Purpose

- Degrade organic matter in wastes to a more stable end products
- Combine primary and secondary treatment in most systems

Process Types

- Anaerobic – process occurs without free oxygen, high BOD wastes are liquefied and/or degraded, most efficient
- Aerobic – wastes are mechanically aerated and BOD is degraded via aerobic processes, good for reducing odor but expensive to operate
- Facultative – facultative organisms are tolerant of both oxidative and anoxic conditions
- Most lagoons provide some of each type of treatment. If left relatively undisturbed, an aerobic zone develops near the surface with facultative and anaerobic zones beneath.

Anaerobic Lagoons

- Advantages
  - Effluent appropriate for irrigation/land application
  - Storage time allows flexibility for effluent irrigation
  - Breakdown during storage helps control odors during application
  - Provides good reduction of nitrogen – reduces land requirements for N-based application (won’t help much with P-based application though)
- Disadvantages
  - Sudden changes in manure loading or temperature likely will cause odor problems
  - Spring and fall turnover may occur in areas with cold winters – causes odor problems as bottom materials rise to surface and as microorganisms reestablish
  - More effective in warmer climates – less in cool
  - Good reduction of nitrogen concentrations decreases value of effluent for fertilizer

Siting and Sizing Considerations

- Lagoon Location
  - Downwind of homes (duh), check local and state regulations regarding set backs
  - Use gravity flow when possible, a sump with pump if gravity flow is not an option
  - Check underlying soils – bottom and side walls need to be nearly impervious, best to use native materials if they are present
  - If native soils are not sufficiently impervious, install a synthetic or clay liner
  - Have a nearby source of fresh water for dilution and water supply
Lagoon Shape

- Make lagoon as deep as possible and practical – reduces surface area generating odors and promotes vertical mixing
- Surrounding berms should have a top width of 12 feet or so for equipment access, gentle side slopes as well (1 vertical to 3 horizontal minimum), slopes may be steeper below the liquid level
- Single stage – keep a relatively square shape for even loading and sludge accumulation
- Multiple stage – lagoons may be long and thin (up to 5 times as long as wide), put inlets and outlets so flow travels full length of lagoon

Inlets and Outlets

- Extend inlets well over lagoon surface to help distribute load and sludge and to help prevent erosion
- If ice is likely to form on the lagoon, allow sufficient inlet height and storage space above the anticipated ice level
- Put outlets well away from inlets to avoid short-circuiting

Determining Total Lagoon Volume

Reference

- ASABE Standards (ANSI/ASABE EP403.3), see handout

Total Lagoon Volume

- Total lagoon volume is calculated as the sum of several individual volumes:
  - minimum design volume (ensures the lagoon works under worst case conditions),
  - waste storage volume,
  - runoff volume, and
  - sludge accumulation

Minimum Design Volume

- This minimum volume assures that the lagoon will function for waste breakdown and odor control even at its lowest volume
- Use Figure 2 in the handout to determine the recommended maximum lagoon loading rate for your geographic location
- The maximum loading rate is the mass of volatile solids per unit lagoon volume per day
• Calculate the minimum design volume as:

\[ MDV = \frac{N \times VS}{VSLR} \]  

(1)

MDV = minimum design volume, m\(^3\) or ft\(^3\)
N = number of animals
VS = VS generated daily per animal, kg or lb
VSLR = recommended maximum volatile solids loading rate from handout, kg/d·1000 m\(^3\) or lb/d·1000 ft\(^3\)

**Waste Storage Volume**

• Provide sufficient additional storage for wastes generated over a one year period
• Allows accumulation of wastes between pump outs
• Follow procedures outlined earlier for estimating daily waste volumes, multiply by the number of days between pump-outs or, if that is unknown, the number of days in a year (365)

\[ WSV = DV \times t \]  

(2)

WSV = waste storage volume, m\(^3\) or ft\(^3\)
DV = volume of waste generated daily as described earlier, m\(^3\) or ft\(^3\)
t = time in days between pump-outs

**Runoff Volume**

• Provide sufficient additional storage for runoff collected from all areas draining into lagoon. Runoff from exposed lot areas or other areas receiving manure must be collected.
• Include rainfall onto the lagoon surface.
• Provide sufficient storage for runoff generated by the 25-year, 24-hour storm in your area. Assume all rainfall becomes runoff (not a bad assumption for heavily compacted animal yards). Rainfall values for U.S. available from handout.

\[ RV = P_{25,24} \times A \]  

(3)

RV = runoff volume, m\(^3\) or ft\(^3\)
P\(_{24,25}\) = rainfall for the 25-year, 24-hour storm, m or ft
A = total area yielding runoff to the lagoon, m\(^2\) or ft\(^2\)

• Runoff from roofs of animal structures may be routed to the lagoon if fresh water is needed or routed around if not needed.
Sludge Accumulation

- This additional volume allows for the accumulation of fixed solids (stuff that doesn’t easily degrade) in the lagoon over time.
- Sludge volume depends on typical manure characteristics (amount of fixed solids in the manure) and the length of time expected between sludge removal events.
- Can be estimated using the amount of total solids generated in the manure and a sludge accumulation factor:

\[ SSV = N \times TS \times sf \times t \]  

(SSV = sludge accumulation volume, m\(^3\) or ft\(^3\)
TS = total solids per animal, kg/d or lb/d
sf = sludge accumulation factor (see below)
t = time between cleanouts, days)

- Typical sludge accumulation factors are:

<table>
<thead>
<tr>
<th></th>
<th>m(^3)/kg TS</th>
<th>ft(^3)/lb TS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Layer</td>
<td>0.00184</td>
<td>0.0295</td>
</tr>
<tr>
<td>Broiler</td>
<td>0.00284</td>
<td>0.0455</td>
</tr>
<tr>
<td>Swine</td>
<td>0.00303</td>
<td>0.0486</td>
</tr>
<tr>
<td>Dairy</td>
<td>0.00455</td>
<td>0.0729</td>
</tr>
</tbody>
</table>

- No sludge accumulation factor is published for beef (at least that I found), however dairy values should be similar or slightly higher

Estimating Length of Sides

- For square lagoons, choose a maximum depth of liquids in the lagoon (leave room for freeboard) and a side slope ratio (horizontal:vertical or z)
- The length of a side along the bottom of a lagoon is:

\[ l_b = \sqrt\frac{V}{(d-f)} - z^2(d-f)^2 - z(d-f) \]  

(l\(_b\) = the side length at the bottom, length
V = total lagoon volume
d = maximum allowable depth in the lagoon, length
z = horizontal:vertical side slope ratio
f = freeboard (extra depth added to prevent over-topping of the lagoon)
The value for f is typically 0.3 m or 1 ft.)

- The length along the side at the maximum liquid level (l\(_t\)) is:
\[ l_t = l_b + 2z(d - f) \]  
\[ (6) \]

- and the length along the embankment \((l_T)\) above the freeboard is:

\[ l_T = l_b + 2z(d) \]  
\[ (7) \]

**Example**

Determine the total lagoon volume for a swine finishing operation consisting of 2000 animals located in the panhandle of Texas. Assume an average weight of 154 lb per animal, no bedding is used, and 200 ft\(^3\)/day of water is used for flushing. Also assume that the lagoon receives runoff from a 5 acre area, including the lagoon surface. Finally assume the lagoon will be cleaned of accumulated sludge every 10 years.

Determine the minimum design volume:

\[
MDV = 2000 \text{ animals} \left( \frac{99 \text{ lb VS}}{\text{finished animal}} \right) \left( \frac{1}{120 \text{ d}} \right) \left( \frac{d \cdot 1000 \text{ ft}^3}{4.5 \text{ lb}} \right) = 367,000 \text{ ft}^3
\]

Determine the livestock waste volume:

\[
WSV = \left( \frac{20 \text{ ft}^3}{\text{finished animal}} \right) \left( \frac{1}{120 \text{ d}} \right) + 0 + \frac{200 \text{ ft}^3}{\text{d}} \times 365 \text{ d} = 195,000 \text{ ft}^3
\]

Determine the runoff volume:

25-yr, 24-hr storm is 5 in (from handout)

\[
RV = \frac{5}{12} \text{ ft} \times \left( 5 \text{ acres} \times \frac{43560 \text{ ft}^2}{\text{acre}} \right) = 90,750 \text{ ft}^3
\]

Determine the sludge accumulation volume

\[
SSV = 2000 \text{ animals} \times \frac{120 \text{ lb TS}}{\text{finished animal}} \times \frac{1}{120 \text{ d}} \times 0.0486 \frac{\text{ft}^3}{\text{lb TS}} \times (10 \times 365 \text{ d}) = 355,000 \text{ ft}^3
\]

Determine the total lagoon volume:
\[ TV = DMV + WSV + RV + SSA = 367,000 + 195,000 + 90,750 + 355,000 = 1,008,000 \text{ ft}^3 \]