AEROBIC DIGESTION OF SLUDGE

- Introduction to Sludge Treatment
- Sludge Stabilization
- Process Fundamentals
- Aerobic Digestion Operating Conditions
- Use of Thickeners-Clarifiers
- ATAD Process
- Advantages & Disadvantages of Aerobic Digestion

What is a Sludge?

A sludge is a liquid that contains enough solids that it can no longer be considered to have the same physical or hydraulic properties of water.

Chemical sludges: water treatment
metal plating industry

Biological Sludges: primary sludge
secondary sludge
tertiary sludge

Why are sludges an environmental problem?

Sidestreams are produced by every physical/chemical/biological reactor that is designed to remove a specific contaminant. This sidestream is typically concentrated to a sludge which is high in contaminant concentration or biological biomass produced by the consumption of the contaminant.

- May contain high levels of contamination
- May contain high levels of biomass and pathogens
- Contain high levels of liquids that can not be properly disposed in a sanitary landfill.
- Too high in volume

Sludge Treatment & Disposal Options

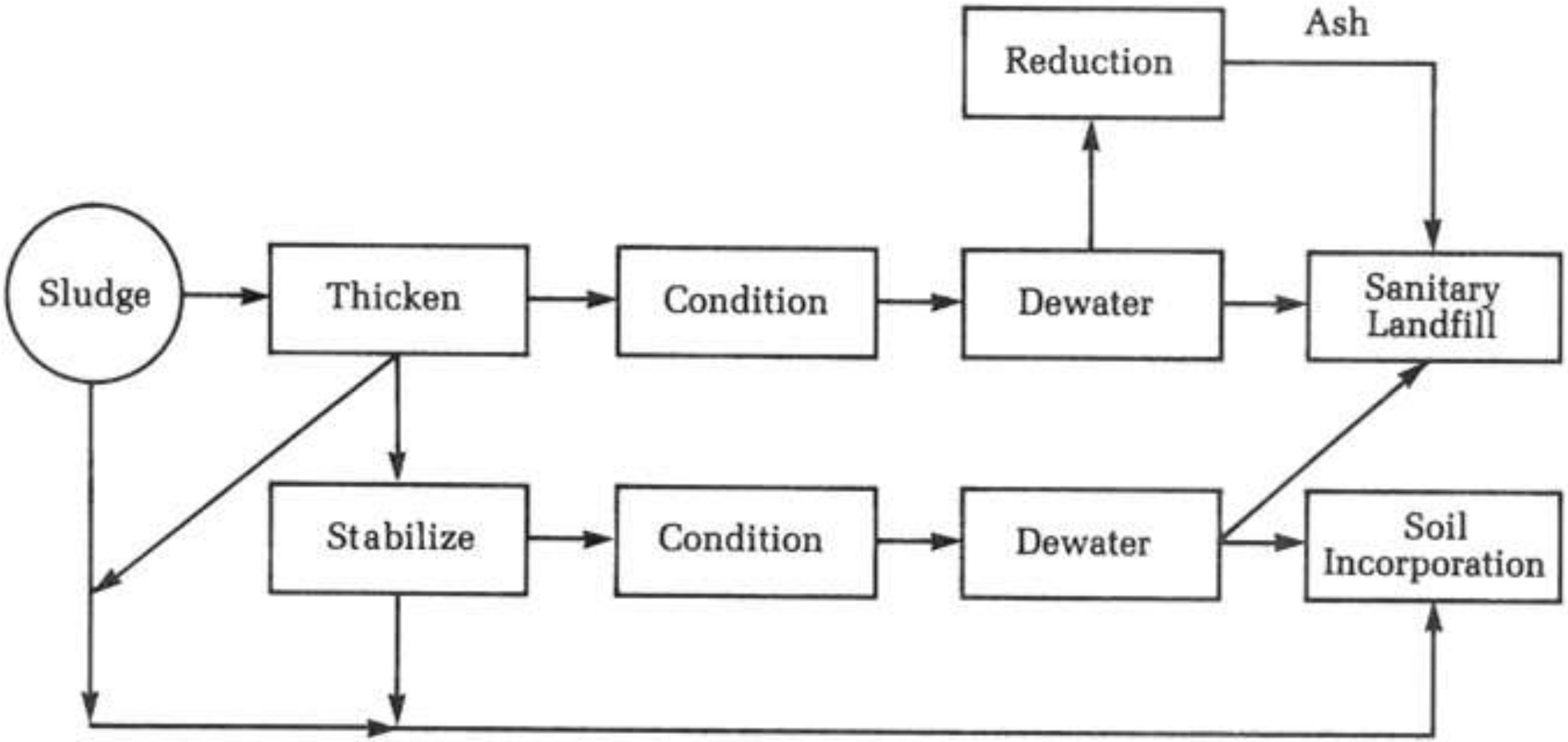


FIGURE 5-31
Basic sludge handling alternatives.

Ref: Davis, Cornwell,1998, Intro to Environmental Engineering

Goals of Sludge Treatment

- Significantly reduce the volume to a level that will not cause any "free liquid" production after final disposal. Remove water.

- Stabilization/Conditioning to increase the biostability and reduce health hazards associated with heavy metals and/or pathogens. Satisfy 503 regulations.

- Ultimate Disposal: Place the sludge in a location that is safe to the environment and/or has beneficial uses to the environment.

Sludge Stabilization

Why stabilize ?

- Reduce pathogen levels prior to final disposal
- Vector attraction reduction
- Increase the biostability of the sludge prior to final disposal

Processes for Stabilization

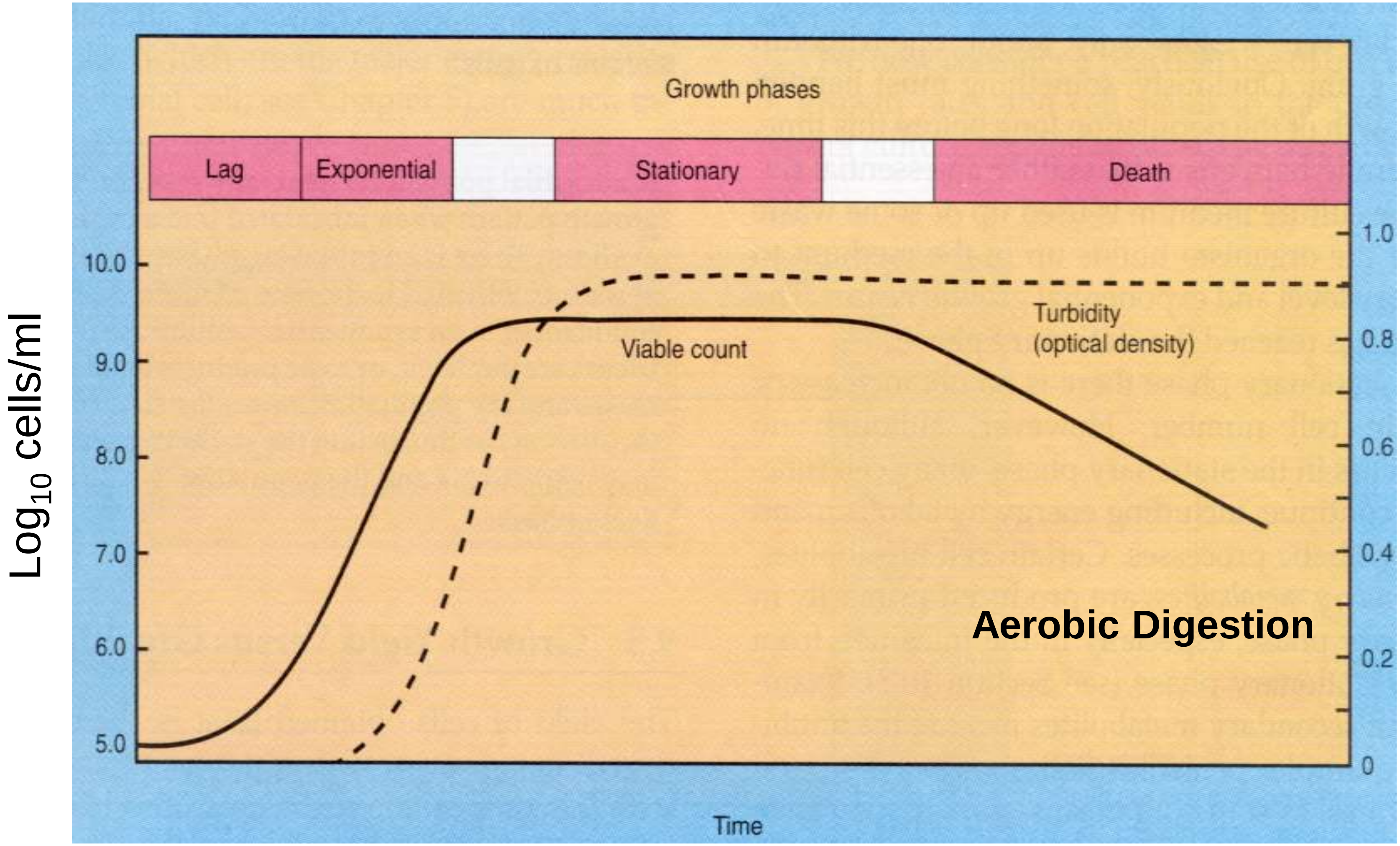
- **Aerobic Sludge Digestion**
- Anaerobic Sludge Digestion
- Lime Stabilization

Aerobic Digestion: Process Fundamentals

$$\text{organic matter} + O_2 \longrightarrow \text{New cells} + \text{Energy for cells} + CO_2 + H_2O + \text{Other end products}$$

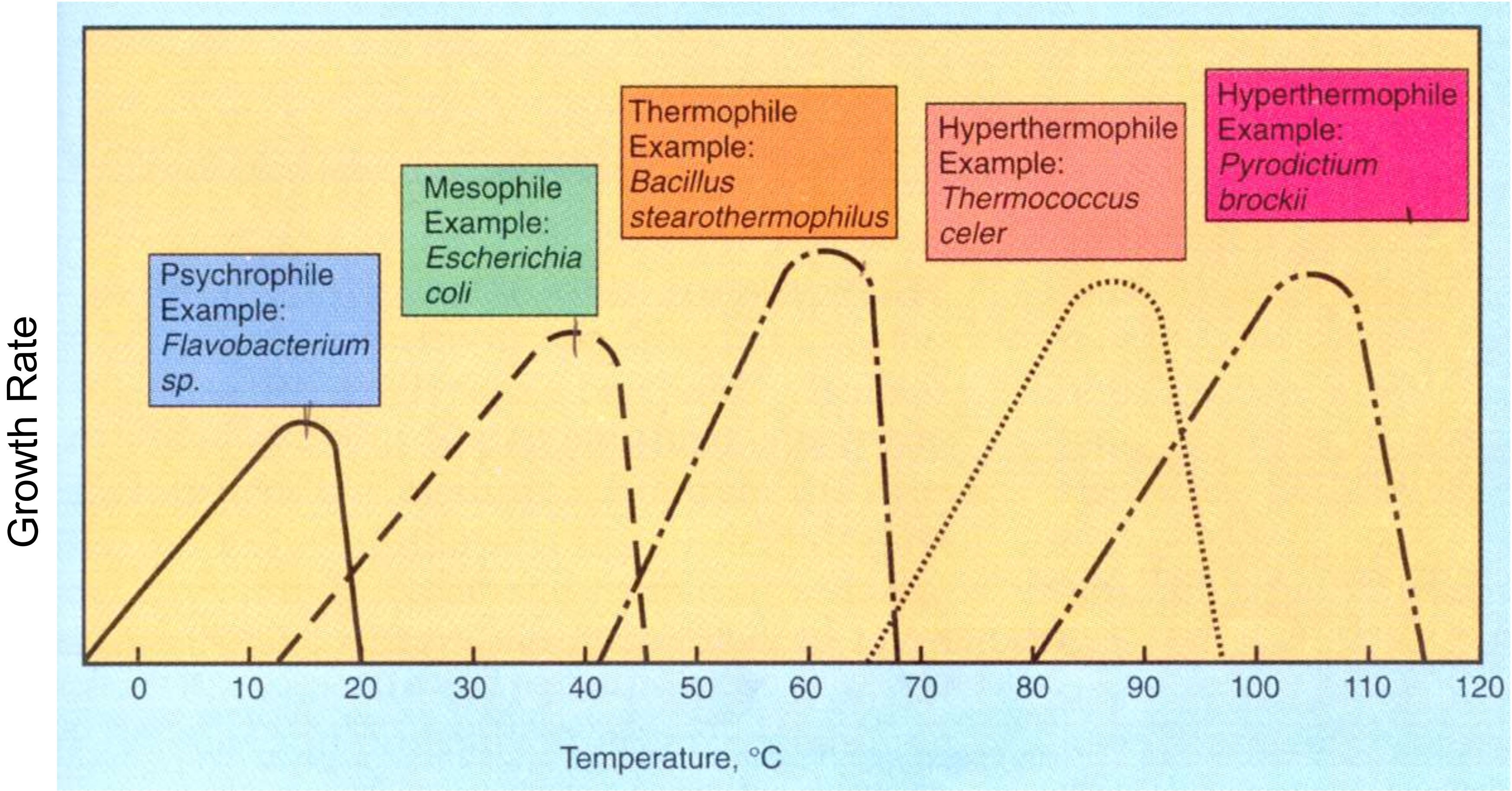
$$\underset{\text{biological cells}}{C_5H_7NO_2} + 5O_2 \longrightarrow 5CO_2 + 2H_2O + NH_3$$

Microbial Growth Phases



Ref: Brock, Madigan, et al, Biology of Microorganisms

Temperature Classifications



Aerobic Sludge Digestion

$$C_5H_7O_2N + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3$$

$$NH_3 + 2O_2 \rightarrow NO_3 + H_2O + H^+$$

$$C_5H_7O_2N + 7O_2 \rightarrow NO_3 + 5CO_2 + 3H_2O + H^+$$

Theoretical oxygen requirements = 2.0 lb O_2/lb biomass

Aerobic Digestion Design

- SRT at 20˚C = 40 days; SRT at 15˚C = 60 days (503)
- Volatile solids loading = 0.1 to 0.3 lb/(ft3-day)
- Oxygen requirements = 2.3 lb O_2/lb VSS destroyed
- Energy requirements for mixing = 100 to 200 hp/mil gal
- Dissolved oxygen residual = 1 to 2 mg/L
- Reduction of VSS = 38 to 50%

How You Operate Depends on…

- If treating sludge for direct land application
- If treating sludge for subsequent dewatering
- Type of dewatering equipment
  - Belt Filter Press
  - Centrifuge
  - Recessed plate pressure filter
  - Screw Press
  - Sludge drying beds
- If pursuing Class A
- If you are hauling sludge away

Other Factors to Consider

- Your influent sludge characteristics
  - % Total SS
  - % VSS
- Frequency of wasting
- If you are chemically treating influent or effluent
- Given digester design that you have
  - Batch/continuous
  - Single or multi-tank & tank config/volume
  - Type of aeration
  - Amount of O_2 provided (e.g., blower size)
- Level of automation/instrumentation

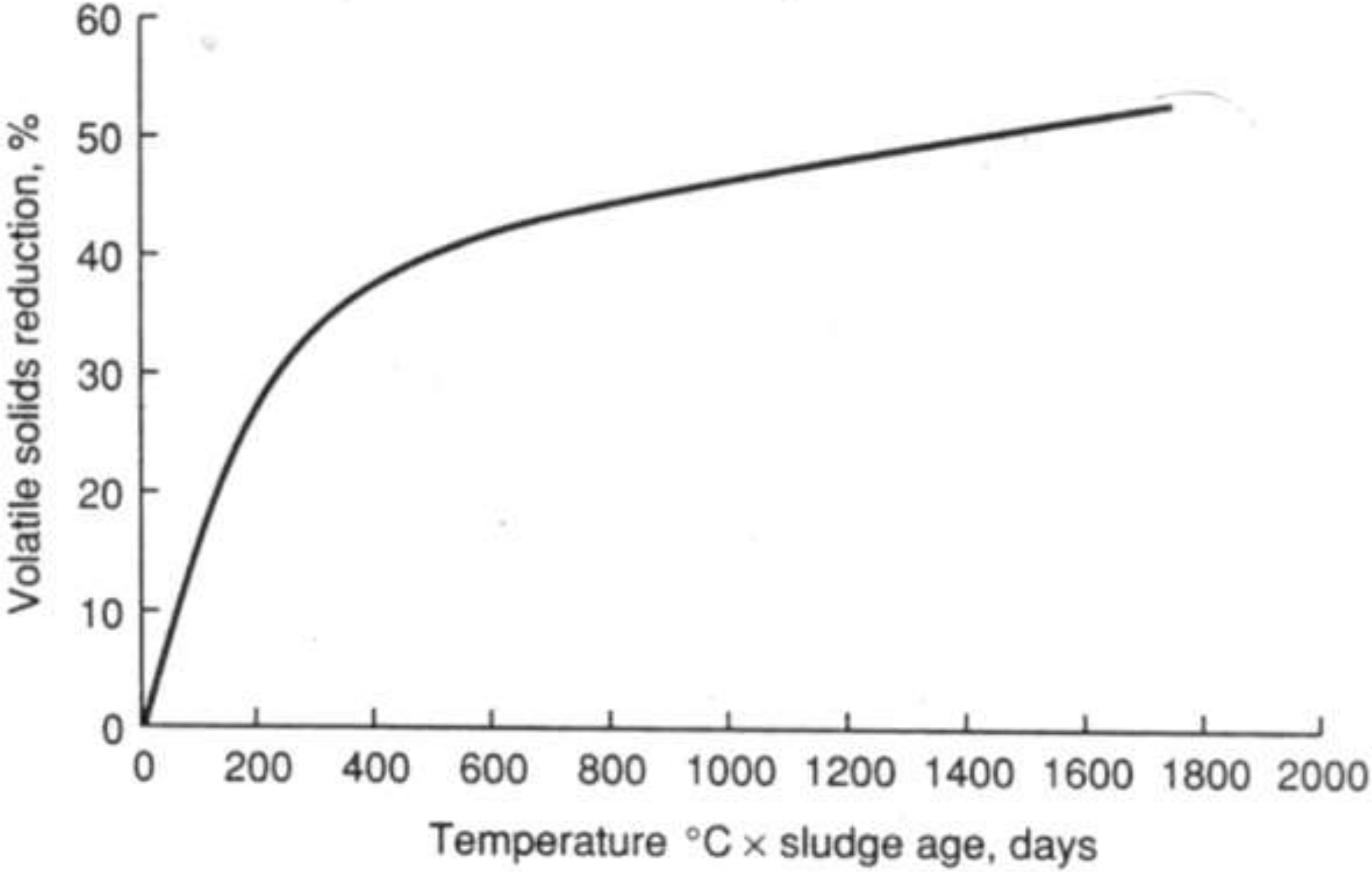
To Meet 40 CFR 503

- Pathogen Reduction Alternatives (Class B):
  - MCRT of 60 days @ 15 C or 40 days @ 20°C

    OR
  - Pathogen ≤ 2,000,000 CFU or MPN per g TS
- Vector Attraction Reduction Alternatives:
  - VSS Reduction ≥ 38%

    OR
  - SOUR ≤ 1.5 mg O_2 per hr per g TS @ 20°C

Aerobic Sludge Digestion



Aerobic Sludge Digestion: Scenario #1

- Activated sludge SRT = 10 days
- Desired VSS destruction in digester = 45%
- Design temperature = 20°C
- From previous figure, °C x days = 1100
- Required digester detention time = 55 days
- Oxygen requirements = 2.3 lb O_2/lb VSS destroyed

Aerobic Sludge Digestion: Scenario #2

- Activated sludge SRT = 40 days
- Desired VSS destruction in digester = 45%
- Design temperature = 20°C
- From previous figure, °C x days = 1100
- Required digester detention time = 55 days
- Thus, only an additional 15 days of digestion time is needed; additional VSS destruction ≈ 3%; oxygen requirements in digester are small.
- Reduce run time of digester aeration equipment

Anoxic Operation

- Take advantage of anoxic operation, when possible
- But watch out for anaerobic conditions
  - Could lead to settling problems
  - Nocardia-like bulking

Aerobic Sludge Digestion

$$\text{Volume} = \frac{Q_i X_i}{X\left[k_d\left(\frac{\text{MLVSS}}{\text{MLSS}}\right) + \frac{1}{\theta_c}\right]}$$

V = volume of aerobic digester, ft^3

Q_i = influent sludge flow rate, ft^3/d

X_i = influent sludge concentration, mg/L

X = sludge concentration in digester

k_d = endogenous respiration rate, day^{-1}

θ_c = sludge age in digester, days

Volatile Solids Reduction Depends On:

- Nature of the sludge
- Hydraulic detention time
- Solids retention time
- Operating temperature

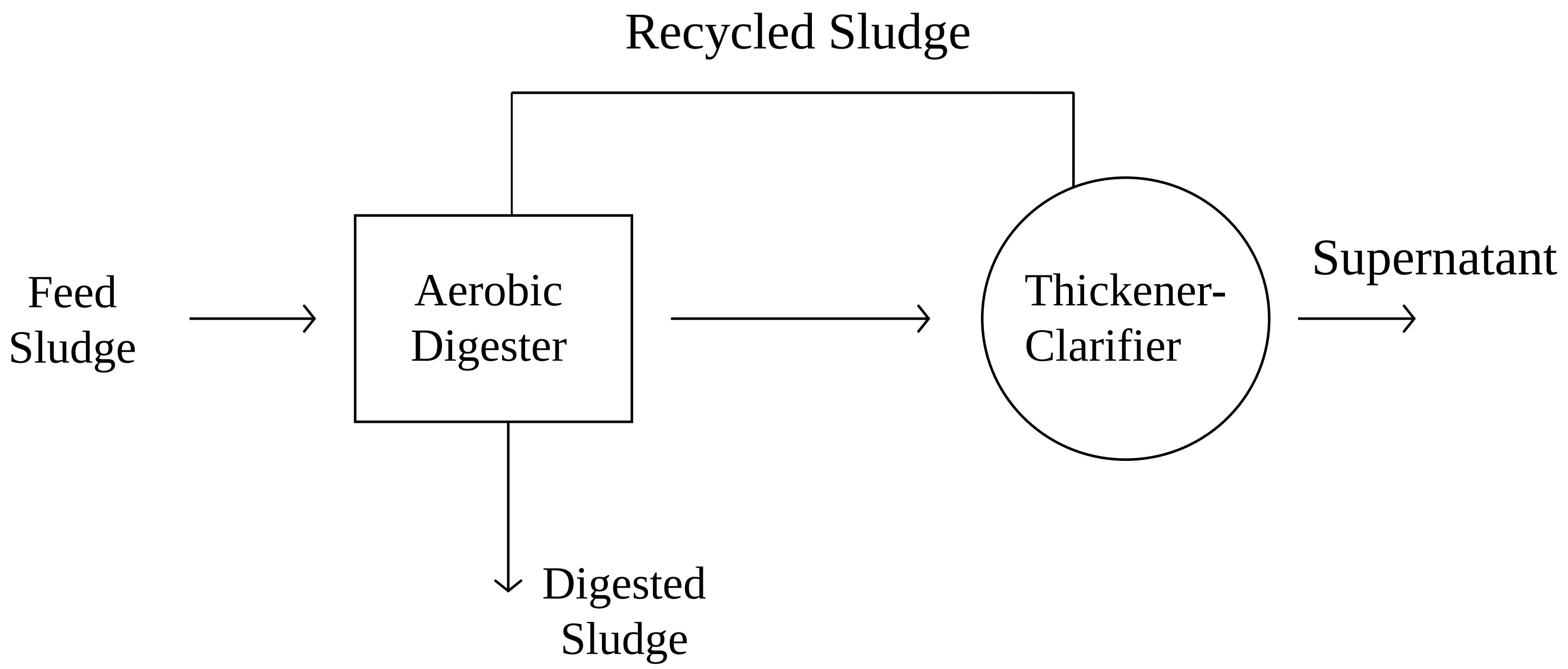
Mixing Requirements Depend On:

- Nature of the sludge
- Solids concentration
- Sludge temperature
- Tank depth

Use of Thickeners-Clarifiers

- Usually placed downstream of digester
- Should be designed for feed sludge plus recycled sludge flow
- Should have capacity to clarify the supernatant liquor and to thicken the settled sludge

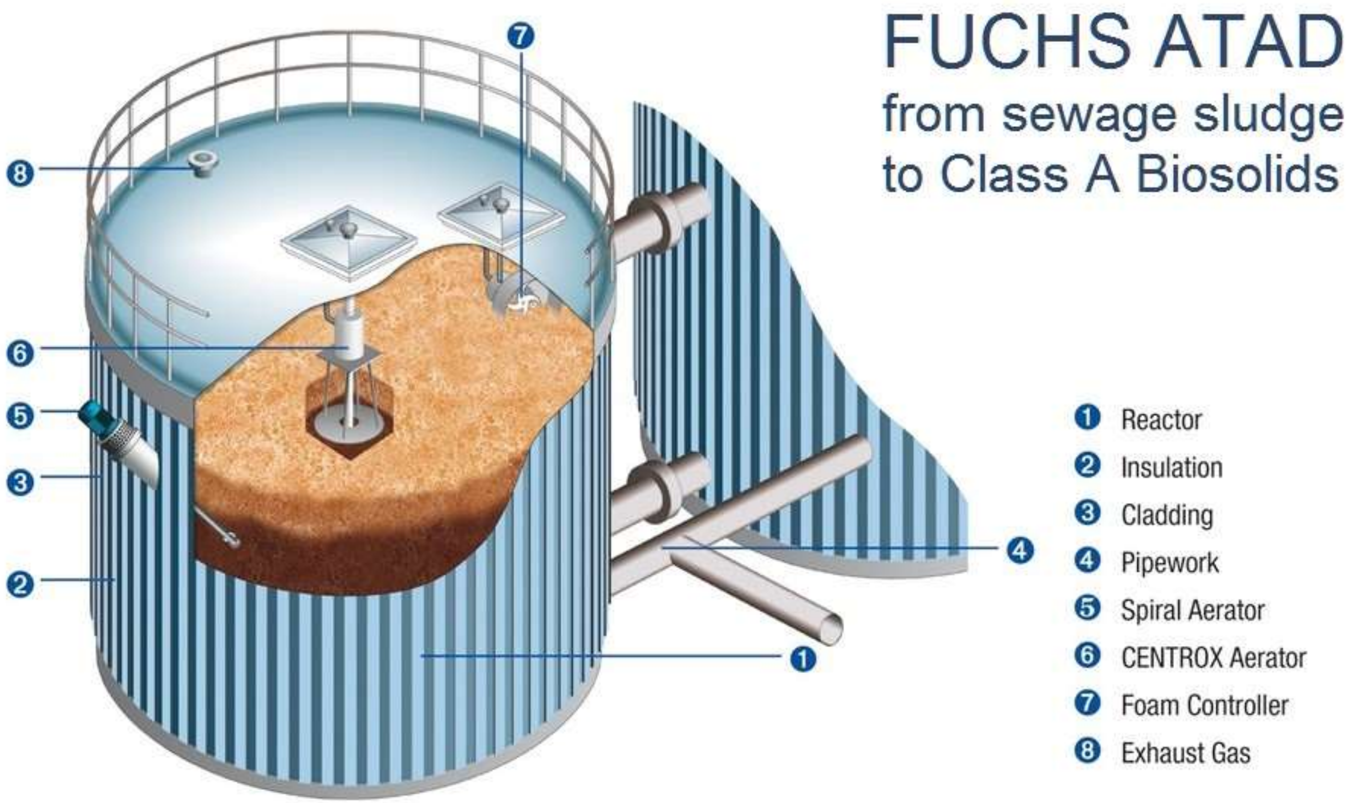
Aerobic Digester with Thickener-Clarifier



ATAD Process

- There is a more advanced aerobic digestion process called *Autothermal Thermophilic Aerobic Digestion*
- ATAD Generally operates at 45-70+ ^{o}C (113-158+ ^{o}F) [i.e., sometimes beyond thermophilic range]
- Essentially pasteurization of sludge
- Very few of these in the U.S. Some in Europe due to stricter requirements for pathogen levels in sludge

FUCHS ATAD System



FUCHS ATAD System

More on ATAD…

- Lower HRT & Higher VSS Reductions achievable
- Robust process but way more complicated to design and operate
- Can achieve 40% VSS reduction in 4-8 days
- 440-640 kWh/Ton TS destroyed [ref: NORAM Bio Systems Inc, 2002]
- Some European utilities are likely really concerned about their energy bills

Aerobic Digester Supernatant Quality

Turbidity	120 NTU
Nitrate-N	40 mg/L
TKN	100 to 1300 mg/L
COD	100 to 25,000 mg/L
PO_4-P	10 to 900 mg/L
BOD_5	10 to 350 mg/L
TSS	100 to 40,000 mg/L
pH	5.7 to 8.0

Advantages of Aerobic Sludge Digestion

- Capital costs lower than anaerobic (Q < 5 mgd)
- Relatively easy to operate
- Does not generate nuisance odors
- Produces supernatant low in BOD, TSS, & NH_3-N
- Reduces quantity of grease in the sludge mass
- Reduces pathogens to low levels

Other Advantages

- Can accept a wide range of waste types with less chance of toxicity (i.e., generally less sensitive to toxicants)
- No gas issue (safer..?)
- No over-pressure concerns
- Likely best without feedstock of high strength organic waste (works good with low substrate levels, too)

Disadvantages of Aerobic Sludge Digestion

- Can produce a digested sludge with poor dewatering characteristics
- Has high power costs to supply O_2
- Significantly influenced by temperature, location, and type of tank design
- Produces no usable by-product such as methane
- More residual sludge to handle
- Possible odors if not operated properly

Common Operating Problems

- Diffusers clogging
- Foaming
- Odors
- Insufficient pathogen control
- Grease buildup
- Digester return overflow
- Settling problems
- Aerator failure ☹