring dewatering and disposal at any one time is also reduced. This will reduce the potential for odour generation problems and open up opportunities for low cost dewatering technologies such as small scale drying beds. The quantity of dewatered sludge requiring disposal at any one time will be reduced and more regular supply to end users can be provided in comparison to identifying large reuse markets once every 20 to 25 years.

A further advantage of small, frequent sludge withdrawal cycles is that attention-causing problems are avoided. Experience would suggest in most cases that the need to desludge is only considered necessary when there is a problem. By that stage, the neighbours and the regulatory authorities are also aware of the problem. Typically the problems can be attributed to excessive sludge accumulation resulting in decreased treatment efficiency and overload of downstream treatment units or discharge of inadequately treated effluent. The desludging operation then typically involves removal of massive volumes of sludge that can present additional problems of odour generation and logistics.

Sludge that has been permitted to accumulate for an excessive period of time will also tend to consolidate. This will increase its resistance to flow and make draw-off more difficult. More frequent desludging therefore simplifies the sludge draw-off operation.

Whilst observing these requirements for the preferred operation of the anaerobic ponds, it is still necessary to achieve effective, low cost sludge removal. The inherent problem with anaerobic pond systems is that they cover a large area. It is not practical to provide mechanical sludge transport systems such as scrapers over the large areas usually encountered. Multiple sludge draw-off points can be provided however it is still necessary to transport the sludge to the draw off point to achieve effective removal. The transport requirements for the various components of the sludge and the sludge mass overall must therefore be considered.

5.2 Sludge Components in Anaerobic Ponds.

Based on the components in the raw wastes discharged to the anaerobic ponds and the microbiological processes occurring, the components of the settled sludge layer that may occur can be identified. These components are categorised as follows.

- Inorganic components-grit, gravel, bone fragments
- Organic Non-Biodegradable-Predominantly cellulose material such as hair or parts of grass and straw
- Bacteria-hydrolysing, acid forming and methane forming bacteria
- Endogenous Residue from death of bacteria
- Organic Biodegradable-Untreated settled material not yet hydrolysed

The transport and removal of the sludge from the lagoon therefore requires transport of all of these components when present to the removal point and effective removal. The transport and removal requirements of an individual component are often influenced by other components present. Thus, the transport requirements of individual components need to be considered. Components with difficult transport requirements can then be identified and measures taken to minimise their discharge to the anaerobic pond

5.3 Transport Requirements for the Sludge Inorganic Components

The inorganic fraction of the raw wastes is primarily composed of grit and other similar material. The grit will have a specific gravity of 2.3 or more and will rapidly settle at the inlet end of the anaerobic pond and accumulate in the settled sludge layer.

To ensure transport of grit in pumping pipework, a transport velocity of at least 1.2 m/s is usually adopted to prevent deposition of the grit in the pipework. Therefore, when desludging anaerobic ponds, similar velocities would need to be induced within the pond to ensure transport of the grit to the suction draw-off point. Generation of velocities in excess of 1.2 m/s within an anaerobic pond would require lining of the pond to prevent scouring.

It is preferable to remove the grit prior to the pond. The significantly higher specific gravity of the grit permits relatively simple gravity separation techniques to be employed. As the grit is primarily generated in the holding pens, this wastewater stream can be isolated and dedicated grit separation facilities provided to reduce capital expenditure and contamination with organic material from other processing areas.

If it is not practical to provide dedicated grit removal facilities, provision must made in the anaerobic pond for the transport and removal of the grit. To achieve this, high transport velocities will need to be generated in the pond. This provision is to be addressed in the overall desludging philosophy to be developed.

5.4 Transport Requirements for the Sludge Non-Biodegradable Particulate Organic Components

The non-biodegradable particulate organic fraction of the wastes is primarily composed of cellulose fibres from grass and straw and hair form hides. This material will, in fact, biodegrade however this usually requires specific fungi not normally found in anaerobic ponds.

The non-biodegradable material has a tendency to form clumps, mats or strings within the anaerobic pond. In the settled sludge layer, this material is therefore unlikely to demonstrate highly fluid characteristics during sludge withdrawal. The transport of this material to the draw off point will require either an entrainment velocity or direct draw off at the base of the settled sludge layer. Typically a velocity of 0.9 m/s is required to ensure transport of the solids.

5.5 Transport Requirements for the Sludge Active Bacterial Component

The active bacterial component of the sludge can settle as either discrete particles or as conglomerates associated with particulate biodegradable material. The active bacterial component within the settled sludge layer tends to be intermeshed with the non-biodegradable particulate organic components. The non-biodegradable particulate organic components therefore tend to determine the flow and fluid transport characteristics. Thus the entrainment velocity requirements and draw-off requirements for the active bacterial component of the sludge is similar to that for the non-biodegradable particulate organic material.

In the absence of non-biodegradable material, the active bacterial component is present as a settled sludge layer comprising small flocs or present as individual bacteria and flocs in the water column. The density of the bacterial floc is close to that of water (the bacteria having a water content of approximately 90%) with a specific gravity only a few percent above that of the water. The settled solids will then have flow characteristics similar to that of water. Typically a velocity of 0.15 m/s is sufficient to ensure transport of the bacterial solids.

5.6 Transport Requirements for the Sludge Endogenous Residue

The endogenous residue is associated with the active bacterial mass. Thus the requirements for transport and draw-off of the endogenous residue is also determined by the fluid flow characteristics of the non-biodegradable particulate organic material. In the absence of non-biodegradable particulate material, the endogenous residue is either present attached to biological floc or present as discrete material. Transport velocities are therefore similar to those for the active bacterial biomass.

6.0 ACHIEVEMENT OF CONTINUOUS OR SEMI-CONTINUOUS SLUDGE DRAW-OFF

6.1 Criteria for Continuous or Semi-Continuous Sludge Draw-Off

The review carried out has demonstrated that the critical issue in providing effective sludge draw off is to generate sufficient transport velocities within the settled sludge layer to transport the sludge without entraining additional liquid from the anaerobic pond. In order to develop the optimum system the following measures need to be implemented.

- Minimise sludge transport velocities required
- Maximise sludge accumulation at the draw-off location
- Minimise liquid entrainment

The first condition can be satisfied through effective pretreatment. The second and third conditions are functions of the design and operation of ponds and require specific design evaluation.

6.2 Minimisation of Sludge Transport Velocities

The minimisation of sludge transport is essential to prevent scour of the pond base and to simplify operation of the system. The most effective method of minimising the sludge transport velocities required is to prevent discharge to the pond of materials requiring high transport velocities. Thus the provision of effective pretreatment is critical to the development of effective sludge draw off systems. Pretreatment systems should therefore be provided to minimise grit discharge to the ponds and to minimise the discharge of non-biodegradable particulate to the ponds.

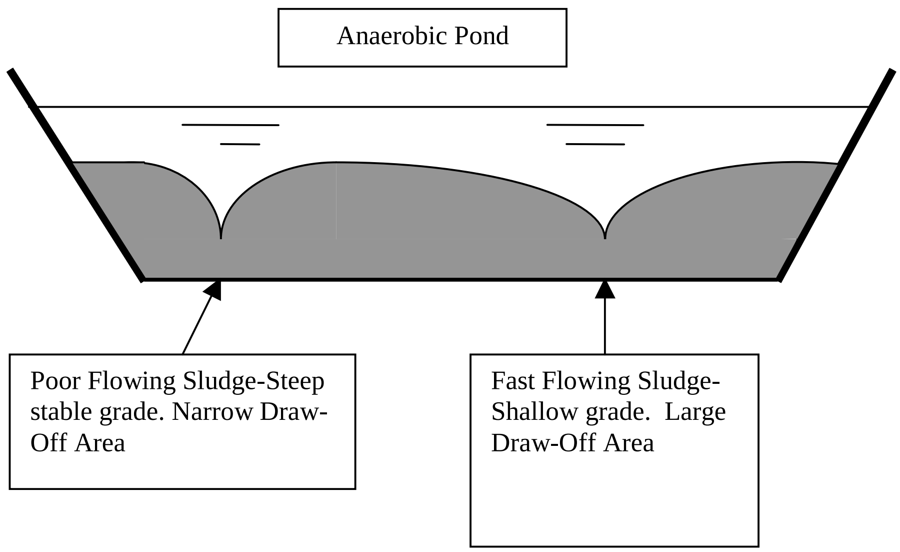
A number of systems are available to provide pretreatment of wastewater from meat processing plants. These include fine screens, grit traps, savealls and dissolved air flotation units. Various combinations of these units are found at most modern plants.

Provision of effective pretreatment has the added advantage that the total rate of sludge generation is reduced. As the grit and non-biodegradable particulate material do not undergo any degradation within the anaerobic ponds, the overall mass of sludge produced is not reduced by discharging these wastes to the ponds. These components in fact consume available volume for the biodegradable wastes and reduce the treatment potential of the pond.

It is therefore critical to minimise the amount of grit and non-biodegradable material discharged to the anaerobic ponds. This minimises both the amount of sludge generated and the transport velocities required for the withdrawal of the settled sludge layer.

As demonstrated in Figure 2.1, the settled sludge layer does not exhibit complete fluid properties due to the slightly higher density of the settled sludge layer compared to water and the viscous nature of the settled sludge. Minimisation of the grit and non-biodegradable particulate material in the settled sludge will improve the sludge flow properties as demonstrated in the following sketch.

Figure 6.1 Impact of Sludge Flow Properties on Sludge Draw-Off



Sludges containing non-biodegradable particulate material that tends to form dense matted sludge layers that exhibit poor sludge draw-off. Due to the steep grade formed, only a small area of sludge can be drained before liquid entrainment occurs.

The free flowing sludge produced when grit and non-biodegradable COD are excluded from the pond is unable to form a steep stable slope. A large area can be drained of sludge with minimal entrainment of liquid as the sludge continues to flow in to fill the void left by the withdrawn sludge.

There is therefore considerable advantage in excluding the undesirable components from the wastewater discharged to the anaerobic ponds.

6.3 Maximisation of Sludge Accumulation at the Sludge Draw-Off Location

The sludge accumulation at the sludge draw off location can be maximised by either;

- Transporting sludge to the sludge draw off location
- Maximising sludge accumulation overall

Transportation of the sludge to the sludge draw-off location can be achieved by a number of methods.

Multiple Sludge Draw-Off Hoppers

Construction of ponds with individual sludge collection hoppers is possible. Multiple hoppers would be required over the entire area of the lagoon with individual draw-off facilities. The capital cost of this type of system is extremely high due to the specialist earthworks involved and the extensive pipework required for the multiple draw-off locations. This system is therefore not considered suitable for general application within Australia.

Grading of Pond Base

Grading of the base of the anaerobic pond to a single or several locations can be carried out. Anaerobic ponds with a slope back to the inlet end where the majority of the sludge accumulation occurs can be constructed. Alternatively, slopes to the sides of the lagoon for simplified draw off pipework could be provided. Floors sloping to both the inlet and outlet end of the pond would also achieve simplified sludge draw-off pipework with the majority of the sludge accumulating at the inlet end. The ponds can also be constructed to slope to a central channel running the length of the pond and sloping to the inlet in order to encourage transport of the settled sludge to this single draw-off location.

This type of pond construction is usually limited to smaller pond systems to prevent excessive depths being required at the draw-off location. The pond must be specifically constructed for this purpose with stable floor and wall slopes provided. Ultimately, a consolidated sludge layer will be formed requiring agitation through mechanical mixing or air sparging. Both of these actions reinforce the need for construction with stable floor and wall slopes. Damage to the surface crust is almost inevitable if agitation of the consolidated sludge layer is required.

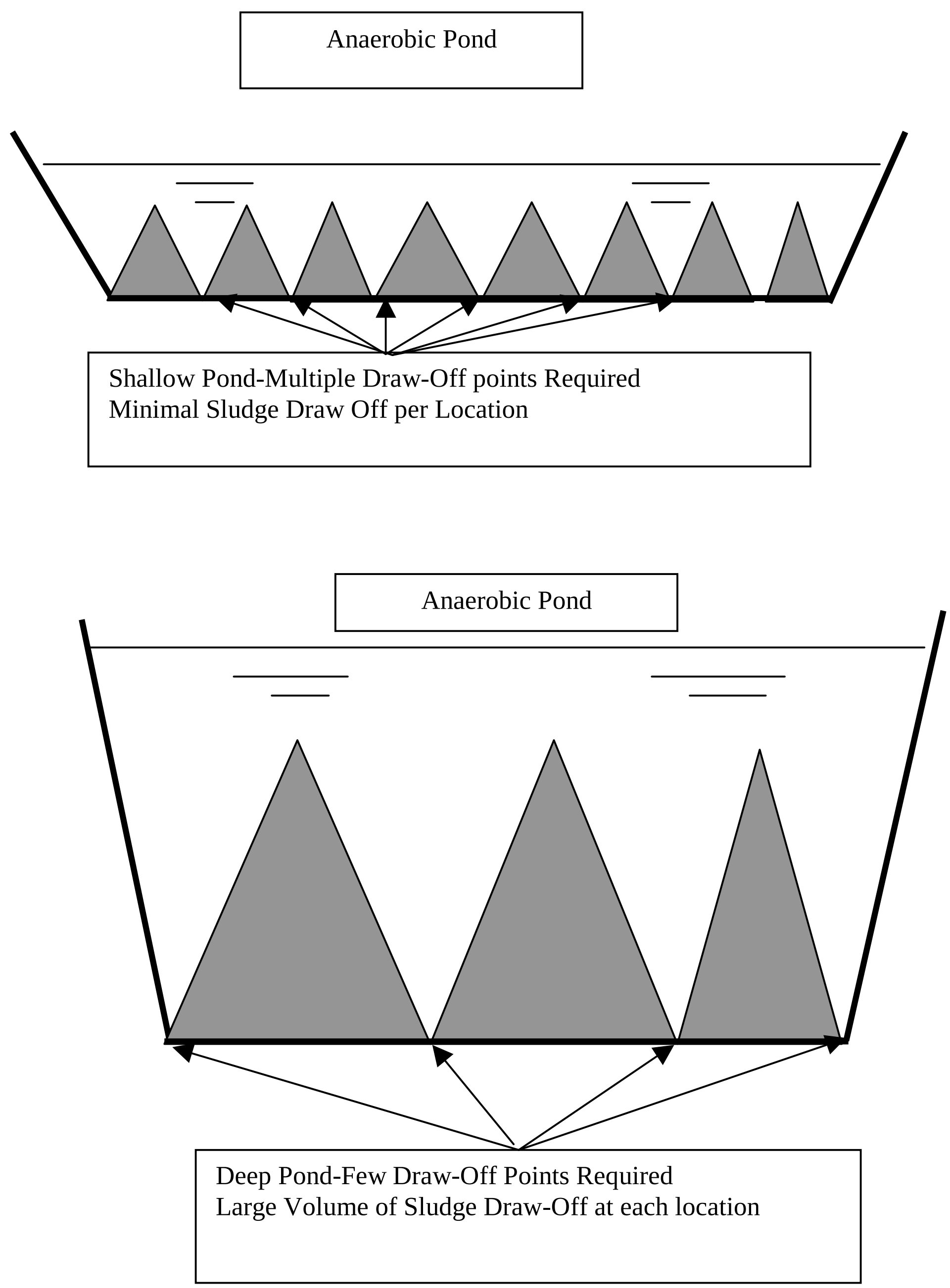
Transport of Settled Sludge through Mechanical Mixing

One system utilised by Australian Pollution Engineering at a number of locations is the use of mixers to “blow” accumulated sludge to a number of selected sludge draw-off points. A relocatable mechanical mixer is provided at the outlet end of the pond. The angle of the mixer is adjusted at intervals to direct the mixer plume at settled sludge to transport most of the sludge to the inlet end of the pond. Draw-off points are located at the inlet end of the pond where the majority of the sludge accumulation naturally occurs.

Construction of Deep Ponds

An internal survey within Montgomery Watson global indicated that current practice in South Africa is to construct very deep anaerobic ponds, typically 6m deep. The principal is that, by constructing deep ponds, a greater depth of sludge can be accumulated and effective sludge draw off can be achieved over a greater area with less draw-off points. The principle is demonstrated schematically in the following figures.

Figure 6.2 Impact of Sludge Accumulation Depth on Sludge Draw-Off



A further advantage of the deep lagoon system is that, as sludge is drawn-off, there is a greater tendency for more sludge to flow in to fill the void due to the greater exposed sludge slope adjacent to the draw-off location. This takes advantage of the natural tendency of the sludge to exhibit some slump characteristics.

6.4 Sludge Draw-Off Requirements

A number of key aspects of the sludge draw-off system have been identified. These requirements include;

- Creation of sufficient suction velocity to entrain the sludge
- Creation of sufficient head to maintain sludge flow in the pipework.

These design aspects can usually be satisfied by either providing submerged pipework or pipework extending above the surface of the pond and provision of a suitable sludge pump with good suction characteristics.

A further problem experienced with pumping of sludge from anaerobic ponds is pumping of foreign objects. Anaerobic ponds have a tendency to accumulate rocks and other objects that can cause blockages when pumping.

To minimise problems with pump blockages, pumps that have an access hatch should be used. The self-priming pumps as supplied by Gorman Rupp are an example of a pump that is relatively easily accessed to remove blockages. These pumps can be powered by various means and this can eliminate the need for large temporary or permanent power supplies.

A simple and effective system refined by Australian Pollution Engineering is the airlift pump. This system is readily fabricated from HDPE pipe. The main pipe is typically 150 mm diameter with a 25 mm air supply pipe discharging into the suction end of the pipe. The airflow rate can be controlled with a simple valve to control the sludge draw-off rate. In the event of blockage of the pump, the discharge from the 150 diameter pipe can be valved shut and the air used to free any blockage. This system has been demonstrated to able pump objects up to the size of the main pipe without blockage.

Blowers rather than compressors readily provide air supply for the airlift pumping system. The air requirements are high flow and low head thus making the system well suited to the use of blowers. As the air pipework is relatively small, the air supply can be reticulated to the pump in order to prevent the provision of power supplies.

Advantages of the air lift system include;

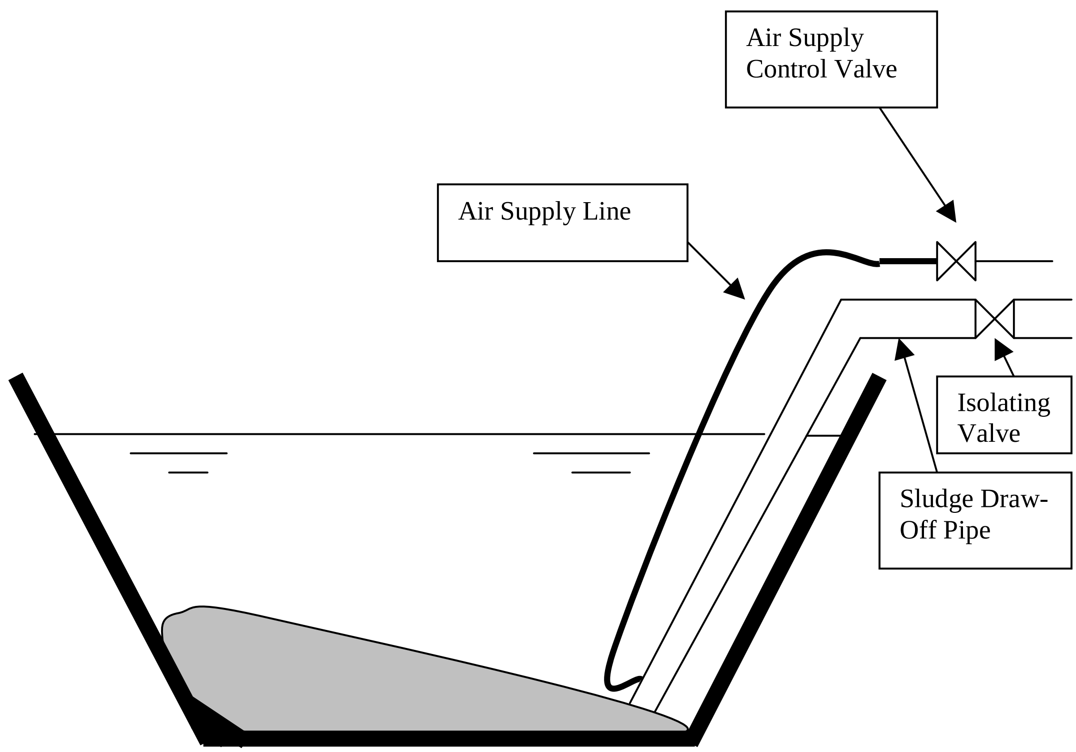
- Minimal blockages
- Able to pump high solids concentrations
- Can be used to mix sludge by simply closing the main discharge valve.
- Light weight
- Simple system
- Low maintenance

Disadvantages of the air lift pump system comprise;

- Low discharge head
- Poor performance in shallow ponds

The poor performance of the airlift pump in shallow ponds is a further factor supporting the use of deep ponds. Once the sludge has been pumped from the anaerobic pond, it may be necessary to provide supplemental pumping if the sludge storage or processing facility is not in close proximity to the draw-off location. Sludge channels can be provided to transport the sludge however this would require dedicated design.

Figure 6.3 Airlift Pump Schematic



6.4 Summary

The review of the problems encountered in the draw-off and pumping of sludge from anaerobic ponds has demonstrated that there are considerable advantages to constructing deep ponds. The benefits of the use of deep ponds of approximately 6 m depth include;

- Increased sludge accumulation volume
- Less draw-off points required
- Larger sludge draw-off volumes before “rat-holing” occurs.
- Permits the use of mixers to transport sludge to draw-off point

The review of the microbiology of the treatment process has demonstrated that the increased detention time in deeper lagoons will not have any detrimental impact on the treatment process. The volumetric organic loading has no impact on anaerobic conditions. The key factor for anaerobic conditions is the surface organic loading rate as this must exceed the oxygen transfer capacity through the surface of the pond.

The use of deep ponds permits the use of simple airlift pumps for sludge draw-off. These simple and low cost pumps can be provided as permanent fixtures with either a reticulated air supply or a relocatable blower used for air supply.

7.0 FEATURES OF PREFERRED SYSTEM FOR CONTINUOUS OR SEMI CONTINUOUS SLUDGE DRAW-OFF.

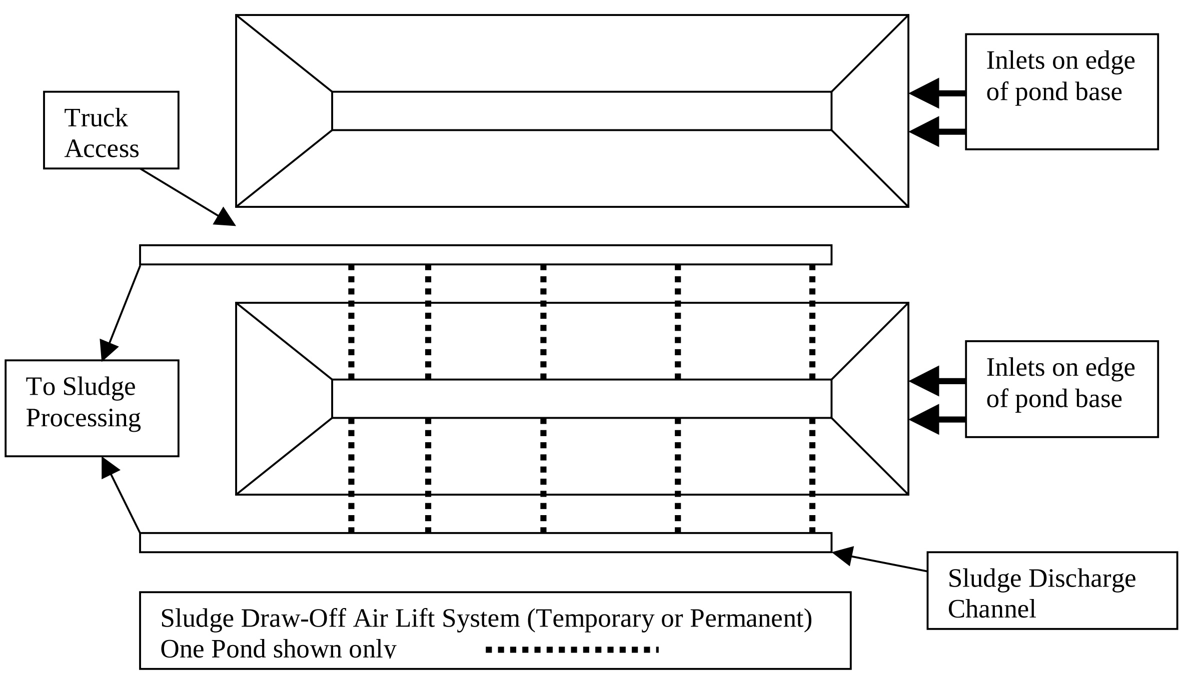
The evaluation carried out permits the features of the preferred system for continuous or semi-continuous sludge draw-off to be identified. Critical aspects of the process comprise;

- Use of deep ponds to increase sludge flow to draw-off point
- Use of long narrow ponds to permit draw-off from side of pond
- Two inlets to be provided to pond discharging towards the sides of the pond to preferentially deposit heavy sludge components closer to draw-off point
- Provision of sludge discharge channel alongside of pond to receive removed sludge and discharge to the sludge processing area.

The evaluation of the processes occurring within the ponds suggests that relatively small volume ponds with a reduced detention time can be used. This will reduce the overall costs of the ponds and the overall area requirements. This conclusion is supported by the findings of the brief industry survey carried out. The majority of the anaerobic ponds had detention times in excess of 20 days with some ponds providing detention times of the order of 80 days. Some plants however reported satisfactory operation at detention times of 6 to 10 days. If advantage is taken of continuous reseeding of the water with bacteria from the sludge layer, considerable reductions can therefore be made in the size and cost of the anaerobic ponds. Operation of the anaerobic ponds at reduced detention times has been confirmed from the literature review.

A desirable layout of a pond system is shown in the following figure.

Figure 7.1 Desirable Features of Anaerobic Pond Layout.



The use of the deeper ponds makes them well suited to the airlift pump system. Permanent facilities can be provided or relocatable temporary systems used. Truck access around the pond is considered essential to permit ease of installation, maintenance and relocation of the pumping equipment.

The provision of a sludge collection channel is considered desirable to simplify operation. If it is impractical to provide a sludge collection channel, alternative pumping systems such as the Gorman Rupp type pumps will need to be utilised.

Once deep ponds have been provided, regular desludging of the pond should be carried out. This prevents over-consolidation of the sludge and simplifies pumping of the sludge. The actual frequency of desludging required will be site specific.

A number of biological additives for anaerobic ponds are available on the market. The use of these additives can improve the sludge digestion process and therefore reduce the amount of sludge to be withdrawn and treated. Australian Pollution Engineering has had considerable success with the use of a specific additive on a number of pond installations. Again, each site should be specifically evaluated as some brands of additives have been known to cause odour problems and caused severe difficulties during sludge dewatering.

8.0 OPERATION OF ANAEROBIC PONDS FOR CONTINUOUS SLUDGE DRAW-OFF

With the provision of the air-lift pump system for sludge draw-off, operating procedures can be implemented to assist in achieving routine and regular effective sludge draw-off. These procedures are aimed at not only maintaining the settled sludge in a fluid state, but may also assist in maximising treatment within the anaerobic pond.

Anaerobic ponds without a synthetic cover and reliant on a surface crust can be periodically air sparged at approximately weekly intervals. This is achieved by shutting of the isolating valve on the air-lift pump (see **Figure 6.3**) resulting in air mixing at the bottom of the lagoon. Benefits achieved by this procedure include;

- Prevents consolidation of the settled sludge therefore maintaining the sludge in a more fluid state and promoting better flow of the sludge.
- Mixes anaerobic organisms back into the water column and improving contact with substrate to achieve improved treatment
- Releases accumulated anaerobic gases regularly thus minimising periodic large odorous gas eruptions
- Releases accumulated anaerobic gases regularly thus minimising generation of toxic conditions such as pH and inhibitory concentrations of gaseous by-products
- May prevent very low oxidation reduction potential conditions that increase hydrogen sulphide generation.

Adoption of periodic mixing of the sludge layer therefore will improve the overall digestion process in addition to maintaining the settled sludge in a more fluid condition. As the facilities required for the mixing (the air lift pumps) have already been installed, it is clearly a relatively simple matter to gain the maximum benefit from these facilities. The entire process can be fully automated through the use of solenoid valves on the air supply line to each air-lift pump.

Anaerobic systems utilising synthetic covers can achieve similar benefits however this will require the use of strategically located mechanical mixers. The use of mechanical mixers is essential to prevent the introduction of oxygen under the gas collection cover and the generation of a potentially explosive atmosphere.

9.0 EXTENSION OF CONCEPT TO AEROBIC PONDS

The concept developed for the semi-continuous desludging of anaerobic ponds is equally applicable to aerobic ponds. The review of the design and operation of treatment ponds (**Chapter 3.2**) demonstrates that it is the organic surface loading rate of the pond that determines whether the pond operates in an aerobic or anaerobic state. Thus aerobic ponds can also be constructed with depths of the order of 6 m. The air lift pump can be installed for periodic sludge draw-off and to maintain the settled sludge in a fluid condition. The withdrawn sludge can either be directly dewatered or returned to the anaerobic pond for further digestion.

The simplicity of the concept developed for the anaerobic ponds is therefore readily extended to aerobic ponds. Similar benefits are achieved and the need for periodic isolation of ponds and drainage is eliminated.

10.0 SUMMARY

Through the evaluation of the microbiological processes occurring within the anaerobic ponds and evaluation of the characteristics of the sludge generated, it has been possible to determine the desirable features of anaerobic ponds to facilitate semi-continuous sludge draw-off. During the development of these features, it has been demonstrated that there is considerable potential to make use of smaller ponds achieving the same level of treatment. Significant capital cost savings can therefore be made in the provision of wastewater treatment facilities.

The use of smaller ponds will also reduce the potential for odour generation through the reduction in surface area for odour release. Anaerobic conditions are also more readily maintained with reduced surface area as the total oxygen transfer into the pond is reduced with the reduced surface area.

As demonstrated, there are therefore considerable advantages to the system proposed in addition to the implementation of semi-continuous sludge draw-off.

It is recommended that Meat and Livestock Australia review this report and its conclusions. Consideration can then be given to provision of a trial system or modification of an existing facility to confirm the findings of this report.

APPENDIX A

Current Experience With Anaerobic Pond Desludging

CURRENT EXPERIENCE WITH ANAEROBIC POND DESLUDGING

A.1 Costs Associated with Dewatering Anaerobic Ponds

The actual cost to desludge anaerobic ponds depends on a variety of factors. Some are applicable to any desludging operation whilst others are unique and site-specific. The following information details the cost items and highlights some of the difficulties encountered during desludging operations.

<u>Transportation of Equipment to and from Site.</u>

Costs are proportional to the distance from the location of the work site to the contractors depot or last project site. There are advantages in programming works in advance to minimise transport of equipment and take advantage of drier weather periods. Once on site, the degree of difficulty in establishing plant and equipment near the lagoons and having access for sludge disposal will impact on costs. The following items demonstrate some of the specific factors that impact on the cost to perform the actual desludging.

- Access around the ponds, e.g. roads and embankments, trees blocking access, prolific weed growth on and around the ponds, unsuitable ground conditions for heavy machinery, leaking pipes and pond embankments, overhead power lines and underground services security fences built too close to the ponds and insufficient useable space to carry out all of the tasks involved.
- The degree of weed cover on the ponds
- Degree of debris in the ponds such as waste from the meat processing operations and other rubbish such as plastic bags, rags, timber and rocks that will block desludging pumps. Clumps of hair and hide are particularly hard to pump.
- The shape of the lagoon has a bearing on the type of pumping and/or desludging equipment necessary to remove the sludge. Large shallow ponds are more difficult to desludge than small surface area deep ponds.
- The age of the sludge and the pretreatment facilities utilised have a large bearing on the selection of suitable pumping equipment and the type of mixers that should be used. Relatively fresh sludge or regularly desludged ponds can be desludged quite easily as the sludge flows relatively freely. Older sludge ponds have compacted sludge accumulations that require energy in the form of submersible mixers or sparge pipes to fluidise the sludge prior to pumping. There exists a point where very old or thick sludge that it becomes cheaper to remove the water layer from the surface and excavate the compacted sludge with conventional earth moving equipment. This form of desludging is subject to the ability to take the pond off-line for a period of time.

- The size of the pond and the volume of sludge to be removed and dewatered obviously have an impact on costs. Establishment and disestablishment costs are the same both large and small pond systems.
- The initial design of the pond system has the greatest potential to minimise future desludging costs. Where possible, the ponds can incorporate such features as scour pipes and valves, sloping floors, good access roads around and into the ponds, power supply and water supply.

Based on these considerations, the features of a readily desludged pond system can be identified as carried out in the main report.

A.2 Commonly Used Desludging Technologies for Anaerobic Ponds

The desludging technologies used for anaerobic ponds are as varied as the sites are themselves. The desludging technique and, more importantly, the sludge disposal or management requirements, are usually dictated by the site location, proximity of neighbours, regulatory authority requirements and cost. Experience would suggest in most cases that the need to desludge is only considered necessary when there is a problem and by that stage the neighbours and the regulatory authorities are also aware of the problem. Avoidance of the initial problem minimises the potential for heightened problems during the desludging exercise. Drawing attention to the treatment facilities initially will almost guarantee that they will continue to be kept under close scrutiny.

The desludging operations, the type of desludging equipment required and the sludge disposal strategy should be addressed on a site specific basis. The most suitable and cost-effective management strategy at an outback New South Wales town would be totally unsuitable for the suburbs of Sydney.

The range of desludging operations available includes;

- Excavation with conventional earthmoving equipment
- Pumping onto adjacent land for air drying
- Pumping onto adjacent land and incorporation into the soil with a disc plough
- Educting the sludge into a sludge eductor and injecting into the soil or spraying onto forests
- Dredging the sludge and mechanically dewatering the sludge with a belt filter press or centrifuge.

Many waste producers are using enzyme and other biological additives to increase anaerobic pond treatment performance, improve sledge digestion rates and reduce odours. The enhanced biological activity can dramatically improve the pond performance but it must be understood that this is often only highlighting that there were fundamental problems prior to the addition of the additives. Typical problems include gross overload in terms of solids, organic or hydraulic overload, shock loads, intermittent loads, chemical spills (including cleaning compounds and disinfectants), mechanical failures, short-circuiting or excessive sludge accumulation.

Some anaerobic treatment systems incorporate floating covers designed to collect the biogas for reuse as a fuel. Unless properly designed, the covers can present a wide range of problems with respect to future desludging operations. The typical problems encountered include limited access for desludging equipment, explosive environment under the cover, accumulations of floating debris and the cost of removing the cover for desludging operations or working underneath the cover during desludging.

A.3 Considerations for Continuous or Semi Continuous Desludging Techniologies

Need for Desludging.

The main problem with any form of pond or lagoon based treatment system is that they work relatively well most of the time with little or no attendance. They are relatively big and forgiving and the sludge accumulation usually cannot be seen and so it is not perceived as a problem. Unfortunately most treatment ponds are stressed prior to desludging operations being considered necessary.

- Regular desludging should be carried out, whether perceived to be necessary or not to prevent system failure and drawing attention to the treatment system.

Scale of Desludging Operations

Most waste producers have the potential to minimise the costs associated with desludging and maximise their treatment process performance by installing some form of sludge wasting, sludge thickening or sludge drying operations on-site. Regular withdrawal of a small amount of sludge on a regular basis will increase the treatment capacity of the pond system and reduce the frequency of major desludging operations. Disposal of a small amount of sludge on a regular basis is generally easier than a large amount at infrequent intervals.

One of the low cost options that becomes available for sludge dewatering when small frequent desludging is carried out is the use of earthen drying beds. The supernatant from the drying beds can be returned to the pond system and the sludge permitted to dry. Small drying beds can be used if annual sludge draw off is carried out during the drier weather. Provision of drying basins for a major desludging event would require a significantly increased area, increased sludge pumping and supernatant pumping requirements, increased potential for odour generation due to the increased area of drying beds and increased capital cost for preparation of the beds. Excavation of the sludge becomes a major exercise with dust and transport machinery.

- Small, frequent desludging operations have less environmental and logistical problems.

Pumping of Sludge

The degree of difficulty in pumping the sludge is usually proportional to the degree of effort put into housekeeping and the pretreatment facilities.

- The cost of the operation of the wastewater treatment system must be seen as part of the total costs of the meat processing plant. Total costs can then be minimised by taking a holistic approach to house keeping and pretreatment.

Often submersible mixers are used to homogenise the sludge prior to pumping. This system ensures that the sludge can be pumped and a relatively consistent solids concentration can be achieved which provides a consistent product for mechanical sludge dewatering. Without this mixing phase in shallow lagoons, only free draining water is drawn off leaving a thicker sludge layer. It will not be possible to pump this sludge layer without the addition of further water.

- Desludging operations require detailed consideration of the sludge flow characteristics to prevent subsequent increased problems.

Sludge Pipework

Many problems occur in anaerobic ponds and pond systems in general due to the use of small diameter pipes. These pipes may suit the flow rates at the time of construction but inevitably the flow rate increases and the pipe diameter decreases due to accumulation on the walls of the pipe. These compounding problems render the pipework unsuitable and in need of replacement. Above ground or exposed pipework offers greater flexibility in the ease and cost of modifying the flow patterns or adding extra influent and effluent distribution systems.

- Accumulations will occur in pipework and ease of replacement must be provided during design.

APPENDIX B

Literature Survey-Anaerobic Pond Treatment Technology

Literature Searches

The following data bases were used to collate literature for this report:

- Current Contents
- Water Resources Abstracts 1967-1992
- The World Wide Web (WWW)
- Specific Journals (Water Research, Water Science and Technology, The Journal of the Water Pollution Control Federation)
- Science Direct

The searches were carried out to find information on anaerobic pond design and operation, not necessarily specific for meat processing wastes although abattoir and meat processing were included in the keywords used for the searches. Important parameters included in the searches included: Loading rates (hydraulic and organic); Removal efficiencies; Sludge generation rates.

Many authors reported loading rates and removal efficiencies as listed in the abstracts provided below. Sludge generation rates, an extremely important parameter for design, operation and maintenance, were not reported by any of the authors.

Australian Experience

NSW EPA have produced documents that are available on the WWW, specifically as guidelines for the utlisation of treated effluent by irrigation (from anaerobic ponds) (www.epa.nsw.gov.au/mao/ind/ab/).

The EPA recognise that several treatment options may be used for secondary treatment of abattoir wastes, including

- Anaerobic ponds
- Facultative ponds
- Mechanically forced aerated ponds
- Naturally aerated ponds
- Dissolved air flotation (DAF) cells
- Other package treatment plants (eg activated sludge)

This report is dealing with the operation and desludging of anaerobic lagoons, thus the other treatment options will not be discussed.

Operation of ponds

Minimisation of odours

i) During commissioning, odours are produced by anaerobic waste treatment ponds. Methods to minimise odour generation as suggested by the NSW EPA

- Allow some solids and grease to pass through the primary treatment system to establish a crust of 100mm thick on the surface
- Layering hay or straw on surface
- Using artificial covers that break down over time and mixes with the fat on the surface

The importance of covers and surface composition is discussed in the report, Section 4.1.

ii) During operation

- All detergents and chemicals used in abattoir processes must be biologically compatible
- Bioremediation (starter cultures or enzymes) may be implemented to re-establish pond ecology should the pond fail
- Continuous desludging by siphon (the topic of this report) prevents disturbance of pond crust
- Adequate, well planned design, operation and maintenance of ponds minimises odours

SELECTED ABSTRACTS: LOADING RATES and REMOVAL EFFICACIES, MODELLING and CASE STUDIES FOR ANAEROBIC PONDS

Steffan, A. J. (1970).
Waste Disposal in the Meat Industry/2.
Water and Wastes Engineering **7**(5): C1-C4.

Anaerobic lagoons, aerobic lagoons, aerated lagoons, extended aeration lagoons, facultative lagoons, and many combinations of these types are all currently being used in the meat processing industries. Analysis of the various installations revealed that anaerobic ponds operated at Union City, Tennessee, produced an 80% BOD removal at a loading in excess of 15 lb BOD/1000 ft3. Data from 29 other ponds revealed BOD loadings of from 175 to 6060 lbs BOD/acre/day with removals of from 65 to 95%. Data on 50 aerobic pond systems without supplemental aeration revealed a median loading of 72 lb BOD/day/acre, median depth of 3 ft, median area of 1.3 acres, and 70 days detention time. Both dilute and concentrated wastes can be treated. Similar data is reported for anaerobic-aerobic systems, and three-pond systems. Single case studies are also reported for the anaerobic contact process.

Steffen, A. J. (1968).

Waste Treatment in the Meat Processing Industry.
Advances In Water Quality Improvement 477-491.

Chemical treatment evoked interest 20-30 years ago, is now limited to pre-treatment achieving only 50-70% BOD removal in current, optimally designed and operated plants. Aerobic treatment such as washable trickling filters have been successful; activated sludge treatment has been effective, but requiring pre-treatment to reduce BOD; aeration systems in concrete tanks and lagoons have been effective for poultry waste treatment; irrigation has been effective for raw meat packing wastes disposal (Illinois and New Zealand) but overall impacts on soil, crops and livestock disease transmission need closer study. Anaerobic ponds are effective as 'roughing' ponds for meat packing wastes because wastes are warm, have high BOD, high organic solid content, and provide proper nutrient balance. Combined aerobic and anaerobic ponds have proven effective. The anaerobic contact process can remove 90-96% BOD in a waste of 1400 mg/l at a digester loading of 0.16 lbs/day/cu. ft, with equalized flow. The digester is a completely mixed system; mixed liquor is degasified by vacuum before gravity separation of sludge which is recirculated to digesters at ratios of 3:1 or 4:1. The process can be closed down on weekends or extended periods without loss of treatment efficiency. With aerobic pond polishing, BOD removal of 80% and suspended solid removal of 88% can be achieved.

White, J. (1970)
Current Design Criteria For Anaerobic Lagoons.
2nd International Symposium For Waste Treatment Lagoons, June.

Pollution control agencies of the government were surveyed to determine the state of development of anaerobic lagoon design criteria. Industries currently using this type of treatment were also contacted for information on loading rates, BOD removal efficiencies, etc. The information gathered revealed that: (1) none of the states contacted had published design criteria, although many had certain accepted design criteria which they followed, and (2) the industries surveyed responded with such a variety of dimensions for the measurement of organic loading that, unless the data was complete, there was no way to compare one with another. The data was seldom complete. From the available literature, and from state and local agencies, it was found that: (1) the majority of states allow loading rates of 12-15 lb BOD/1000 cu ft/day with considerable variation allowed for climatic conditions, degree of isolation, etc.; (2) lagoon temperature should be above 55 to 60f to provide efficient treatment; (3) depth should be 10 to 15 ft although care should be taken not to contaminate groundwater supplies; (4) series operation of lagoons shows little or no advantage; (5) additional treatment is required for both BOD and nutrient removal before discharge to the receiving water.

Litchfield, J. H. (1981).

Meat-, Fish-, and Poultry-Processing Wastes.
Journal of the Water Pollution Control Federation **53**(6): 787-791.

Meat-processing wastes included physicochemical processes, anaerobic filtration, activated sludge with mechanical aeration, coagulation with ferric sulfate-magnesium chloride-aluminum sulfate, cellulose activated with inorganic salts, lignite treated with sulfuric acid, a modular waste treatment plant featuring flocculation with anionic and cationic polymers and filtration through fiberglass cartridges, activated carbon adsorption, membrane processes, lagoons, flotation, electrocoagulation, sulfide liquor as a coagulant, calcium carbonate or calcium peroxide, anaerobic systems, the Aminodan process, sedimentation, heating followed by centrifugation, ultrafiltration, and combinations of the preceeding.

Hammer, M. and Dale, J.(1970)
Anaerobic Lagoon Treatment of Packinghouse Waste Water
2nd International Symposium For Waste Treatment Lagoons, June

Anaerobic lagoons are currently being used as first stage treatment processes for meat-processing waste water in rural areas. Meat processing wastes, being of relatively high temperature (80 to 85f), high strength, and containing sufficient inorganic nutrients are highly amenable to anaerobic biological degradation. However, the variability of the process waste per unit of meat processed, the operation of by-product recovery and processing units, and the total work stoppage on week-ends produces a highly variable flow with a highly variable organic content. Anaerobic lagoons, with their storage capacity, long solids retention time, and ability to survive both periods of zero loading and periods of high or 'shock' loading, are well suited to treating packing-house wastes. The pertinent parameters in anaerobic lagoon construction are: pretreatment on the waste water; lagoon dimensions, particularly liquid depth and sideslopes; and placement of inlets and outlets. Pretreatment removes some grease and lowers the solids content which would otherwise fill the lagoon. Depths of greater than 12 feet along with sideslopes of 1 to 1 are recommended and inlets are to be placed 2-3' from the floor to prevent clogging. When operated at: organic BOD loadings of 20lb BOD/1000 cu ft/day, minimum hydraulic detention time of 6 days, and minimum temperature of 75f, then BOD removal efficiences of 75% or greater are attainable.

Kostyshyn, C. R., Bonkoski, W. A. and Sointio, J. E. (1987).
Anaerobic Treatment of a Beef Processing Plant Wastewater: A Case History.
Proceedings of the 42nd Industrial Waste Conference. Purdue University, West Lafayette, Indiana May 673-692.

Excellent digester biochemical stability was observed without the addition of nutrients or pH neutralization chemicals. Excellent restart responses to both short (2 day) and intermediate (3 week) length shutdowns were observed. Solids production was F/M ratio dependent and averaged .13 TSS/kg COD added during Phase II. Prehydrolysis of the wastewater solids before the anaerobic reactor was neither significant nor necessary. Good solids settleability was observed during the entire pilot program, including high shock loadings, extended high loadings and high F/M ratio stresses. Start-up was rapid and trouble free using readily available municipal digester seed sludge. The pilot plant demonstrated the technical feasibility for full-scale treatment of this wastewater and provided the database on which to make an evaluation of the economics of such a facility relative to PPC 's operations.

Coerver, J. (1970)
Anaerobic Lagoon Treatment of Packing Wastes in Louisiana
2nd International Symposium For Waste Treatment Lagoons, June

Since the early 1960's some 50 slaughterhouse operations in Louisiana have constructed anaerobic lagoon facilities for treatment of paunch manure, blood, fleshing, and other unsalvaged by-products. Anaerobic lagoons are mainly popular because of their low initial cost, ability to handle 'shock loads, and dependable nuisance-free performance. A Houman, Louisiana slaughterhouse already using a lagoon system was evaluated to determine temporary design criteria so that other installations might be constructed. Volume requirements were based on the number of hog units processed per week, with all other animals being measured to equivalent hog units. Lagoon volume is still based mainly upon the number of animals processed per week, but the approximate BOD loading has been found to be 300 lb BOD/acre-ft/day. At this loading, these units have provided satisfactory BOD reductions (from 76.7 to 94.3%) with a minimum of expense.

Saqqar, M.M. and Pescod, M.B (1995)
Modelling the performance of anaerobic wastewater stabilization ponds
Water Science and Technology 31 (12), 171-183

The performance of the primary anaerobic pond at the Alsamra Wastewater Treatment Plant in Jordan was monitored over 48 months. Overall averages for the removal efficiencies of BOD, COD and suspended solids were 53%, 53% and 74%, respectively. An improvement in removal efficiency with increase in pond water temperature was demonstrated. A model, which takes into account the variability of raw wastewater at different locations, has been developed to describe the performance of a primary anaerobic pond in terms of a settleability ratio for the raw wastewater. The model has been verified by illustrating the high correlation between actual and predicted pond performance. [Author abstract; 22

Saqqar, Muwaffaq M. and Pescod, M.B. (1995)

Modelling sludge accumulation in anaerobic wastewater stabilization ponds
Water Science and Technology 31 (12), 185-190

Sludge accumulation in the first anaerobic pond at the Alsamra Wastewater Treatment Plant in Jordan has been monitored over a period of years. Homogeneous distribution of sludge over the pond bottom has not been achieved. The maximum amount of sludge has not accumulated near the inlet. This is due to scouring of the settled materials near the pond inlet and outlet by the high jet velocity of the incoming flow. A model has been developed to describe the volume of sludge accumulated (VAS) in the primary anaerobic pond. The model has been derived on the basis of the non-biodegradable materials in settled sludge. VAS has been described in terms of the mass rates (F) of suspended solids and total BOD5 in the raw wastewater and an accumulated sludge coefficient (KAS).

Goerguen, E.; Ubay, Cokgoer E.; Orhon, D.; Germirli, F. and Artan, N. (1995).
Modelling biological treatability for meat processing effluent.
Waste Management Problems In Agro Industries, 43-52.

Biological treatability of major agro-industries wastewaters, such as meat processing effluents, can only be evaluated with specific emphasis on slowly biodegradable substrate and using a multi-component modelling approach. This paper reviews the framework of the endogenous decay model and summarizes the necessary COD fractionation and the kinetic information to be incorporated in this model as applied to a meat processing effluent. Model interpretations of the respirometric experiments are used to define the fate of slowly biodegradable COD. Behaviour of this wastewater in continuous activated sludge systems is studied by model simulations based upon experimental results.

Shelef, Gedaliah; Kanarek and Adam (1995)
Stabilization ponds with recirculation
Water Science and Technology 31 (12), 389-397

The first facultative pond in a series of stabilization ponds, or else the first part of a large pond, is sensitive to organic overloading creating anoxic or anaerobic conditions at the pond's surface, resulting in malodors and nuisances. Such adverse characteristics are usually manifested seasonally when climatic conditions change to lower temperatures and/or reduced solar irradiance. The design organic loadings on such ponds are therefore determined by the critical season and they are lowered accordingly. Introducing recirculation of effluent from a later pond in the series (usually from the second or third pond) back to the inlet of the first one, at a ratio of 1.0 - 2.5 (recirculated effluent) to 1 (raw sewage influent), can be most advantageous, as follows: (1) organic loadings on the first facultative pond in the series can reach 400-600 kg BOD5 per hectare per day (khd) during summer time and 300-400 khd as a yearly average, compared with a yearly average of 60-140 khd on ordinary facultative ponds, while still maintaining odor-free facultative conditions; (2) reseeding the first pond with active adapted algal biomass; (3) mixing the influent (which is often septic) with oxygen-rich recirculated effluent, thus enhancing the biological process in the first pond and suppressing septic odors, and (4) the increased inlet flow (by combining influent flow with the recirculated effluent) increases the area of solids (sludge) settling in the first pond. Altogether, the recirculation is manifested by reduced land requirements, better stability in pond operation, improved pond's performance and reduction or elimination of malodors and nuisances. Step feeding of the ponds further accentuates the effect of recirculation. Obviously, recirculation requires pumping (low head), energy, piping and connection to a power supply. The cost of operation and maintenance amount to US $ 0.01-0.02 per cubic metre of treated wastes. The advantages of recirculation nevertheless significantly outweigh the added costs. The paper describes the experience and data which have been gathered during the operation of 120 hectares of ponds with recirculation in the Dan Region (Greater Tel-Aviv) over a period of almost 20 years.

Walsh, J. L.; Ross, C. C. and Valentine, G. E. (1993)
Food Processing Waste
***Water Environment Research* 65 (6), 402-407**

The impact of the Clean Water Act on the food-processing industry is reviewed with particular emphasis on enforcement policies and new pretreatment requirements. The regulatory aspects and marketability of composted food-processing wastes are also reviewed. Methods for conducting an environmental audit of a food-processing facility are outlined. Pollution prevention and wastewater reduction are reviewed for several food-processing industries. An extensive literature search of disposal and utilization options for solid vegetable, fruit, and other organic wastes was conducted. The study considered anaerobic digestion, animal feeding, composting, edible fiber recovery, fermentation, incineration, pyrolysis, and soil amendment as options. Wastewater treatment and pre-treatment processes are reviewed for the beverage industries. Options include coagulation/flocculation followed by extended aeration, anaerobic pretreatment, biomass disposal, anaerobic treatment, upflow anaerobic sludge-blanket systems, and land application. In the vegetable-processing industry, a sequencing batch reactor system has been used for pretreatment of potato-processing wastewater. Recovery of solids using a belt press from a secondary clarifier was also reported at a potato-processing plant. The 8-yr performance of an upflow anaerobic sludge blanket system for treatment of potato processing wastewater is presented. A precipitation system for phosphorus removal from oilseed and vegetable production wastewater is described. Wastewater treatment in the grain and sugar industries involves several new anaerobic processes. Wastewater treatment in the meat/poultry industry includes disinfection and odor control, foaming and bulking control, and composting techniques. Anaerobic cocomposting of seafood sludges and process upgrades to meet National Pollutant Discharge Elimination System permit requirements at a clam-processing industry are described. Anaerobic and aerobic systems for treatment of dairy wastewaters are also reviewed.

Martinez, J.; Borzacconi, L.; Mallo, M.; Galisteo, M. and Vinas, M. (1995)

Treatment of slaughterhouse wastewater
Water Science and Technology 32 (12), 99-104

In this paper an evaluation of the effluent treatment plant of a slaughterhouse which processes 650 head of cattle a day is presented. Some problems in the operation of the anaerobic reactor and anaerobic lagoons caused by the presence of fats and suspended solids in the effluent were detected. A flotation system by pressurized air injection was tested at the plant. The fat removal efficiency obtained was 63% and 37% for red water and green water, respectively. In order to improve the hydrolysis of particulate matter, a system of two UASB reactors with recirculation, connected in series, was tested at laboratory scale. Removal efficiency was 77% for soluble COD and 82% for insoluble COD, at a volumetric load of 1.8 kgCOD/m3/d. Based on the results of these studies, several modifications in the treatment plant were proposed.

McComis, W. T. and Litchfield, J. H. (1989)
Meat, Fish, and Poultry Processing Wastes
Journal Water Pollution Control Federation (61) 6, 855-858

Reviews for meat processing wastewater treatment and by-products recovery include biological treatment methods, applications of biotechnology, and recovery of proteins and fats. Treatment processes included activated sludge, pasture irrigation with effluent, an anaerobic contact process, dewatering, fat separation, electroflotation, and ultra filtration membranes. Wastes from fish processing plants were monitored and treated by a variety of methods including activated sludge, marsh polishing, sedimentation, chemical coagulation/flocculation, aerobic biological processes, oxic-anoxic-oxic activated sludge, alum, polyamide membranes, and HOAc to remove protein prior to anaerobic digestion. Poultry processing systems reviewed included dissolved air flotation, aerobic and anaerobic lagoons, ozonation, screening and diatomaceous earth filtration, shell-and-tube microfiltration, anaerobic packed bed reactors, and anaerobic filtration followed by a sequencing batch reactor activated sludge process. In addition, case studies dealing with removal efficiencies are discussed.

Campos, J. R.; Foresti and E.; Camacho, R. D. P. (1986)
Anaerobic Wastewater Treatment in the Food Processing Industry: Two Case Studies
Water Science and Technology (18)12,87-97

Two experiments with wastewater treatment in the food processing industry were described. One of them refers to the use of an anaerobic filter (meat processing industry) and the other to the use of an upflow anaerobic sludge blanket (UASB) reactor (vegetable and fruit processing industry). In the first case, the performance of an anaerobic filter which has been working for 6 years and provides COD removal efficiency (including primary treatment) equal to or better than 80% with an organic loading of 1.4 kg of COD/cu m/day was described. The reactor has a bed of broken stones with a size of 0.75

m having a medium hydraulic detention time of 13 hours. Discharges of accumulated sludge in a false bottom below the filter are made at intervals of 2 or 3 months. In the second case, the performance of a UASB reactor (88 cu m) during 255 days of operation including the adaption phase or start-up was described. This reactor receives wastewater from vegetable and fruit processing including tomato, corn, guava, and peach. At the end of each operational phase studied, the COD removal efficiency was about 80%. In the last phase (7.5 h hydraulic detention time), the organic loading was 1.4 kg of COD/cu m/day and the hydraulic loading was 3.2 cu m/cu m/day.

Ang, H.M. and Himawan, P.
Treatment of wool scouring wastewater for grease removal
Curtin Univ of Technology, Perth, Australia

Most of the wool scouring wastewater treatment systems in Australia consist of open anaerobic and facultative ponds which require large open areas. Apart from being unsightly and emitting odours, the plants are usually located in environmentally sensitive areas thereby causing environmental problems. There is a great need to look at alternative treatment systems which are more efficient and more environmentally acceptable. This study set out to investigate ways of reducing the grease content of the wastewater so that the pretreated wastewater can be fed to some high rate anaerobic digester. Various combinations of additions of coagulants, flocculants as well as using sulphuric acid for pH adjustment of the wastewater were attempted for assessing the extent of grease and COD removals. The study was also conducted at temperatures of 20 to 45°C. It was found that up to 98% of grease and 79% of COD could be removed by just using sulphuric acid at a pH of between 2 and 3 and at a temperature of 20°C. This work was first done on a batch basis. The work was extended into a continuous laboratory scale mixer-settler assembly which produced comparable results to those obtained batchwise.

Mendes, B. S.; do Nascimento, M. J., Pereira, M. I., Bailey, L. Nuno; Morais, J. and Santos O. J. (1994)
Ecoclimatic influence on waste stabilization ponds (WSP) efficiencies. Case study of the sesimbra system
Water Science and Technology (30)8, 269-279

Portugal has a great diversity of ecoclimatic areas and Sesimbra was chosen to carry out a study on WSP efficiencies over five years (1989 to 1993). According to Pina Manique & Albuquerque (1954), the climate is classified as Atlantic Mediterranean (AM). Some environmental and climatic parameters have been studied in order to define the area. The treatment system at Sesimbra has three ponds: anaerobic, facultative and maturation. The physical and chemical parameters studied in the WSP system were: Temperature, pH, Dissolved Oxygen, Conductivity, BOD5, COD, nitrates, nitrites, ammonia and total nitrogen, total and volatile suspended solids, total phosphorus and orthophosphates. Algal populations and the following microbiological parameters were studied: total and fecal coliforms, fecal Streptococci, *Clostridium perfringens, Pseudomonas aeruginosa* and some Enterobacteriaceae. The K and K20 kinetic parameters were studied and derived for the three ponds utilizing the seasonal regional characteristics from the surrounding area. These values were then correlated with temperature and the subsequent removal efficiencies for each pond deduced. The data obtained indicate a necessity to determine the seasonal fluctuations of the K and K20 kinetic parameters for the WSP systems.

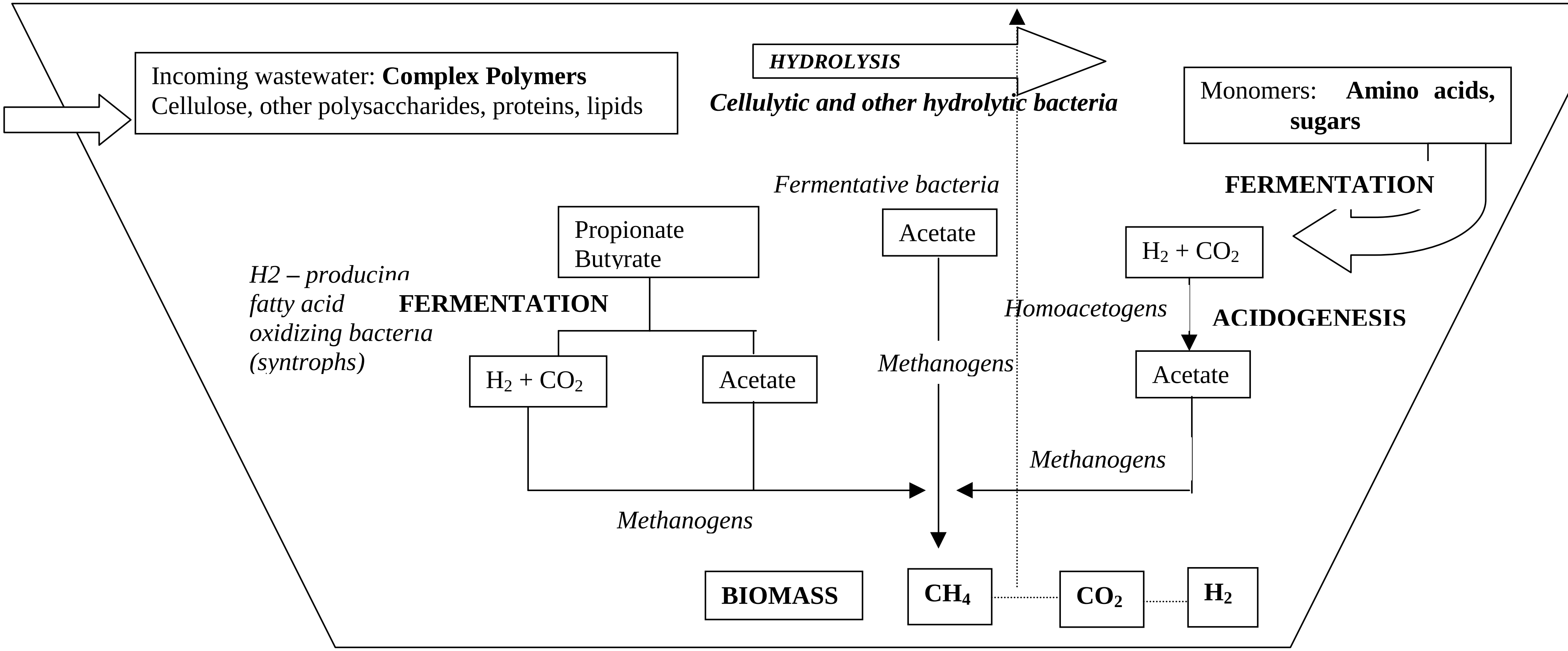
Scaief, J. F. (1975)
Effluent Variability in the Meat-Packing and Poultry Processing Industries
Proceedings of the Sixth National Symposium on Food Processing Wastes April, 2-76

The efficiencies of various combinations of in-plant controls and wastewater treatment processes were evaluated at six meat processing plants and four poultry processing plants. Water consumption at the meat processing plants ranged 525-1,870 gal/1 ,000 lbs. Waste water at the poultry processing plants was generated at a rate of 24.7-26.0 liters/bird. Reductions in water consumption reduced wastewater treatment requirements. The meat packing plants achieved 1977 standards for BOD in effluents. A duck processing plant achieved 1983 standards for BOD and suspended solids. For both types of plants, abnormal weather conditions produced high pollutant loads in the effluent. Poultry processing plants having aerated lagoon or activated sludge systems were more capable of meeting effluent standards than plants using other types of wastewater treatment. A plant which exceeded daily effluent standards was also likely to exceed weekly and monthly limitations. This suggested that daily BOD discharges had to be below the 30-day average for compliance with monthly BOD limitations.

The Microbiology of Anaerobic ponds

The yield of cells (biomass) produced can vary greatly under different conditions. The production of biomass in a treatment pond depends on the type of pond. Aerobic catabolism produces substantially more biomass than anaerobic metabolic processes. The successful operation of an anaerobic pond for treatment of wastes relies on the exclusion of oxygen to maintain a viable population of anaerobes. Three main groups of organisms are known to be obligate aerobes including: a wide variety of prokaryotes, a few fungi and a few protozoa. The obligate anaerobes include sulphate reducing and homoacetogenic bacteria and methanogens. The success of an anaerobic ecosystem relies on microbial interactions known as synotrophy. Microorganisms work (or feed) together to carry out anabolic and catabolic processes that neither can do alone. Thus, the product of the metabolism of one organism becomes the nutrient source for another. A schematic diagram demonstrating the anaerobic synotrophy between cellulytic, hydrolytic, acetogenic and methanogenic microorganisms is presented in the following figure.

This diagram only represents the carbon degrading organisms in an anaerobic system. Other organisms also present in anaerobic lagoon include the sulphate reducing and denitrifying microorganisms.



Schematic representation of anaerobic decomposition of complex organic material to ultimately methane carbon dioxide and new biomass. The diagram indicated the interaction between different groups of anaerobic bacteria: hydrolytic; fermentative; acetogenic and methanogenic.

(Adopted from Madigan, M.T., Matinko, J.M. and Parker, J. (1996). Brock Biology of Microorganisms. New Jersey, USA, Prentice-Hall.)

