Module 3:
Types of AD Technology

3.1: Introduction

3.2: Passive AD systems

3.3: Low-rate AD systems

3.4: High-rate AD systems

3.5: Dry AD systems

3.6: Choosing an AD design

This curriculum is adapted from: eXtension Course 3: AD, University of Wisconsin

3.1: Introduction

AD designs differ…

… but all designs perform the **same basic function**:

- Contain organic matter
- In the absence of oxygen
- And at operating temperatures

Four AD categories:

1. Passive AD
2. Low-rate AD
3. High-rate AD
4. Dry AD

3.2: Passive Systems

Covered lagoon

1. Manure is placed in a pit covered with an impermeable and gas-tight cover.
2. Oxygen is depleted and anaerobes produce biogas.
3. Biogas accumulates under the cover and is piped to a genset.
4. As manure is pumped into the covered lagoon, digester effluent flows to a smaller open storage pit.

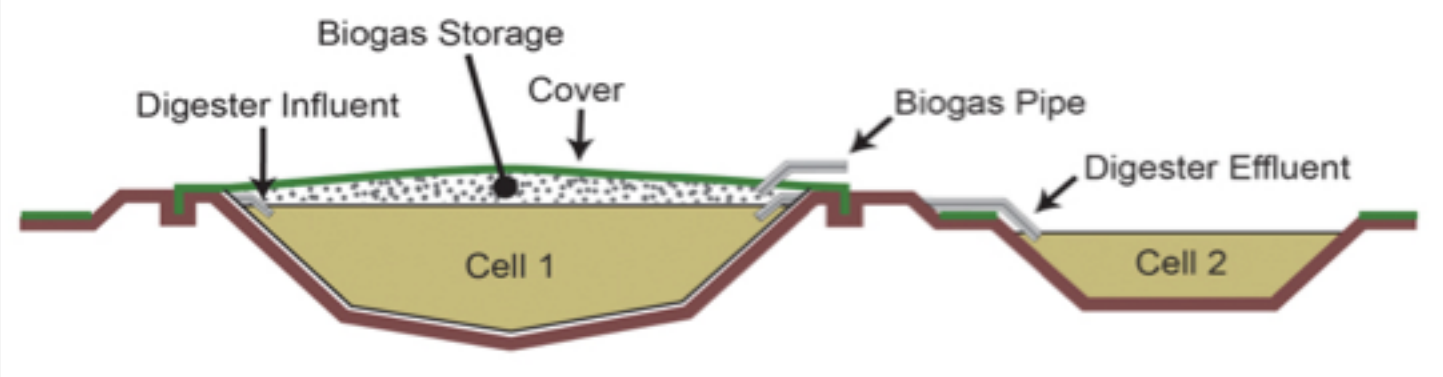
Covered lagoon

Advantages:

- Inexpensive
- Works with hydraulic flushing
- Simple operation

Disadvantages:

- Poor mixing
- Poor energy yield (inefficient)
- 30 – 60 day HRT
- Settled solids reduce useable volume
- Limited AD season in cold climates. Biogas production stops <68F or 20C



3.3: Low-Rate AD Systems

Low-rate AD

Low-rate AD: an AD system where feedstock remains in the system for long periods of time to maximize biogas production.

Types:

1. Complete-mix AD
2. Plug-flow AD

Complete-mix AD

Complete-mix AD: one or more tanks in which manure is heated and mixed.

1. Feedstock is pumped in daily.
2. Input displaces an equal volume of effluent (and bacteria) from the tanks.
3. Slurry is stored continuously or intermittently.
4. HRT is generally 20 – 30 days.
5. Generally low solids content of 3 – 6 % solids in the slurry.
   Note that tanks size must increase as solids decrease.

One phase vs. two-phase:

- One phase systems is a single tank.
- Two phase systems use two linked tanks:
  - First: fermentation of feedstock to organic acids
  - Second: production of methane from organic acids

Complete-mix AD

Advantages:

- Efficient
- Can handle different levels of dry matter
- Can handle energy crops
- Good mixing
- Good solids destruction

Disadvantages

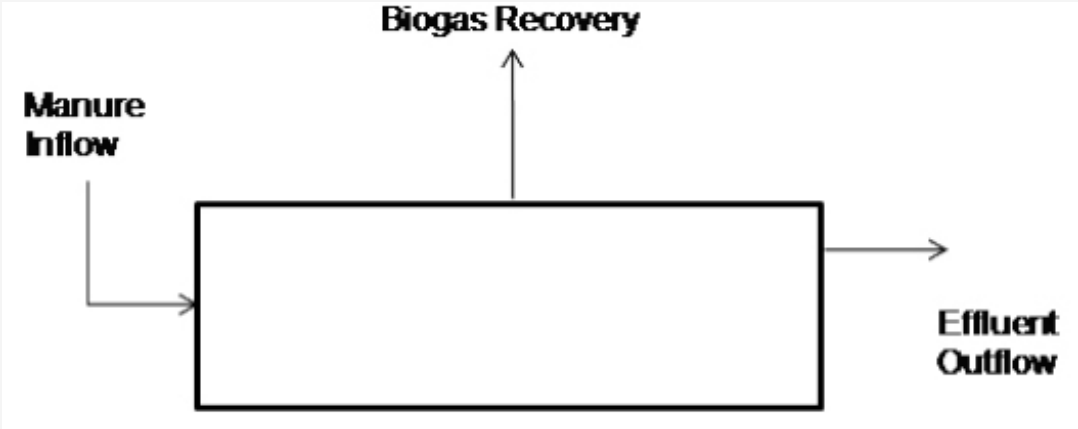
- Difficult to control how much time material spends in the AD
- Bacteria wash out
- Relatively expensive

Plug-flow AD

Plug-flow AD: one long underground tank in which manure is heated

- Plug-flow tanks are generally five-times longer than wide.

1. A 'plug' of manure (10 – 20% total solids) is pumped in daily. Some operators add solids to thicken manure.
2. Input displaces the most distant and digested plug from the other end of the tank.
3. Little or no mixing occurs, but the high solids content keeps particles from settling.
4. HRT is generally 15 – 20 days.



Plug-flow AD

Advantages:

- Inexpensive
- Simple to repair and operate
- Can be adapted to accept energy crops

Disadvantages

- Poor mixing
- Poor energy yield
- Hard to remove settled solids
- Membrane top may be affected by wind and snow

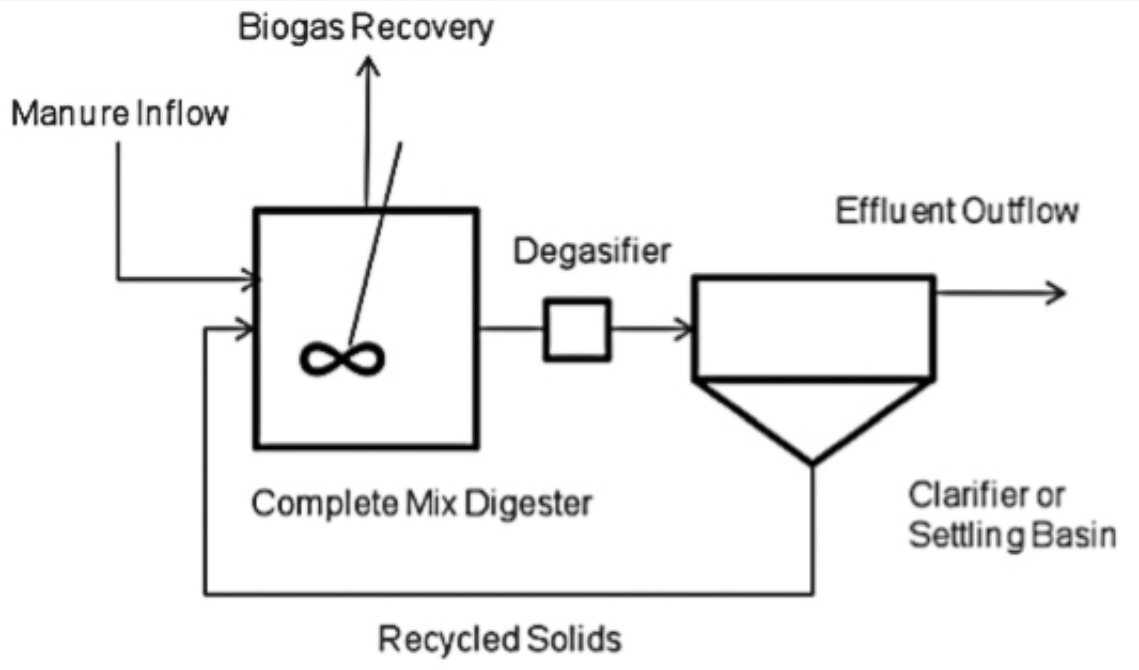
3.4: High-Rate AD Systems

Low-rate AD with solids recycling

Solids recycling modifies the complete-mix and plug-flow designs described by **returning some settled, high-solids effluent to the feedstock inlet**.

This returns some microbes that would have been washed out, increased AD efficiency.

- Advanced plug-flow
- Contact stabilization digesters or anaerobic contact digesters



Low-rate AD with solids recycling

Advantages:

- More efficient
- Useful microbes get a second chance
- Smaller vessel size

Disadvantages:

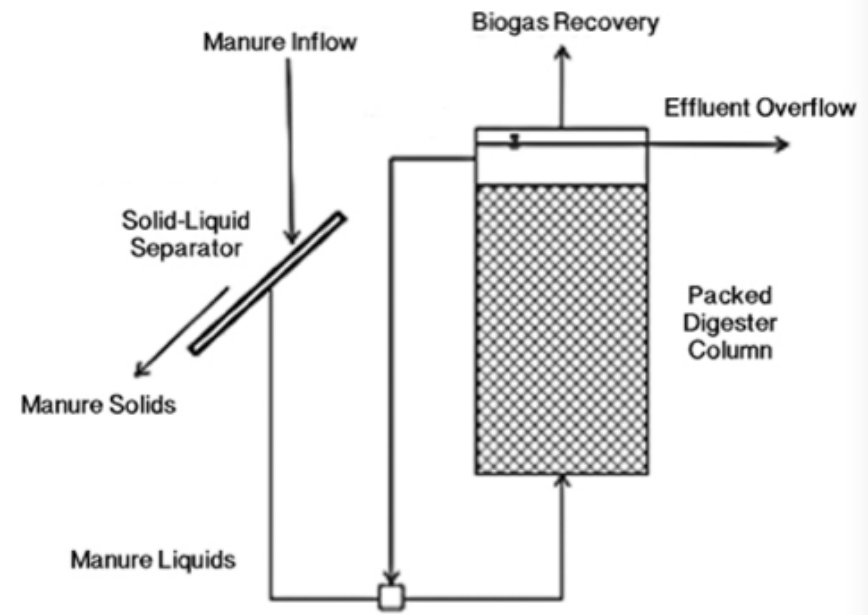
- Increased operational complexity
- More mechanical components

Fixed-film AD

Fixed-film AD: a column packed with media (wood chips or small plastic rings) on which AD microbes are grown and remain as a biofilm.

aka attached growth AD or anaerobic filters

1. Dilute manure or liquid feedstock (1 – 5% total solids) is pumped up and through the media. Solids must be filtered out prior to feeding.
2. Effluent is constantly pushed out of the top.
3. Effluent is usually recycled to maintain a constant upward flow.
4. HRT is 5 days or less, so tank sizes can be small.



Fixed-film AD

Advantages:

- Efficient
- Low bacterial wash out
- High gas production for a small AD tank size

Disadvantages:

- Expensive
- Suspended solids must be filtered out before AD. This increases complexity & may lower biogas yield.
- Bacterial growth media may plug, blocking AD flow.

Suspended-media AD

Suspended-media AD: AD microbes are suspended in a constant upflow of liquid. Small particles wash out while larger particles remain and develop a biofilm of AD microbes. Effluent is often recycled to maintain upward flow.

aka

- Fluidized bed AD
- Upflow anaerobic sludge blanket (UASB) → <3% total solids
- Induced blanket reactor (IBR) → 6 – 12% total solids

1. Dilute manure or liquid feedstock (1 – 5% total solids) is pumped upward.
2. Effluent with small particles is constantly pushed out of the top.
3. Large particles (with AD microbe biofilm) are retained in the column.
4. Effluent is usually recycled to maintain a constant upward flow.

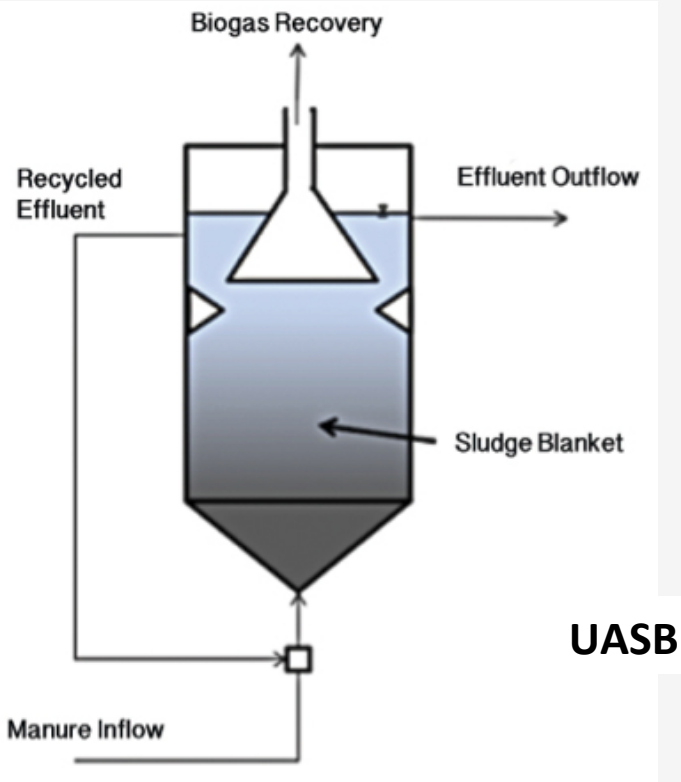
Suspended-media AD

Advantages:

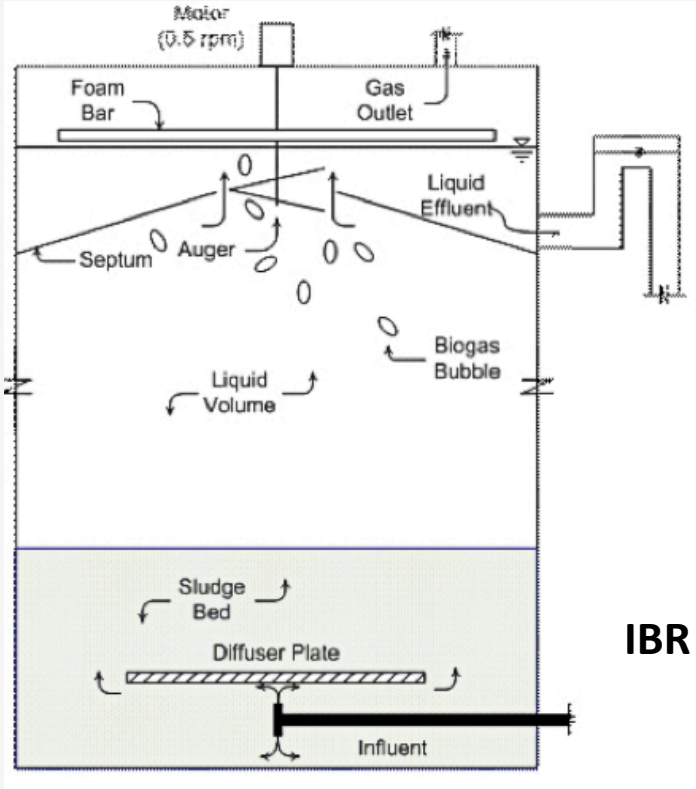
- Very efficient
- Can treat high-strength wastewater
- Good bacterial retention

Disadvantages:

- Expensive
- Complex operation
- Cannot handle FOG



UASB



IBR

Sequencing batch AD

Sequencing batch AD (ASBR): in this variant of an intermittently mixed AD a tank is operated in four distinct phases:

1. The tank is filled with manure or feedstock.
2. Feedstock is mixed during the react phase.
3. Stirring is stopped and solids are settled during the settle phase.
4. Liquid effluent is drawn off during the decant phase.

This operation cycle may be repeated up to four times per day and biogas is removed as it is made.

- Liquid HRT can be as short as 5 days.
- Work will with a variety of feedstock concentrations, down to completely soluble.
- Sludge is removed periodically and has a high concentration of nutrients.

Sequencing batch AD

Advantages:

- High gas yield per substrate load
- Works well with dilute manure
- Small reactor size
- Can accept high energy liquid co-substrates

Disadvantages:

- Relatively expensive
- Complex operation
- Low gas yield per reactor volume
- Works best with dilute (low solids) substrates

3.5: Dry AD Systems

Dry (high-solids) AD

Dry AD (HSAD): (aka dry fermentation) solid, stackable organic feedstock is stacked in airtight bays. Each bay operates as a batch AD.

1. High-solids feedstock (25 – 50% solids) is stacked in airtight bays. Feedstock may include manure but the pile must have 'air' gaps throughout.
2. Leachate (liquids) are collected as they drain from the pile…
3. … and recirculated by spraying back onto the top of the pile.
4. A biofilm of bacteria develops on the pile & soluble organic acids pass over the biofilm again and again until digestion is complete.

Dry (high-solids) AD

Advantages:

- Uses solid feedstock
- Has a long aerobic phase as all of the air in the chamber is consumed prior to the start of the anaerobic phase

Disadvantages:

- Requires at least 25% solids and stackable feedstock
- Complicated operations
- Expensive

AD Technologies

	lagoon	Plug-flow	Mixed plug	Complete mix	Fixed-fimd	IBR	ASBR	Dry
vessel type	In-ground, synthetic liner	In-ground concrete	In-ground concrete	In/above ground tank(s)	In/above ground tank(s)			
Ease O&M	low	Low	Medium	medium	medium			
Add heat?	no	Yes	yes	yes	yes			
% TS	0 - 6	11 – 13	3 – 13	3 - 10				
Type solids	coarse	Coarse	Medium-fine	coarse				
HRT (days)	60+	18 – 20	20 – 30	5 - 20				
Farm type	Dairy, swine	Dairy	Dairy, swine	Dairy, swine				
Optimum climate	Temp or warm	All	All	All				

3.6: Choosing an AD design

Criteria for choosing an AD system?

If the AD system is **chosen thoughtfully**, it will require only modest daily operational attention and periodic maintenance.

- Will this AD technology easily become a component of the farm's daily operations?
- Is the AD technology suited to the farm's manure handling system?
- Is the AD technology and design suited to co-substrates that may be sourced and used locally?

Steps in thinking it through

1. Answer some questions about the farm's management needs and environmental needs that will determine whether AD is a potential benefit.
   - Meyer & Power (2011) have developed a tool that presents both benefits and challenges of AD.

↓ yes

2. Conduct a more in-depth feasibility study using tools or consultants.
   - DIGESTER_ECON.XLSM spreadsheet from University of Minnesota
   - FARMWARE program available on-line from AgSTAR
   - Consultants

AD co-products can be vital to payback

AD provides farmers with many benefits, but not all of them provide fiscal benefits.

- Odor reduction
- Environmental benefits
- Ease of manure handling

Therefore, it's important to make each co-product contribute to the economic success of the project:

- Maximize electric income (net-metering vs. direct sale & purchase)
- Recover waste AD heat to offset fuel use or sell it
- Tipping fees for accepting off-farm feedstock? **
- Sale of separated solids for bedding or compost base

Regulations factor into AD decisions

AD technology itself is not subject to federal regulations.
Instead, AD regulation is happening on a state-by-state basis and is not consistent across the US.

However, handling of waste streams and the impact of wastes and nutrients on land and waterways is regulated at multiple levels: local, state and federal.

Which agencies regulate AD? Often agencies that regulate:

- Solid waste
- Wastewater
- Agriculture

Sources & resources

This curriculum is a modification of the wonderful:

- eXtension Course 3: AD, University of Wisconsin

http://fyi.uwex.edu/biotrainingcenter/online-modules/series-three-anaerobic-digestion/

Additional sources & resources:

DVO designs & installs zonally mixed plug-flow AD in North America

- www.dvoinc.net

RCM designs & installs both plug-flow and complete mix AD in North America

- http://www.rcmdigesters.com/

Quasar designs, installs & sometimes operates complete mix AD in North America.

- http://www.quasarenergygroup.com/pages/worldwide.html

Lipp of Germany designs & installs complete mix AD and has licensed its technology to several North American companies.

- http://www.lipp-system.de/47-anaerobic_technology.html

Bioferm, North American Subsidiary of Viesmann of Germany, sells complete mix, container scale, and dry AD systems and has partnered with **Schmack**.

- http://www.bioferm-energy.com/en.html

Purpose Energy designed & built Magic Hat's AD

- http://www.purposeenergy.com/