ANAEROBIC DIGESTER MIXING SYSTEMS

ENVE 737

Anaerobic Biotechnology for Bio-energy Production
AD MIXING SYSTEMS

- Natural mixing occurs in ADs with:
  - rise of gas bubbles
  - thermal convection currents created by addition of heat
- These levels of mixing is inadequate → Auxiliary mixing is required

*What is adequate mixing?*

- The uniformity of solids concentrations in any point within the digester will not vary by more than 10%, except for deposits on the tank bottom (containing course sand) and floating scum (containing low density material).
Objectives of mixing

- Provide contact between the active biomass and feed
- Provide physical, chemical & biological uniformity within AD
- Distribute organics & dilute inhibitory substances within AD
- Utilize the digester volume effectively
- Prevent stratification and temperature gradients
- Minimize the formation of a scum layer and grit settling
“Rules-of-thumb” in sizing AD systems

- Digester Volume Turnover Time (DVTT) is a measure of anticipated mixing capacity of the digester
  \[ \text{DVTT} = \frac{\text{Tank volume}}{\text{Pump capacity}} \]

- Hydraulic Retention Time is an indicator of mean reaction time
  \[ \text{HRT} = \frac{\text{Tank volume}}{\text{Sludge flow rate}} \]

- Unit Power (UP) and G-value quantify pump capacity and normalize mixing intensity based on the flow properties of the sludge
  \[ \text{UP} = \frac{\text{Pump horsepower}}{\text{Tank volume}} \times 1000 \]
  \[ \text{G} = \frac{\text{Pump power}}{\text{Tank volume}} \times \frac{1}{\text{Sludge viscosity}} \]

“Rules-of-thumb” in sizing AD systems

- Desirable values
  - DVTT = 0.5–1 h
  - HRT = 15–30 days
  - UP = 0.2–0.3 Hp/1000 ft³
  - G = 50–85 s⁻¹
"G" value

A theory presented by Copper & Tekippe (1982) for determining proper mixing levels on the basis of Root-Mean-Square Velocity Gradient (VGT or “G” Value).

\[ G = \left( \frac{W}{\mu} \right)^{1/2} = \left( \frac{E/V}{\mu} \right)^{1/2} \]

- \( G \) = Root-Mean-Square Velocity Gradient, s\(^{-1}\)
- \( W \) = Power Dissipated per unit volume, J/m\(^3\).s (or W/m\(^3\))
- \( E \) = Rate of Work on energy transfer (power), J/s (or W)
- \( V \) = Volume of Reactor, m\(^3\)
- \( \mu \) = Absolute viscosity of liquid, kg/m.s

"G" value

- For a gas mixing system, the rate of work imposed upon the system can be calculated as follows:

\[ E = 2.40 \, P_1 \, Q \, \ln(P_2/P_1) \]

Where:
- \( Q \) = Inlet Gas flow, \( m^3/\text{min} \)
- \( P_1 \) = absolute pressure at the liquid surface, atm
- \( P_2 \) = absolute pressure at the depth of gas injection, atm

AD MIXING SYSTEMS

- Types of mixing typically used in ADs;
  1. *Long shafted paddle mixing*
  2. *Pumped (jet) mixing*
  3. *Gas mixing*
  4. *Wall mounted draft-tube mixing*
  5. *Submersible mixers*
1. Long shafted paddle mixing

- There are two versions available:
  - Side entry (shaft goes from the side towards centre)
  - Top entry
- Side entry mixers are only suitable for relatively small ADs
- Top entry mixers are used when tank height $>>$ diameter
- Normal operation for both types would be intermittent, i.e. fixed periods of several minutes every hour
1. Long shafted paddle mixing

- Gas tight wall bushings take the shaft of mixer.
- Longer end (inside) facing downwards towards the middle of the digester holds 1 or 2 propellers.
- Motor, gearbox and all electrical connections are located outside the AD.
Advantages/Disadvantages

Advantages
  o A reasonably low power consumption motor is used
  o Motor is mounted externally giving easy access
  o No regular servicing is required (only greasing etc.)
  o Slow speed, large bladed units minimizes risk of mechanical failure

Disadvantages
  o Stratification on some substrates may occur
  o Costly to install because ADs has to remain gas/liquid tight
  o If fails then total shutdown is required to remove the unit or carry out repairs.
2. Pumped mixing

- One or more internally or externally mounted pumps deliver a recirculated flow into a series of nozzles.
- No in-basin moving parts.

Vaughan’s Rotamix® system; floor mounted nozzles fed by a Vaughan® chopper pump.
2. Pumped mixing

- Mounted at ground level and fixed to the outside of tank.
- Large diameter nozzles are installed externally through the tank walls.
- Short pipe run resulting in minimal friction losses and maximum energy imparted to fluid.

Hidrostal’s Externally Mounted Pump Mixing Systems

Screw centrifugal impeller pump
Advantages/Disadvantages

Advantages
  o Pump unit is mounted externally so regular service is facilitated.
  o Externally installed nozzles may be removed without entering the digester

Disadvantages
  o Nozzles may become blocked over time which will degrade mixing performance and increase power costs.
  o Internal nozzles may not be cleaned without emptying the digester.
3. Gas mixing – Lances

- Gas mixing involves recirculating a fraction of the digester gas through the digesting sludge via a compressor and a series of lances and nozzles.
- Sequencing the gas flow to various points causes mixing action to be distributed throughout the tank.

Siemens - Pearth™ gas mixing
3. Gas mixing – Bottom diffusers

- Bottom diffuser mixing systems include diffusers on the floor.
- All diffusers receive and discharge equal amounts of compressed gas, creating a rising gas column.
- Gas flow must be checked periodically, because diffusers are prone to plugging.
- Plugging can be cleared by directing entire gas flow through affected diffuser or by flushing it with high-pressure water.
3. Gas mixing - Bubble gun system

- Re-circulated gas is continuously fed to bubble generator and intermittently discharged into stack pipe as a large piston bubble.
- Piston bubble fills the entire cross section of pipe, driving out liquid as it rises and creating a siphon.
- As one bubble leaves stack pipe at the top, another enters from generator for both continuous mixing and prevention of solids settling.
- Large bubbles burst as they leave liquid surface, creating substantial turbulence that prevents scum buildup.
3. Gas mixing – Gas lifter

- Gas is injected into a vertical tube via lances typically below the midpoint of draft tube.
- As the gas is released, it carries solids upward through draft tube, drawing in more solids at the base of tube.
- Solids that leave the top of tube flow away radially.
- Large tanks are equipped with multiple draft tubes; smaller vessels typically contain a single tube located in the center.
Advantages/Disadvantages

Advantages

- The compressors are mounted externally as is most of the pipework, easing the maintenance requirements.
- With some systems, a separate mixing chamber is provided which is accessible from the outside of the tank for maintenance.

Disadvantages

- Initial purchase cost is slightly more expensive than other systems
- But whole life costs are usually the lowest.
4. Wall mounted draft-tube mixing

- Mounted on the wall with a short shaft and high speed impeller
4. Wall mounted draft-tube mixing

- External draft tube
- Roof mounted Type I
- Roof mounted Type II
- Roof mounted Type III
Advantages/Disadvantages

Advantages
- Major components are mounted externally with automatic oilers and grease applicators.
- Submerged unit requires only a limited amount of maintenance every two to three years.
- No entry into the tank is required at any time as the whole unit is removed by a very simple guide system.

Disadvantages
- As the mixer position is fixed, there is no room for adjustment and the position needs to be correct for the mixer to operate efficiently.
5. Submersible mixers

- Similar to submersible pumps except that the pump head is replaced by a normally quite slow running propeller.
- The unit is mounted on guide rails through the roof of the tank.
- They can be electrically or hydraulically powered and are usually operated continuously.

Amaprop submersible mixers - KSB
5. Submersible mixers

Typical ragged up submersible mixer, which has to be lifted out of the tank for cleaning.
Advantages

- Low cost in terms of initial purchase cost.
- Very efficient and controllable mixing with the possibility of raising and lowering mixer.
- Some systems are available with a gas tight chamber at the top of the guide rail which allows the submersible mixer to be removed without the total loss of gas production.

Disadvantages

- Regular servicing must be completed to prevent breakdowns.
- Seals can be a weakness on these units.
Innovative mixing systems

Landia – GasMix™