ENVE 424
Anaerobic Treatment

Lecture 9
Start-up and Operation of Anaerobic Reactors

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Assist. Prof. A. Evren Tugtas

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Digester Start-up

- Seed
  - Economical haul distance
  - Quality of the seed
- Raw sludge concentration
  - Expected to be 4%
  - 60% is volatile
- Detention time
- Digester heating/mixing

Digester Start-up

- Fill the digester with sewage
- Bring temperature to operating temperature
- Start the mixing equipment
- Close the system, wait for oxygen to be flushed from the system
- Pump sludge/seed to digester
- Analyze digester contents for pH, alkalinity, VFAs at least daily

Digester Start -up

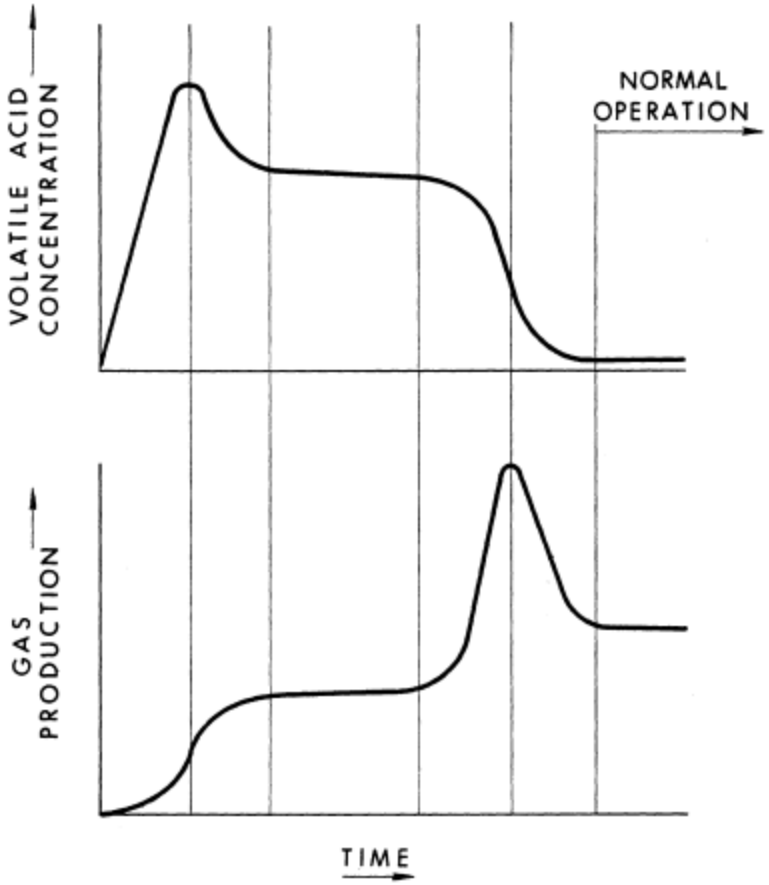


FIGURE 1.—Volatile acids and gas production relationships in high-rate primary digester startup.

Ref: Filbert WB. 1967. Procedures and problems of digester startup. Water Pollution Control Federation. 39(3):367-372

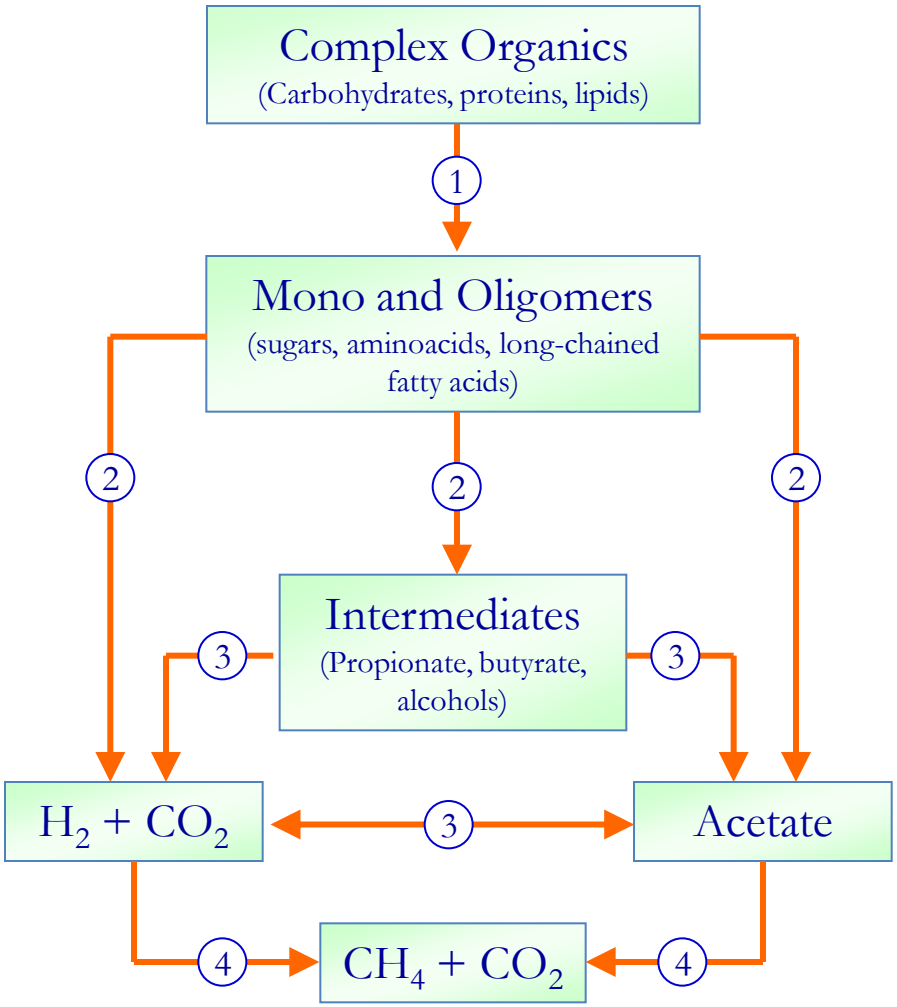
Digester Start-up

- Facultative anaerobes and methane forming anaerobes are required in an anaerobic digester.
- Facultative anaerobes are required for;
  - Hydrolysis of particulate and colloidal compounds
  - Degradation of soluble organic compounds to VFAs
- Methane forming anaerobes are required for the degredation of volatile acids and to produce methane

Rate limiting reactions

- The rate-limiting reaction in AD is usually the conversion of organic acids (i.e. VFAs) to CH_4.
- Methanogens obtain very little energy from degradation of VFAs and most of this energy is transferred to CH_4.
- Low energy yield restricts growth rate of methanogens.
- Therefore, optimum operational conditions must be maintained for satisfactory rates of solids (VS) removal and CH_4 production.

Anaerobic Digestion



1. Hydrolysis
2. Fermentation
3. Acetogenesis
4. Methanogenesis

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Rate limiting reactions

- Methanogens are strict anaerobes and are extremely sensitive to changes in alkalinity, pH and temperature.
- Therefore, operational conditions in ADs must be periodically monitored and maintained within optimum ranges for acceptable activity of methanogens.
- If the substrates fed to ADs are mostly slowly degradable particulate materials, then the rate-limiting reaction will be the hydrolysis of particulate material.

Start-up with seeding

- Start-up of anaerobic reactors is determined by the initial transient period with operational instabilities.
- Adequate seeding of anaerobic reactor at start-up is more critical than for aerobic systems.
- If the quantity of seed inoculated to AD is not adequate, the start-up may fail or reaching to steady state may be prolonged for up to a year.
- As well as the quantity, activity of the seed also affects the rate of start-up.

Seeding with sewage sludge

- To seed an AD with an adequate population of anaerobic bacteria and methanogens, a ratio of 1:10 of secondary sludge (WAS) to primary sludge may be used.
- Methanogens are strict anaerobes and die quickly in an activated sludge process, therefore an AD cannot be successfully seeded with secondary sludge (WAS) alone.
- However, WAS is highly concentrated with facultative acidogenic (fermentation) bacteria.

Seeding with sewage sludge

- Primary sludge provides not only some (1) facultative anaerobes such as fermentative bacteria but also (2) many anaerobes including methanogens and (3) many organic particulates.
- Therefore, primary sludge that contains an abundant population of methanogens is necessary if there is no AD sludge nearby to use as seed.

Seeding with adapted sludge

- Use of seed sludge from an identical process to inoculate an anaerobic reactor increases the rate of start-up in comparison to the rate achieved when seeding with waste sludge of sewage treatment plant.
- The bacteria required are already present in the seed taken from an identical process treating a similar waste.
- In case of seeding with sewage sludge, relevant populations have to be selected for before the treatment in new anaerobic reactor could efficiently occur.

Seeding with AD sludge/manure

- If a seed sludge adapted to the waste to be treated is unavailable, an anaerobically digested sewage sludge or manure can also be used.
- Presence of a heterogeneous microbial population in AD sludge and manure grown on complex substrates ensures the rapid selection of relevant organisms upon inoculation into the new anaerobic reactor.
- Aftering seeding, provision of trace elements such as metals has reported to shorten the adaption period.

Start-up without seeding

- Anaerobic reactors can also be inoculated with bacteria existing in the feed (sewage sludge, food waste).
- If the concentration of microorganisms in the waste is limited, the time required for the retention and selection of a large microbial mass can be very long.
- Therefore, this is considered the most unfavorable way to start up high-rate anaerobic reactors used in treatment of industrial wastewater.

Granulation

- Development of a granular sludge is necessary for the start-up of UASB reactors if sewage sludge is used as seed instead of a granular sludge of another UASB.
- Divalent cations (Ca^{2+}) are known to aid flocculation of anaerobic sludge and thus enhance sludge retention.
- Types of microorganisms in the seed sludge and start-up procedures including loading rate and amount of seed sludge are also important in granulation.

Operation of ADs

- Operating ADs properly is often difficult, because numerous conditions are interrelated and changes in one condition may directly or indirectly affect others.
- Low concentrations of solids and short SRTs maintained in completely mixed ADs render the process susceptible to toxic upsets and shock loadings.
- Another difficulty is the presence of different microbial groups that have different optimum values or ranges of values for operational conditions.

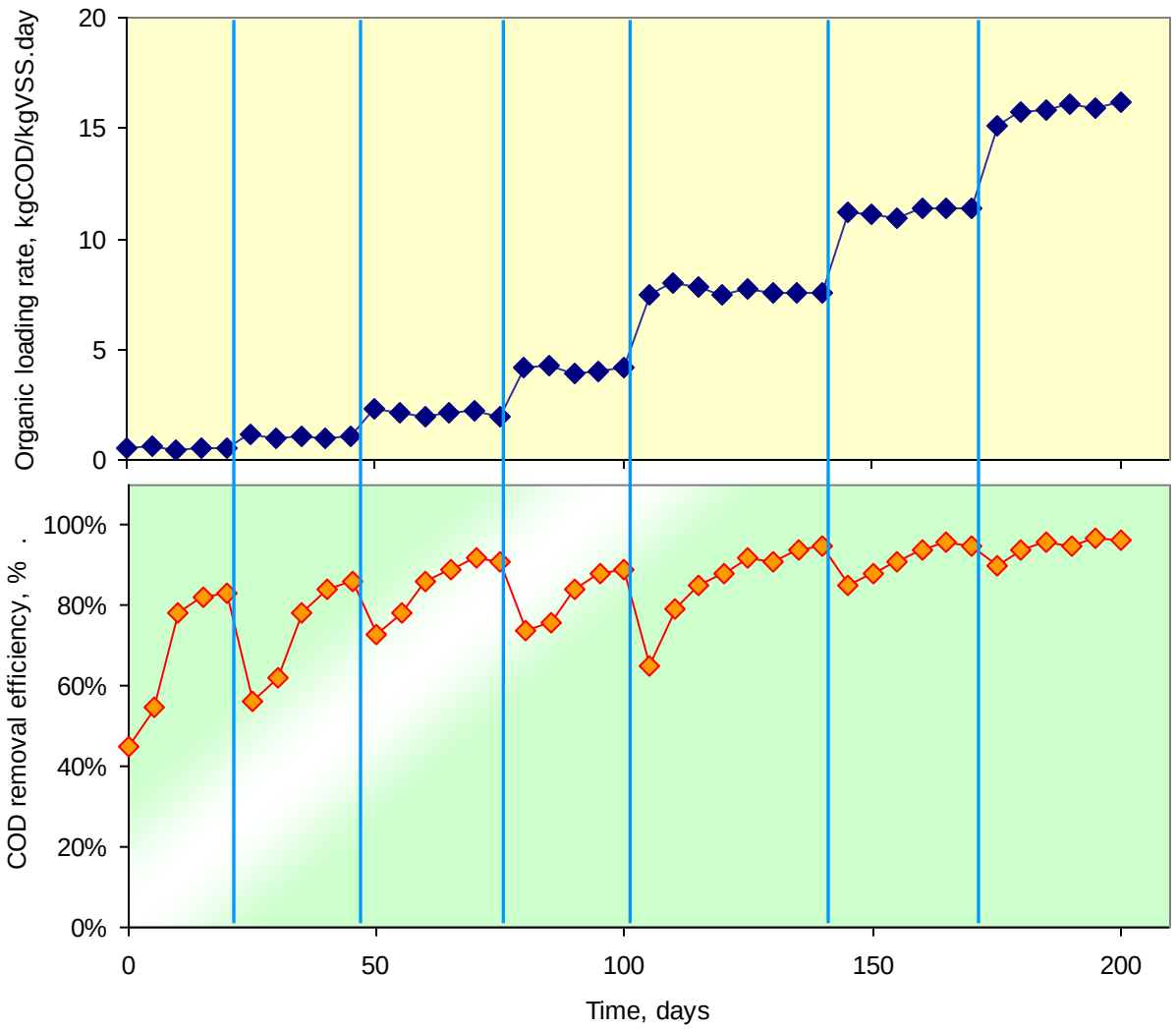
Operation of ADs

- Common objectives in operation of high-rate ADs are;
  - Control of solids retention time
  - Preveting accumulation of inert solids and grease
  - Development of favorable conditions for mass transfer
- These objectives are generally achieved when the reactors are well designed and constructed.
- Besides appropriate procedures during the start-up and operation of the system have to be followed.

Organic loading rate

- In start-up, it is recommended to determine the organic loading rate (kgCOD/kgVS.d) according to the specific methanogenic activity (SMA) of seed sludge utilized.
- If SMA data is not available, organic loads of 0.10-0.50 kgCOD/kgVS.d may be applied.
- The initial load has to be gradually increased according to efficiency of the system (COD removal > 70% and acetate in the effluent < 1000 mg/l) and improved activity of bacterial mass.

Start-up procedure



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