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BULLETIN

Anaerobic Lagoons

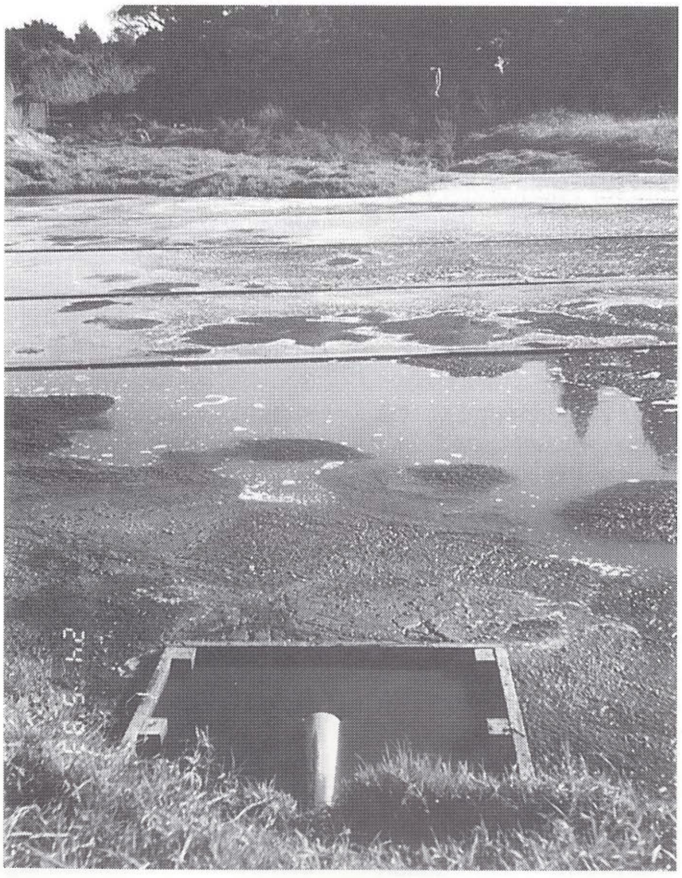
Anaerobic lagoons, which use little or no energy, are a popular form of effluent treatment in the meat industry. In these lagoons, bacteria degrade the effluent organic matter in the absence of oxygen. This Bulletin describes how anaerobic lagoons work, discusses their advantages and disadvantages and outlines their design.

HOW DO ANAEROBIC LAGOONS WORK?

In anaerobic treatment systems, anaerobic and facultative bacteria break down organic biological wastes to three main end products: methane (CH_4), carbon dioxide (CO_2) and ammonia (NH_3).

Facultative bacteria can grow whether or not oxygen is present, but for anaerobic bacteria to grow, even small amounts of oxygen cannot be present. Thus, for anaerobic treatment systems to work, oxygen must be strictly absent. It is therefore important that the rate of loading of anaerobic lagoons is such that dissolved oxygen is never present (i.e. the lagoon remains anaerobic throughout the treatment process).

Although anaerobic treatment has traditionally been used for very strong wastes (e.g. sewage sludge), anaerobic lagoons can be used to treat more dilute wastes such as those from meat processing.



Anaerobic lagoon during early stages when scum layer is being established.

Meat processing wastes are complex, containing various types of organic molecules.

For a complex waste to be degraded anaerobically, several types of bacteria must be present. These are:

- Hydrolysing bacteria, which break down complex molecules such as fats, proteins and complex carbohydrates (e.g. cellulose) to simpler components such as short chain fatty acids, amino acids and sugars.
- Acetogens and hydrogen producers, which convert short chain fatty acids, sugars and amino acids to acetic acid or hydrogen gas.
- The methanogens, which convert either acetic acid to methane and carbon dioxide gases:

$$CH_3COOH \rightarrow CH_4 + CO_2$$

  or hydrogen and carbon dioxide to methane:

$$4H_2 + CO_2 \rightarrow CH_4 + 2H_2O$$

The methanogens are probably the most sensitive bacterial group contributing to the anaerobic breakdown of wastes. They require strictly anaerobic conditions and a pH in the range of 6.5 - 8.0.

ADVANTAGES OF ANAEROBIC LAGOONS FOR MEAT WASTES

Low Cost

After primary treatment by screening or sedimentation, meat wastes typically have biochemical oxygen demands in the range 1000 - 3000 g m^{-3}.

Conventional aerobic treatment of these wastes requires a high power input to get enough oxygen into the wastewater to satisfy the oxygen demand.

In contrast, anaerobic lagoon treatment reduces the oxygen demand without adding oxygen. Thus, anaerobic lagoons have low operating costs compared to aerobic treatment.

The second factor contributing to the low cost of anaerobic lagoons is their simple construction needs.

Low Maintenance

The simplicity of lagoon construction and operation means that maintenance costs are also low.

The main maintenance need is desludging. A sludge layer can build up in anaerobic lagoons and this can eventually reduce their effectiveness. This layer builds up slowly, however, so an anaerobic lagoon should need desludging only every 10-15 years.

High Stability

The balance of carbohydrates, proteins and fats in meat-processing effluents means that anaerobic lagoons that treat these wastes will be highly stable.

This high stability appears to be due in part to the ammonia produced by the degradation of the proteins. The presence of ammonia results in a well-buffered system that is unlikely to become acid. (Acidity is a common problem with some types of effluent and leads to instability.)

Lagoons may become unstable if used to treat other types of effluent as well as meat wastes. When this type of use is proposed, professional advice should be obtained.

Able to Handle Shock Loads

Anaerobic lagoons can accept shock loads better than many other treatment processes. They also respond rapidly when a load is again applied after an extended shutdown.

DISADVANTAGES OF ANAEROBIC LAGOONS FOR MEAT WASTES

Need for Further Treatment

Effluent treated by anaerobic lagoons usually requires further treatment before discharge. The reason for this is the high ammonia content of the treated waste. Ammonia is extremely toxic to aquatic life.

Effluent from anaerobic lagoons is usually further treated in aerobic or oxidation ponds. In these ponds the ammonia is oxidized to nitrate, which is less toxic. Effluent from anaerobic lagoons can also be irrigated to land.

Odours

Odour problems have been associated with some anaerobic lagoons. However, the impact of odours can be reduced by siting lagoons carefully; for example, away from housing, and by encouraging a scum layer to form on the lagoons.

Unsuitable for Fellmongery Effluents

Anaerobic lagoons are not a suitable treatment option for fellmongery effluents. This is because these effluents contain high concentrations of sulphide and oxidized sulphur compounds, which will be reduced to hydrogen sulphide gas in the lagoon environment.

As a result, large quantities of hydrogen sulphide will be released from the lagoon. Not only can this gas cause an odour nuisance, but also it is very toxic, and relatively low concentrations in confined spaces can be fatal.

Therefore, fellmongery effluents will generally require segregation and alternative treatment. This is often done by discharging the fellmongery effluent directly into a subsequent aerobic pond.

DESIGN OF ANAEROBIC LAGOONS

Lagoon Volume and Retention Time

Anaerobic lagoons generally remove 60-80% of the incoming soluble chemical oxygen demand (soluble COD). After treatment their effluent contains only 100-200 g m^{-3} of total suspended solids.

Various equations can be used to help design anaerobic lagoons. These include an equation for predicting the percent removal of soluble COD and an equation for predicting the concentration of soluble COD in the lagoon effluent.

The following equation predicts the percent removal of soluble COD for removals of 0-80%:

$$\%\text{ removal of soluble COD} = 5.74 \times (1.04)^{T-20} \times Rt$$

where T is the lagoon temperature (°C) and Rt is the lagoon hydraulic retention time (days)

This equation was developed at hydraulic retention times of 2 to 14 days and at lagoon temperatures of 10 to 20°C.

Caution should be exercised if the equation is used outside these ranges. (Lagoon temperatures are about 6 to 7°C above the average ambient temperature in winter and 3 to 4°C above ambient in summer.)

The equation predicting the concentration of soluble COD in the effluent is:

$$\text{Soluble COD} = \text{COD} - 1.1 \times \text{TSS}$$

where TSS is the suspended solids concentration.

The biological decomposition of the effluent solids is slow compared to that of the soluble component. Anaerobic lagoons should therefore maximize the

retention of the solids within the lagoon. Hydraulic retention times of 8 or more days give satisfactory retention of solids.

Based on these design criteria and operating temperatures of 10 to 20°C, anaerobic lagoons treating screened or settled meat processing effluents will typically be designed with hydraulic retention times of 8 to 20 days.

Lagoon Shape
There is no best shape for anaerobic lagoons.

The larger the length in relation to the width, the more likely the lagoon will show plug-flow characteristics and the less likely effluent will short-circuit in the lagoon. Lagoons with plug-flow characteristics usually have a better performance.

If there is enough land area, two or three lagoons may be built in series, to enhance plug flow characteristics.

To minimize the lagoon surface area, and hence the amount of oxygen that can enter the lagoon from the atmosphere, anaerobic lagoons should be 3-4 m deep.

Inlet/Outlet Structures
The inlet to the lagoon should be submerged so warm effluent does not form a layer on the lagoon surface.

Designing the inlet structure so the incoming waste mixes with the sludge layer at the bottom of the lagoon may be of benefit, as the sludge layer contains many active bacteria.

The lagoon outlet should be of the submerged weir type so effluent is discharged from below any scum layer that forms.

Scum Layer
A layer of scum on the lagoon surface inhibits the escape of unpleasant odours, so the formation of a scum layer should be encouraged.

Mature anaerobic lagoon with vegetation growing on the scum layer.

During the initial start-up phase of a lagoon, when odours can be a particular nuisance until a scum layer is present, the development of a scum layer can be encouraged by feeding some paunch content and fatty material into the lagoon.

Once a scum layer develops, however, these materials should no longer be released into the lagoon, as their prolonged addition may overload it.

During scum formation a network of floating rope barriers may be required on the lagoon to prevent the scum layer from being broken up by wind action.

Lagoon Lining
Depending on how porous the natural soil is, the lagoon may need to be lined with a water-impermeable barrier to prevent effluent seeping out of it, as such seepage may contaminate groundwater. This lining may be a compacted layer of suitable clay or a plastic membrane.

Solids Recycle
Recycling of sludge to the lagoon inlet, either after clarification of the lagoon effluent or by pumping directly from the bottom of the lagoon, should enhance lagoon performance. However, so long as incoming effluent mixes adequately with the lagoon sludge, solids recycle is not necessary.

Site Requirements
Lagoon areas must be adequately fenced to prevent trespassers. Adequate fencing is also required if sheep are used to keep the area surrounding the lagoons tidy.

Scum layers on lagoons can look like firm ground, and grass may even grow on the lagoon surface. Personnel working near the lagoons must be made aware of this hazard.

It is essential that there be an adequate distance between anaerobic lagoons and nearby housing. A minimum distance of 150 m is recommended.

It is also important to consider the prevailing wind direction when planning where to site anaerobic lagoons.

Planting trees around anaerobic lagoons enhances their appearance and may help to reduce any odour nuisance. Shelter belts will also prevent the wind from breaking up the scum layer that helps to contain odours within the lagoon.

Characteristics of anaerobic lagoon influent and effluent from an anaerobic lagoon treating meat processing effluent.			
	Influent ($g\ m^{-3}$)	Effluent ($g\ m^{-3}$)	Removal (%)
COD	1385	355	74
Soluble COD	595	190	68
Total Kjeldahl nitrogen	80	85	—
Ammonia nitrogen	24	58	-142
Total solids	920	345	63
Suspended solids	450	155	66
Fat	210	45	79

EFFLUENT QUALITY FROM ANAEROBIC LAGOONS

The effluent quality from anaerobic lagoons depends on the hydraulic retention time, climatic conditions, lagoon configuration and so forth.

Results from one lagoon treating meat-processing plant effluent in New Zealand are shown in the table above. This lagoon had a hydraulic retention time of 10-12 days.

During the period that these results were collected, the lagoon temperatures ranged between 18 and 25°C.

Untreated meat plant effluent contains faecal material and therefore contains faecal indicator bacteria (faecal coliforms and enterococci) that are normally at concentrations of 10^5 - 10^7 per 100 ml of effluent.

In anaerobic lagoons the concentrations of these bacteria are typically reduced by one to two orders of magnitude (90 - 99% reduction). The mechanisms causing this reduction are not completely understood.

IN SUMMARY

- Anaerobic lagoons are effective in treating relatively strong meat processing wastes at low operating cost. They have the following disadvantages:
  - Their effluents need further treatment (to reduce their high levels of ammonia).
  - They may cause an odour nuisance if not sited properly.
  - They are not suitable for certain types of waste, such as fellmongery effluent.
- Anaerobic lagoons should be managed such that:
  - A scum layer is encouraged to form.
  - The rate of loading is such that dissolved oxygen is never present.
  - The hydraulic retention time is long enough to encourage solids retention.
  - The waste flows into the lagoon below the water surface and mixes with the lagoon sludge.
  - Plug flow is encouraged.
  - Effluent flows out of the lagoon from beneath the water surface.
  - Worker safety is ensured (by fencing).

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