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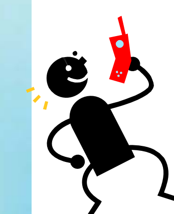
Welcome!

Aerobic Digesters – An Operator's Guide from Design through Operation

We're Glad You're Here!



Please, put your cell phones on vibrate during sessions and, take calls to the hallway

Aerobic Digesters – An Operator's Guide from Design through Operation

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Class Objectives

- Provide a basic understanding of aerobic digestion biological mechanics
- Discuss regulatory requirements for digestion
- Review the engineering design considerations and options for aerobic digestion
- Discuss operations with regard to tankage and troubleshooting

References

- Process Design Manual for Sludge Treatment and Disposal-U.S. Environmental Protection Agency, 1979
- Standard Methods for the Examination of Water and Wastewater, 22nd Edition,2012
- Design Manual-Fine Pore Aeration Systems-U.S. Environmental Protection Agency, 1989
- Biological Process Design for Wastewater Treatment, L. Benefield and C. Randall, 1985
- Aerobic Digestion Workshop. Vol. 1, Enviroquip, Inc, 1997
- Pumping Station Design, 3rd Edition, G. Jones et al. 2008
- Other sources are noted on the slides

Aerobic Digestion

From the U.S. EPA:

Aerobic digestion is the biochemical oxidative stabilization of wastewater sludge in open or closed tanks that are separate from the liquid process system.

- Presence of oxygen
- Absence of food

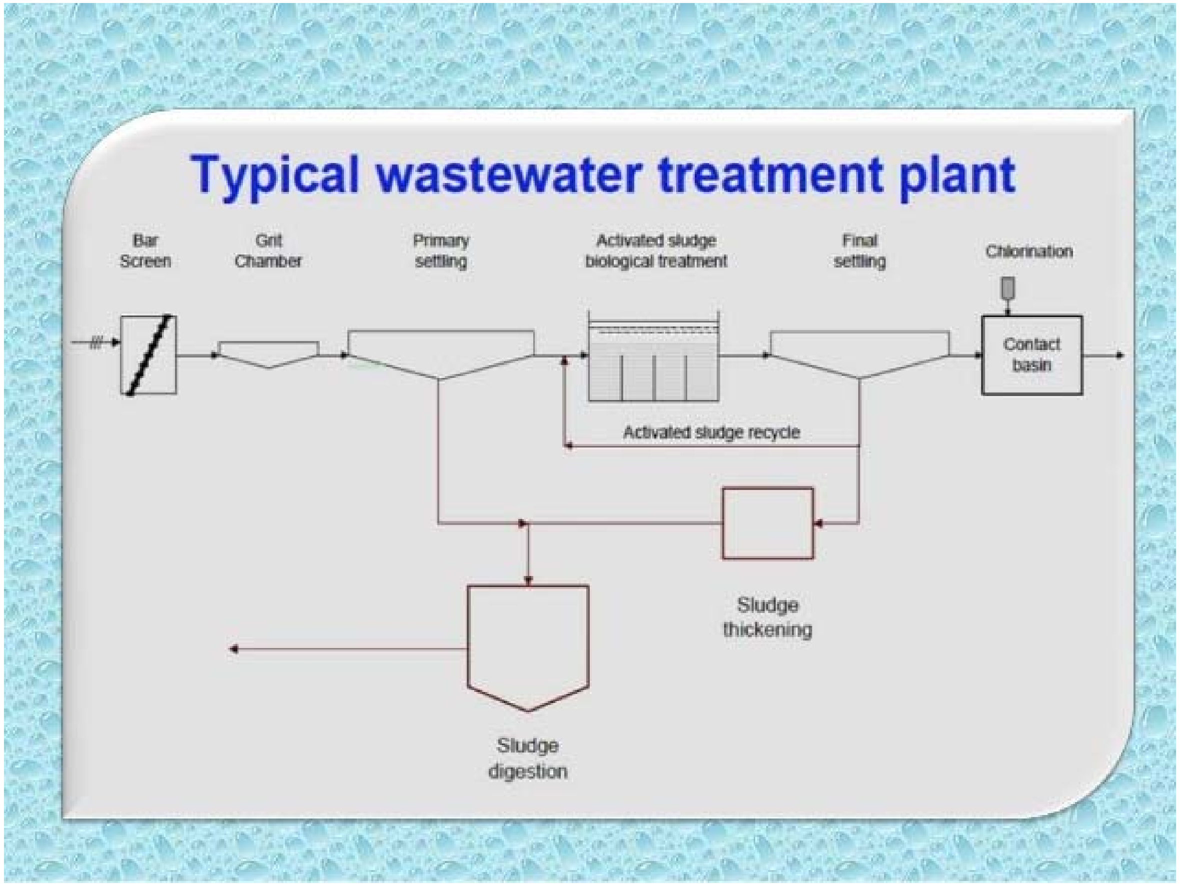
Waste Activated Sludge (WAS)

Biosolids versus Sludge

That mixed liquor that is wasted from an activated sludge system as performed as a process control measure during wastewater treatment.

We will touch on aerobic digestion of primary sludge. However, most of our limited discussion will revolve around WAS.

Process Flow



SOURCE: https://www.slideshare.net/ashishaligarh2010/waste-water-treatment-processes

Total Suspended Solids (TSS)

WHAT IS SLUDGE?

Standard Methods

- Know volume filtered through a 0.45 micron filter
- Dried between 103 °C and 105 °C
- Dried until a relatively constant weight is achieved

Volatile Suspended Solids (VSS)

- Same filter and contents from the TSS test
- Temperature increased to 550 °C for 30 minutes

The difference between TSS and VSS is considered the inert portion. Inert portions do not have any biological use and in most cases do not apply an oxygen demand.

Biosolids

Total Suspended Solids (TSS) versus Volatile Suspended Solids (VSS)

- VSS is considered the biosolids portion
- VSS is a subset of TSS
- TSS includes inerts (cellulose, plastics, stone, etc.)
- Some of the VSS is not degradable (30%) “BUG BONES”
- Some of the TSS is soluble or will become soluble during digestion
- Biosolids are typically 70 to 80% VSS

In order to keep this more approachable we will limit our discussion to TSS and VSS.

Endogenous Respiration

Big Words: Simple Concept

$$\text{Cellular Material} + O_2 \xrightarrow{\text{BACTERIA}} \text{Digested Sludge} + CO_2 + H_2O$$

- Limited food
- Death and dying
- Cannibalization
- Extracellular enzymes

Digestion Equation

Total Solids = NDSS + DVSS * e^{-kt}

Where:

NDSS = Non-Degradable Solids

DVSS = The Degradable portion of the VSS

e = Natural Log = 2.72

K = The rate of decay (day^{-1})

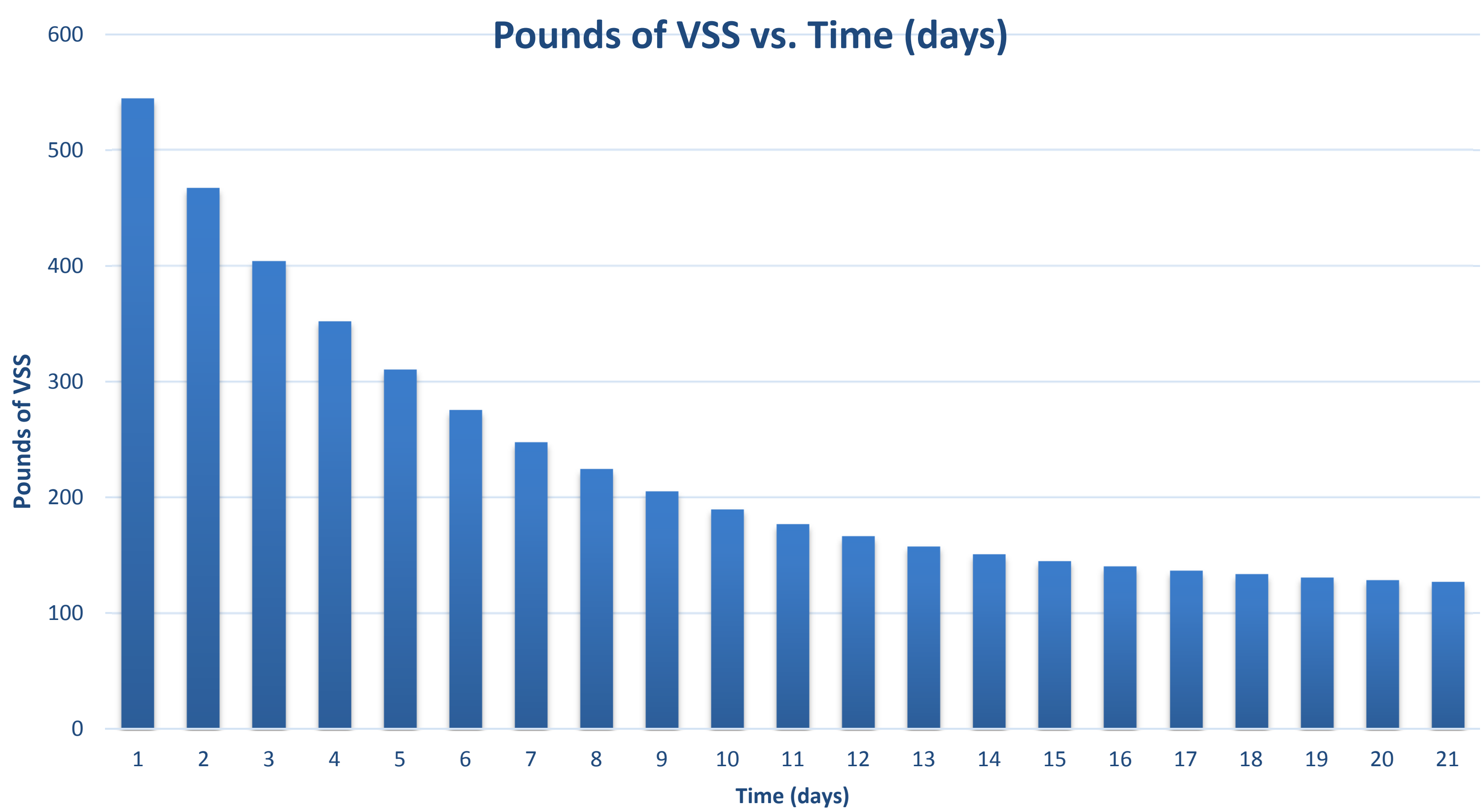
t = Time (day)

Decay

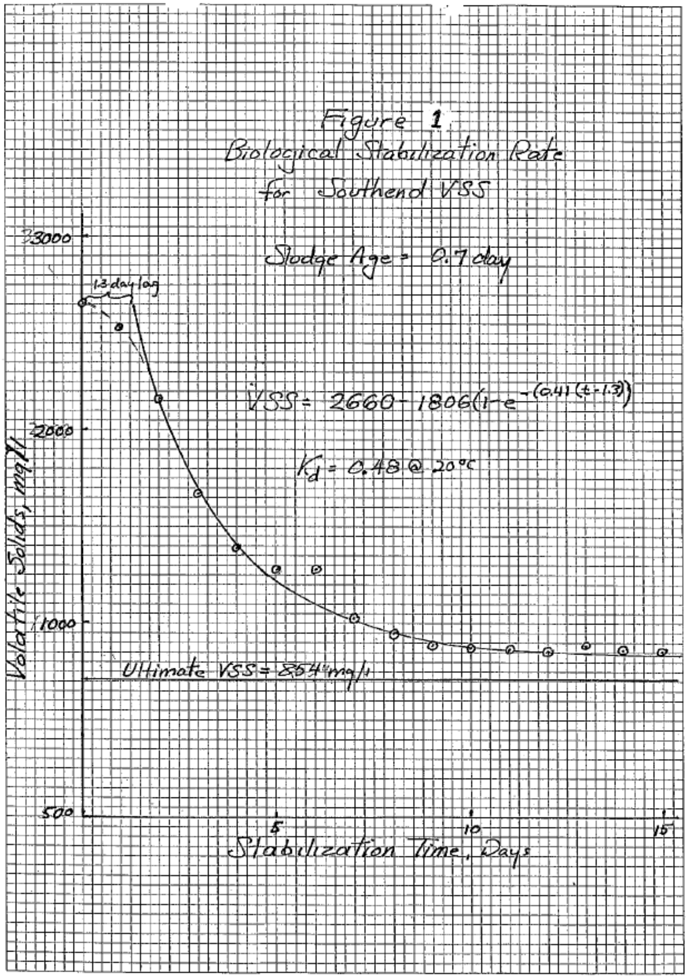
The following two slides are description of the decay of sludge under aeration when no new additional sludge is introduced to the reactor.

WHY IS THIS IMPORTANT TO UNDERSTAND?

Decay of VSS in a Digester



VSS Decay



SOURCE: Vernon Stack, P.E.

VSS Decay

- New sludge shows the greatest reduction in VSS (Day 1 through 5)
- This higher rate of destruction requires the highest amount of oxygen
- There is a lull between the first and second day (impacts oxygen demand if not considered)

Decay of VSS in a Digester

- The rate of decay is exponential
- The majority of the decay occurs over the first 10 days
- The rate can be tested in a lab (fish tank test)
- Lab results are ideal conditions and do not resemble field results
- Constant temperature and constant aeration (no decanting)

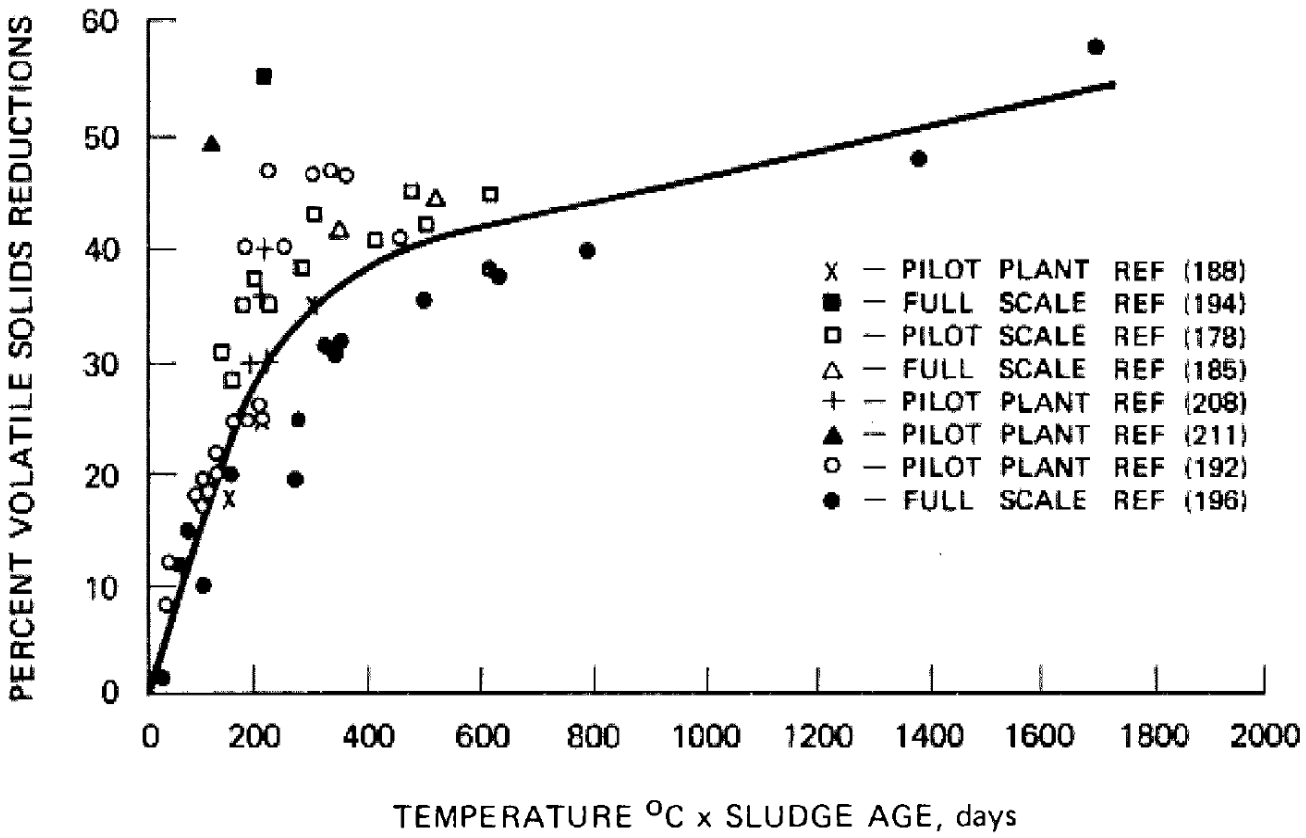
Solids Retention Time (SRT)

SRT is used to mathematically describe the average time (days) that a microbial will inhabit the digester.

The simplified way to calculate SRT is:

$$SRT = \frac{\text{TOTAL SOLIDS RETAINED IN THE DIGESTER}}{\text{SOLIDS LEAVING THE DIGESTER}}$$

Decay of VSS



SOURCE: U.S. EPA

Decay of VSS

Meaning of the graph

- VSS destruction is the product of both temperature and SRT
- VSS destruction at an SRT of 20 days at 20 C = 40 days at 10 C

  Enables you to estimate the effects of temperature during design
- At 500 days *C the increase in destruction is limited

HOW LONG AND AT WHAT TEMPERATURE DO YOU DO YOUR COOKING?

Digester Bacteria

Mesophilic bacteria (Goldy Locks) is an organism that grows best in moderate temperature, neither too hot nor too cold, typically between 20 and 45 °C.

Thermophilic Bacteria is an organism that thrives at relatively high temperatures, between 41 and 122 °C.

(NOTE: Thermophilic ranges are beyond the suitable environment for nitrifiers.)

Primary Solids

- Wasted from primary clarifiers
- Can have a high organic component
- Large amount of grit
- Increases the oxygen demand when wasted to the digester
- More contemporary approach to complete in two separate steps; screening and grit removal

Grit

- Can ultimately end up in your digester unless consideration is given in design
- Can take away needed digester capacity
- Can act as an abrasive on internal piping, valves and diffusers

Aerobic Digestion – Advantages

- Relatively easy to operate in comparison to an anaerobic digester
- Less chance of blowing up (methane)
- Lower construction costs
- Supernatant is easier to treat
- Less odor issues
- Pathogen destruction
- Typically installed in plants less than 1.0 mgd

Aerobic Digestion – Disadvantages

- High energy costs for aeration
- Sludge can be difficult to dewater
- Sensitive to temperature and pH
- Alkalinity can impact performance

Aerobic Digester Design

- Loading
- Regulatory Requirements
- Tank Design
- Aeration Design
- Thickening
- Support Equipment
- Instrument and Controls

Loading Design Basis

- Predicting Loading (Full versus Start Up conditions)
- Temperature Conditions
- Expected pH and Alkalinity
- Percent Solids (Worse Case versus Actual)

Predicting Loading

- Difficult for new plants
- Easier for plants with existing data
- Typically based on yields from organic loading
- COD and BOD used to approximate organic loading
- Most methods account for influent TSS as a base load
- Solubility can play a role (Municipal versus Industrial)
- Computer modeling is an additional source

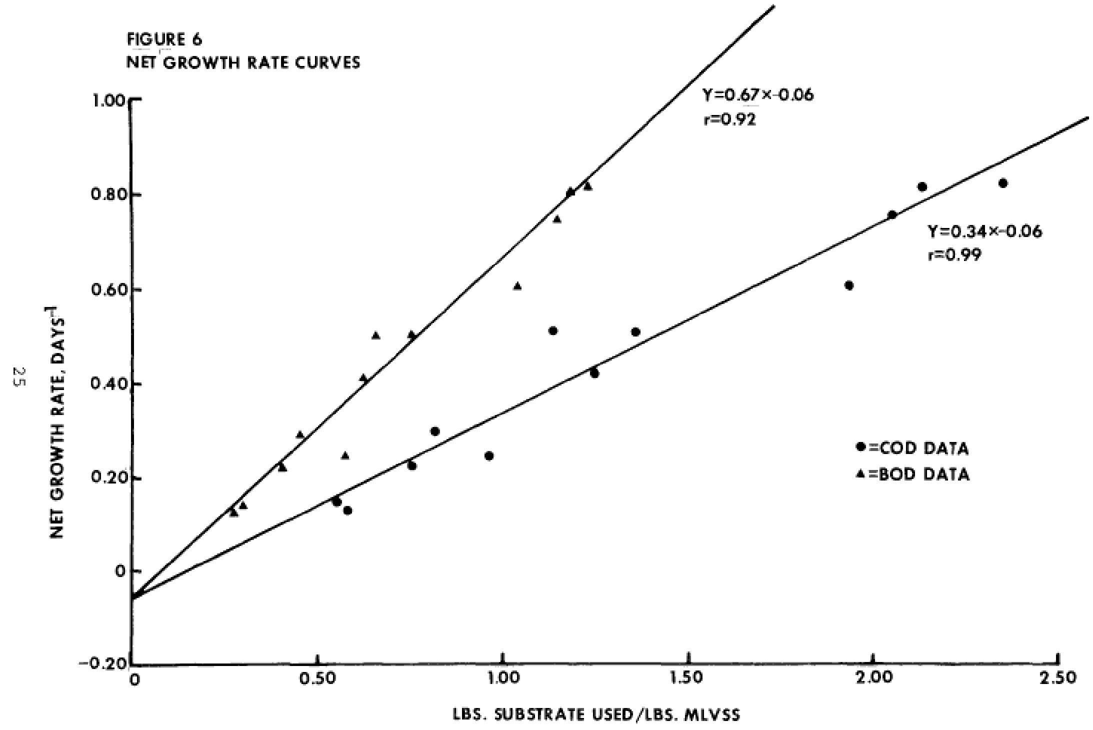
Predicting Loading

Unlike other treatment process units which are designed to meet short term peak events, solids handling equipment is designed to handle long term averages.

Solids generation reacts slowly over time.

Most sizing is completed using a ratio between BOD, COD or TSS to pound of biosolids created.

Example of a Predictive Methodology



SOURCE: U.S. EPA

What does the graph show?

- Loading is correlated to organic loading
- Loading is a function of F/M
    - More food = More Biomass
    - Fully loaded plant versus start up conditions
- COD is a better predictor to biomass production than BOD

DO YOU TRACK YOUR OWN YIELD?

Temperature

- High temperature increases rates of decay
- Low temperature decreases rates of decay
- High temperatures increase sludge production
- Low temperatures decreases sludge production
- Oxygen transfer is harder at high temperatures
- Oxygen transfer is easier at low temperatures

WHAT DOES THIS MEAN:

1. High temperatures mean you are generating and destroying more solids. YOU NEED MORE AIR
2. Cold temperatures mean you are generating less and destroying less. YOU NEED A BIGGER TANK

pH and Alkalinity

pH and alkalinity are not the same thing.

- In simple terms, pH is the punch and alkalinity is the ability to take the punch.

pH

- Nitrification can occur during digestion
- Nitrification will lower alkalinity and pH
- General guidance suggests that a pH lower than 6.8 can start to inhibit digestion
- As pH decreases so does destruction rate
- Low pH sludges can be more difficult to dewater
- Several studies show that pH control can make the digestion process more efficient
- By controlling pH you have the opportunity to lower nitrogen in the sludge thus enabling a greater land application rate

Alkalinity

- Decreases during nitrification during digestion
- High Dissolved Oxygen (DO) promotes low alkalinity
- Low DO can set an environment for the return of alkalinity through denitrification
- ON-OFF-ON-OFF can balance alkalinity
- Alkalinity creates a stable biological community

QUIZ NO. 1 and 10 minute break

Please complete Quiz No. 1

Percent Solids and Thickening

BASICS:

1,000,000 mg/L = 100 %

500,000 mg/L = 50 %

30,000 mg/L = 3.0 %

15,000 mg/L = 1.5 %

Thickening

- We are going to assume that the TSS and VSS have the same specific gravity as water.
- In other words, 1 liter of pure TSS weighs the same as a liter of water.

Thickening

Let us assume we have:

0.100 million gallons of 1.5 % sludge

We thicken the sludge to 3.0%

How many gallons do we have remaining

(NOTE: The thickening process only removes water (wink))

Thickening

0.100 million gal. * 8.34 * 15,000 mg/L =

12,510 Pounds of TSS

Now thickening to 3.0 percent or 30,000 mg/L we reverse the process:

X million gal. * 8.34 * 30,000 mg/L = 12,510 Pounds of TSS

Solving for X = 0.050 million gallons

Question-Discussion

Does thickening improve dewatering efficiency?

If you thicken from 1% to 2% does your dewatered sludge go from 16% to 20%? Or is it simply a 16% to 17% increase?

Solids Retention Time (SRT)

SRT is used to mathematically describe the average time (days) that a microbial will inhabit the digester.

The simplified way to calculate SRT is:

SRT =

SRT

What is the significance of SRT:

- It shows the age of the sludge.
- Older sludge generally means greater pathogen reduction.
- Older Sludge means greater VSS destruction.
- SRT is a regulated design parameter

Regulatory Design Requirements – PA DEP

From the Domestic Wastewater Facilities Manual 10/97

- DO concentration must be kept between 1.0 and 2.0 mg/L
- Supply 30 SCFM/1,000 CF
- Mechanical aeration shall provide 1.0 hp per 1,000 CF

Regulatory Design Requirements – PA DEP

- It is recommended that VSS loading not exceed 100 pounds per 1,000 CF per day
- SRT normally shall be a minimum of 15 days
- SRT for combined primary sludge and WAS is recommended to be 20 days

Regulatory Design Requirements – PA DEP

DOES PA DEP REQUIRE THAT ALL PLANTS HAVE DIGESTION CAPABILITIES?

Regulatory Design Requirements – 10 State Standards

The following discussion is presented as a comparison in regulatory requirements.

- Multiple digesters designed for independent operation for facilities greater than 0.100 mgd
- Typical volume requirement is based roughly on 3.0 CF per Population Equivalent (extended aeration)
- SRT = 27 days

Regulatory Design Requirements – 10 State Standards

- Aeration and mixing are the same as PA DEP requirements with the exception being redundancy for the blowers
- Sludge storage and holding is based on 2.0 % solids concentration

In general terms, the 10 State Standards appear to apply more structure to values used in sizing.

40 CFR 503 Standards for the Use or Disposal of Sewage Sludge

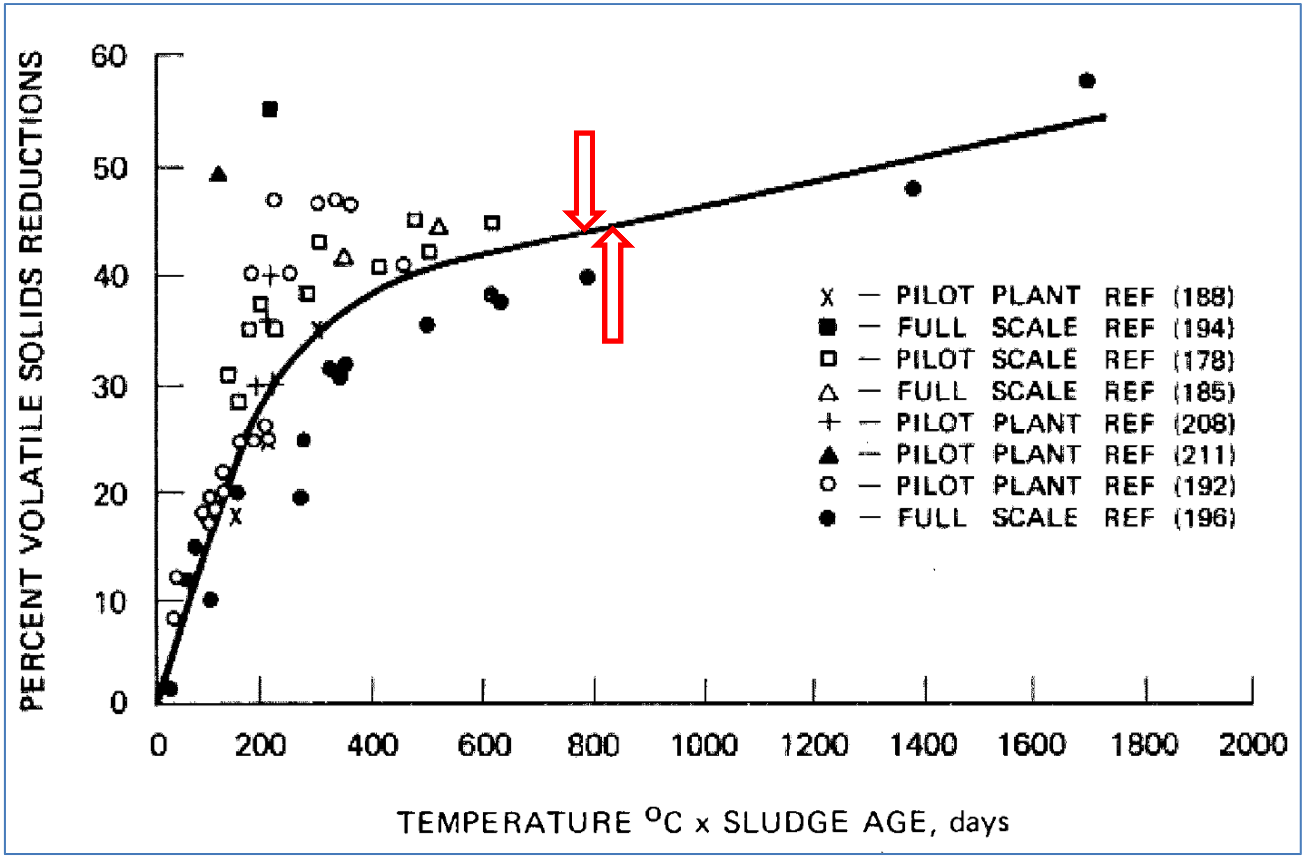
- These are comprehensive standards for all sewage sludge that would be basically land applied.
- Class A is the higher quality sludge with minimal limits on where it can be applied. Aerobic digestion does not typically meet the processing specification for Class A.
- Class B is a lesser quality but still can be land applied.
- Aerobic digestion can achieve Class B designation.

40 CFR 503 Design Implications

- Must achieve an SRT of 40 days at 20 C and 60 days at 15 C.
- VSS destruction must be 38% or greater.

There are other secondary items that can be done to achieve Class B status. However, these are the specific items that can be included in a design.

40 CFR 503 Design Implications



Tank Design

Geometry Considerations

- Depth - Sufficient for oxygen transfer (Greater than 10 feet deep)
- Rectangular versus Circular

Rectangular

Advantages:

- Common wall construction
- Better use of space
- Ease of fabrication
- Efficient diffuser layout

Disadvantages

- Corner filleting or “dead spots”
- Limited mixing methods

Rectangular Tank with Diffused Aeration

Circular

Advantages:

- Steel tank construction
- Multiple modes of mixing and aeration

Disadvantages

- Less efficient use of space

Circular Tank with Surface Aeration

SOURCE:http://blogs.nicholas.duke.edu/fuelforthought/the-wastewater-cycle/

Tank Sizing

Typically based upon:

- SRT (PA DEP 15 days)
- Cold weather destruction rates
- Minimum thickness (typically less than 1.5 % solids)

Typical Means of Aeration

- Surface Aeration
- Diffused Air
- Other Systems

Surface Aeration

SOURCE: https://www.enviropro.co.uk/entry/39029/Spaans-Babcock/O2-Max-surface-aerators/

SOURCE: https://www.indiamart.com/proddetail/fixed-type-surface-aerator-4584867688.html

Surface Aeration

In most contemporary designs, surface aeration for digestion is not the normal selection.

- Less efficient oxygen transfer
- Typically requires round tanks (not always)
- Needs to be on floats
- Electro/mechanical items are floating in the digester

Diffused Air

- Most typical form of aeration for digestion
- In most plant (up to 1.0 mgd) coarse bubble is the most prevalent form of aeration
- Fine bubble and membrane have been experimented with over time (results have been mixed)
- For aerobic digestion it must be understood that the level will vary and the aeration can be turned off for periods of time that allow solids to settle on the diffuser

Derivatives of Aeration

- Intent is to show basic aeration modes
- Many manufacturers have derivatives of the aeration process
- Classes of diffusers that are a cross between fine pore and coarse bubble aeration
- These achieve higher oxygen transfer and withstand rough digester conditions.

Coarse Bubble Design Considerations

- Most designs favor some use of coarse bubble aeration
- Transfer efficiency usually falls between 10 and 20 %
- As depth increases so does transfer efficiency
- Transfer efficiency rule of thumb is 1% increase per foot of depth
- Coarse bubble diffuser less susceptible to fouling
- In most cases the pressure drop across a coarse bubble diffuser is less significant than for fine bubble

Coarse Bubble Diffuser

SOURCE: https://www.xylem.com/en-us/products-services/treatment-products-systems/aeration-equipment/coarse-bubble-aeration

SOURCE: http://www.scogen.in/aeration-products.php

Diffuser Layout

QUIZ No. 2 and 10 minute break

Please complete Quiz No. 2.

Blower Selection

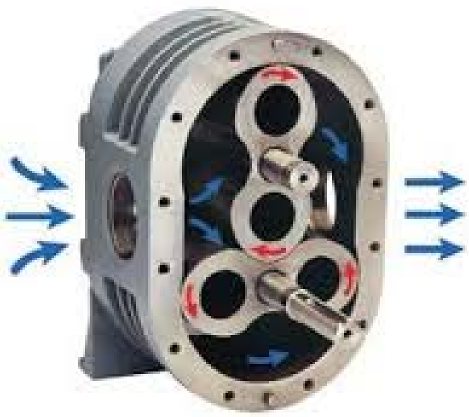
- Mixing versus aeration (discussed later)
- Positive displacement versus centrifugal

Blower Selection

Digester demands are different than biological reactor needs.

- Varying water levels
- Higher temperatures
- More susceptible to fouling
- Pressure varies greatly

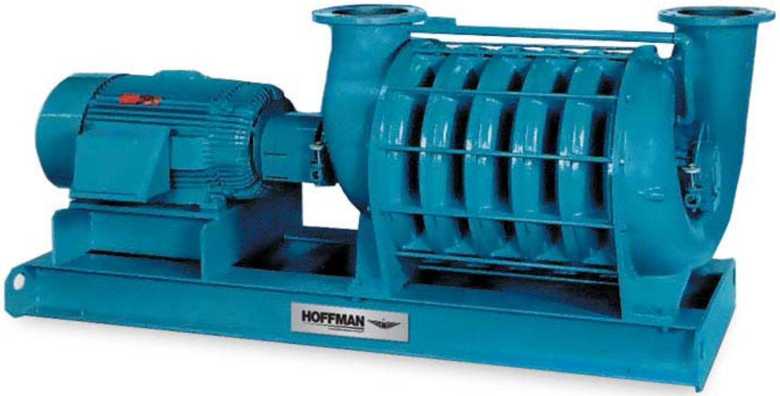
Positive Displacement Blowers

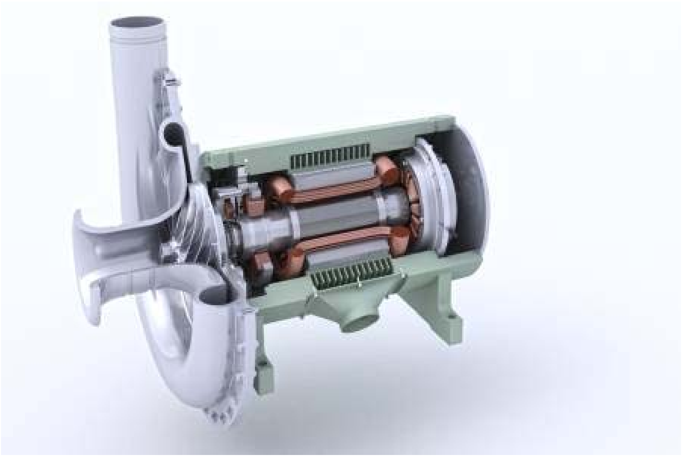


SOURCE: http://www.steam-brite.com/gardner-denver-sutorbilt-legend-truck-mount-vacuum-blower-pump

SOURCE: http://www.powderbulksolids.com/article/low-pulse-twisted-lobe-blowers-0

Centrifugal Blowers





SOURCE: https://www.wateronline.com/doc/skf-solutions-for-aeration-blower-system-cuts-energy-costs-by-up-to-0001

SOURCE: http://gardnerdenver.co.in/products/blowers-vacuum-pumps/multi-stage-centrifugal

Blower Selection

- There are many different forms of the PD and the centrifugal blowers
- For the purposes of this class we are sticking to the basic forms
- Larger applications require different considerations

Blower Selection

Centrifugal

- More efficient with larger volumes of air
- Can be throttled by simple intake control valving
- Can have problems with varying pressure
- Less noise than a PD blower

Blower Selection

Positive Displacement

- More efficient with lower flow rates
- Throttling is more efficient with a VFD
- Constant flow at varying pressures
- Less costly than centrifugal
- Noisy
- Typically seen for facilities less than 1.0 mgd

Aeration versus Mixing

Aeration is designed to support the digestion process with enough oxygen to complete biological reactions.

- Typically 2.0 lbs of Oxygen required per lb of VSS destroyed
- Design values range from 1.8 to 2.3 lbs of Oxygen per lb of VSS destroyed
- Nitrification needs push to the higher values
- High temperature digestion requires less oxygen because nitrifying bacteria are not present

Aeration Design

- Aeration design should be based around summer conditions
- Highest sludge production
- Highest potential destruction rate
- Worst oxygen transfer environment
- Dissolved oxygen concentrations greater than 1.0 mg/l at extreme loading

Mixing

Mixing is meant to keep the biosolids in suspension in order to promote better contact with the active cells and eliminate "dead spots" within a tank.

Dead spots create areas within the digester lacking oxygen. This environment has the potential of fostering differing bacteria cultures. These areas can produce byproducts that may inhibit the digestion process.

Mixing

- Regulatory requirement of 30 SCFM/1,000 CF
- Decent basis overall but does not account for geometry
- Wide and long versus square and deep

Mixing Comparison

Mixing Example:

Tank 1: 10’ long by 10’ wide by 10’ deep = 1,000 CF

Tank 2: 40’ long by 5’ wide by 5’ deep = 1,000 CF

Assume both tanks are aerated at 30 SCFM

Tank 1 is mixed based on 30 SCFM/100 SF of floor or 0.30 SCFM/SF

Tank 2 is mixed based on 30 SCFM/200 SF of floor or 0.15 SCFM/SF

WHICH IS THE BETTER MIXED TANK?

0.40 SCFM/SF has been applied with success in the past.

Thickening

- Large movement towards thicker sludges in the digester (> 2.0 %)
- Can minimize tank sizing
- MAY increase SRT
- Saves on construction costs
- Can give the operator some operational flexibility

Thickening

- Requires vigilant decanting
- Decanting requires settling
- Decanting can remove warm water and replace with cold
- Settling occurs only when air is off

Thickening

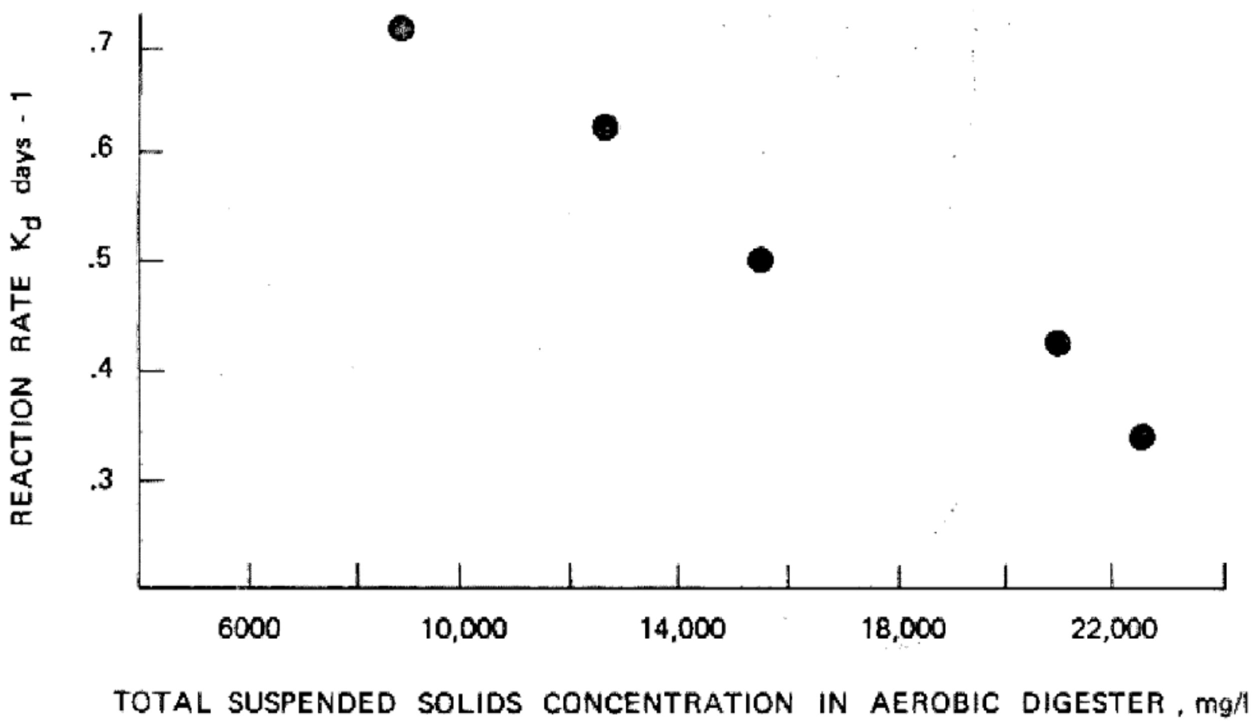
- VSS destruction is highest when sufficient oxygen is present
- Rates of destruction are potentially decreased
- Current thinking is that beneficial extra cellular components (enzymes) are eliminated during the decant process

Thickening and Energy

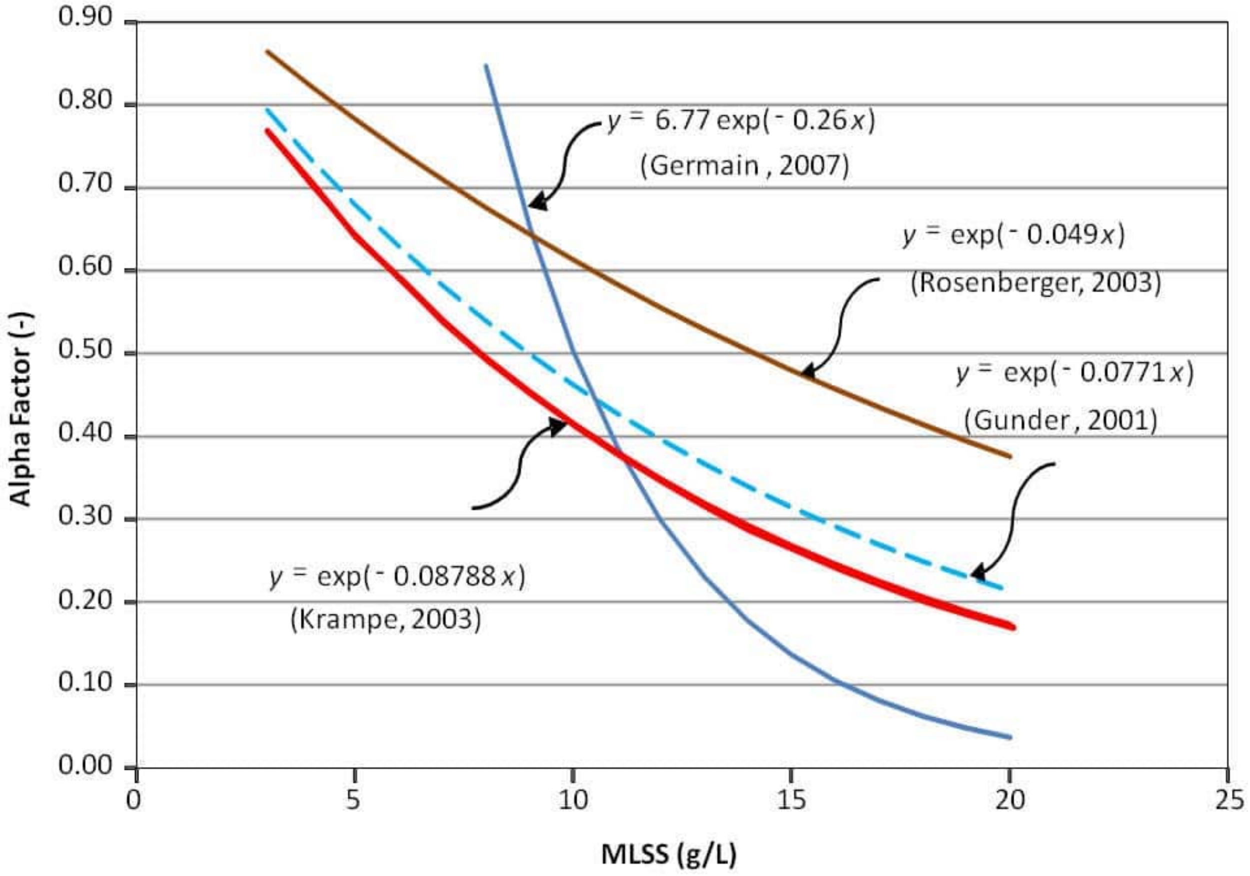
- Can decrease temperatures through decanting
- Mixing is more difficult
- Aeration is significantly impacted by as much as 60%

  (SEE SLIDE ON ALPHA)
- Depending on the consistency of the concentration operational performance and destruction rates can vary widely
- Single tank digestion is more subject to these type of operations

Decreased Destruction Rate of VSS



Thickening versus Aeration Demand



SOURCE: http://onlinembr.info/mbr-design/mlss-and-viscosity/

Thickening versus Digestion

DO THICKENING AND DIGESTION HAVE DIVERGING GOALS?

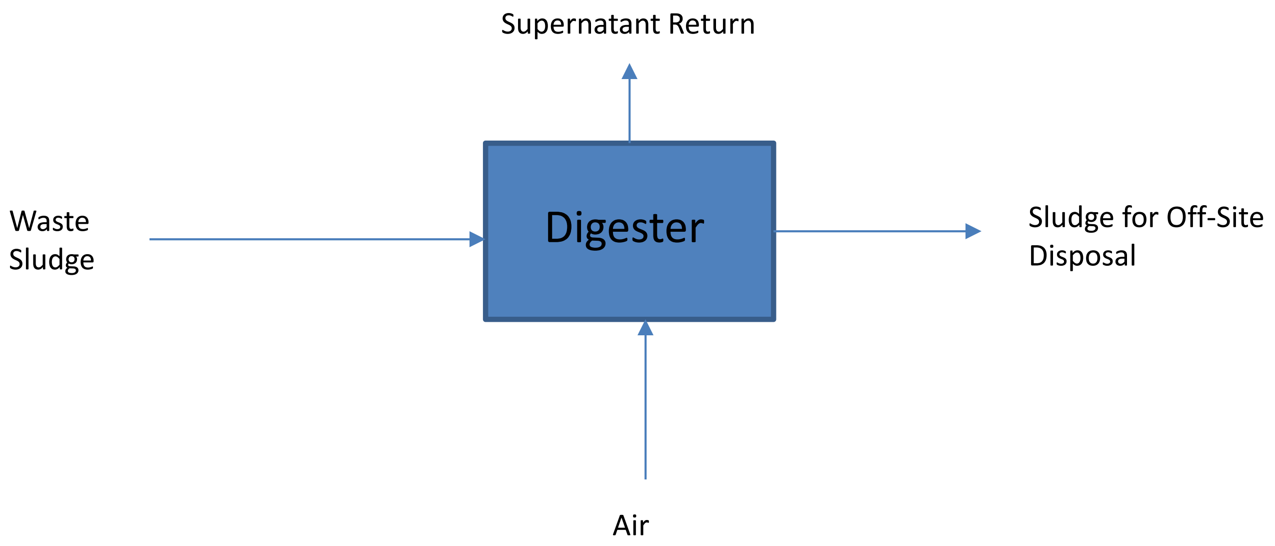
THICKER: SMALLER TANKS AND MORE ENERGY

THINNER: BIGGER TANKS AND LESS OVERALL ENERGY

Tank Configurations

- Single Tank System
- Two Tanks in Parallel
- Two Tanks in Series
- Two Tanks in Series with Intermediate Thickening

Single Tank System



Single Tank System

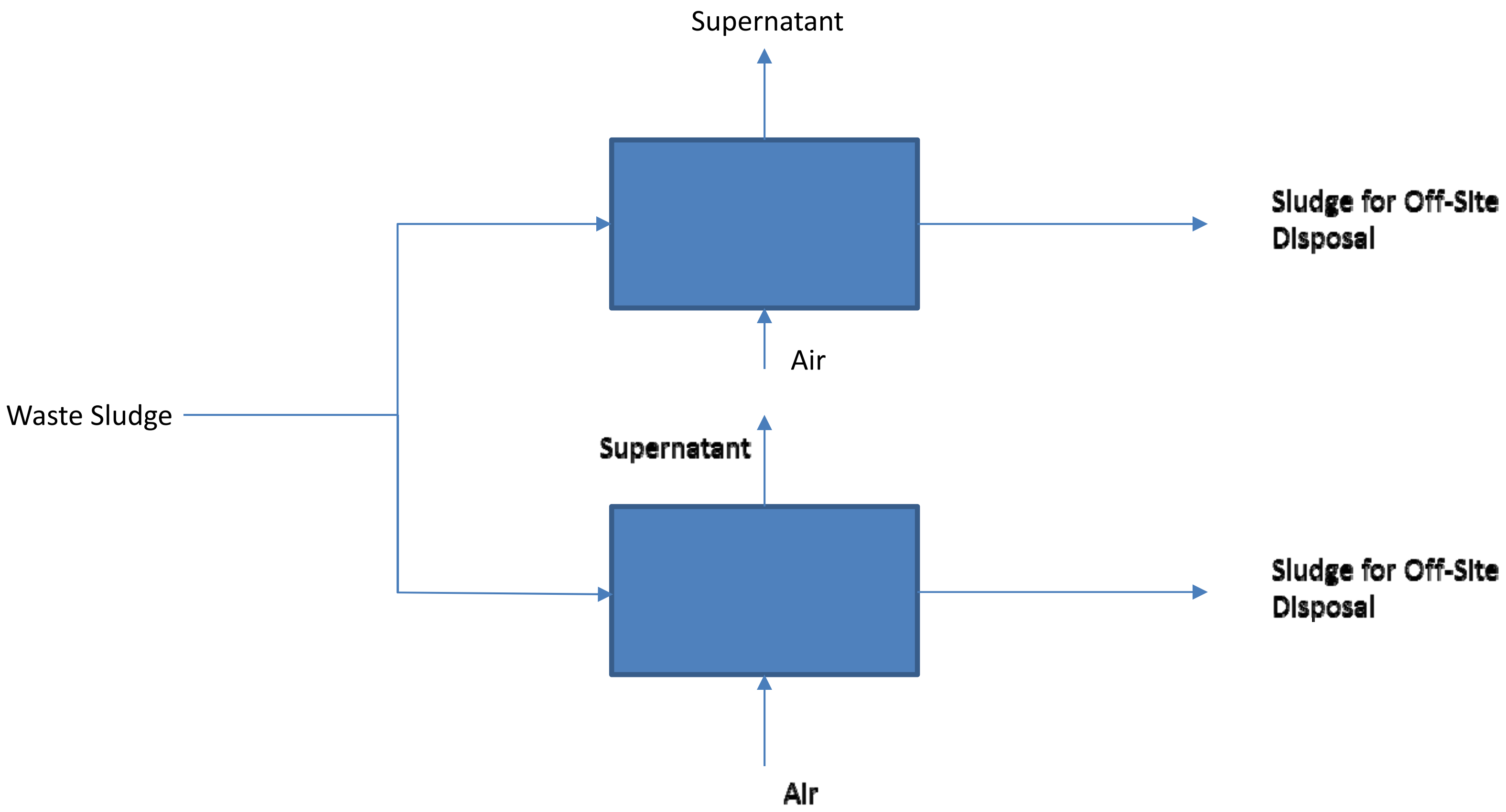
Advantages

- Lower construction costs
- Ease of operations

Disadvantages

- Thickening and digestion have to occur in the same tank
- Decanting is a regular occurrence
- Can be space limited

Two Tanks in Parallel



Two Tanks in Parallel

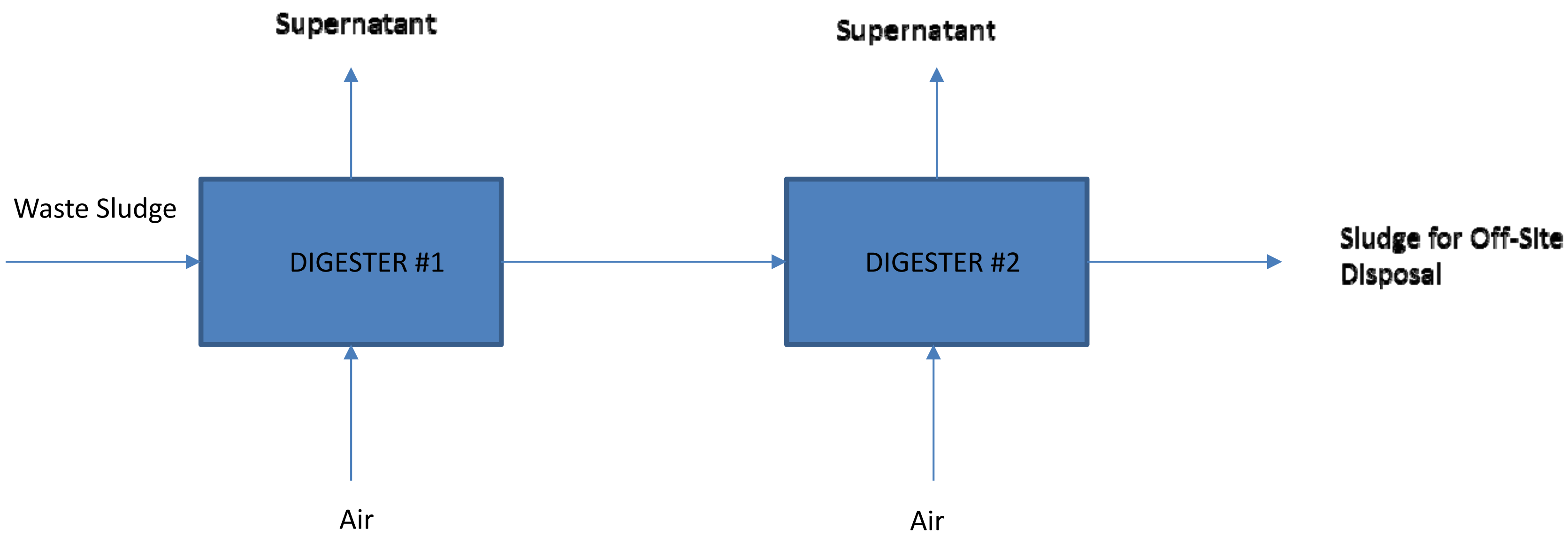
Advantages

- Longer stretches for aeration
- Greater flexibility
- Usually has more space available as part of the design

Disadvantages

- More complex and costly to construct
- Still thickening in the same tank
- Twice the equipment to maintain

Two Tanks in Series



Two Tanks in Series

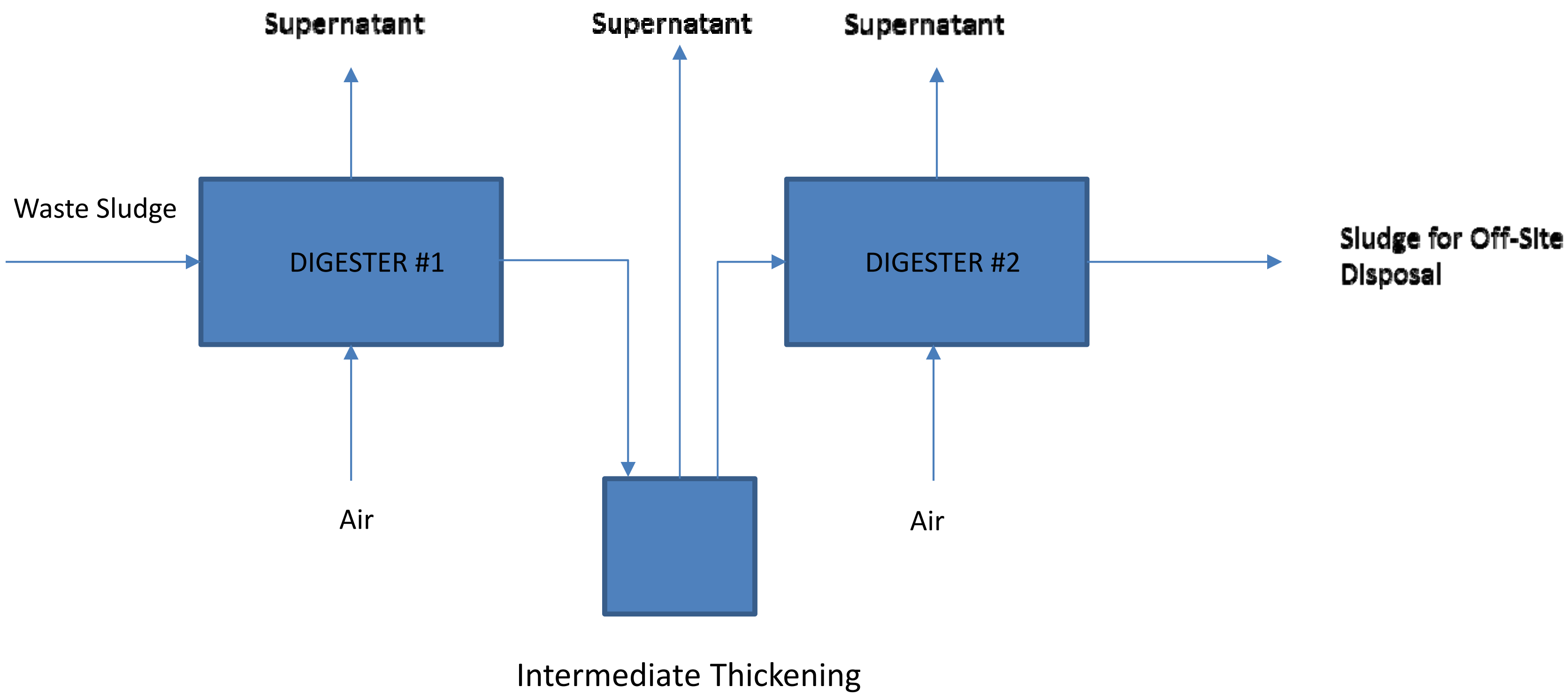
Advantages

- Can separate digestion from thickening
- Potential for increased VSS destruction
- Can maintain a consistent solids concentration = consistent DO level
- Can operate the first tank as a simple flow through reactor
- Easier to maintain consistent conditions in the first tank (level, temp, pH and aeration)

Disadvantages

- Potentially higher construction costs
- May require a large first tank
- Dissimilar size tanks will not be interchangeable
- Can be more complex to operate
- Aeration demands between tanks is unbalanced
- Unbalanced aeration can affect blower selection (non-identical blowers)

Two Tanks in Series with Intermediate Thickening



Two Tanks in Series with Intermediate Thickening

Advantages

- Can separate digestion from thickening
- Potential for increased VSS destruction
- Can operate the first tank as a simple flow through reactor
- Easier to maintain consistent conditions in the first tank (level, temp, pH and aeration)
- Can shrink the size of the second tank

Disadvantages

- Higher construction costs (thickening equipment)
- May require a large first tank
- Dissimilar size tanks will not be interchangable
- Will be more complex to operate
- Aeration demands between tanks is unbalanced
- Unbalanced aeration can affect blower selection (non-identical blowers)
- Thickening operations can be labor intensive

Tank Usage

- If possible separate thickening and digestion
- Varying solids concentration greatly impacts oxygen transfer
- Constant aeration will facilitate better destruction
- Consider larger tanks in lieu of larger blowers
- The more tanks you have the more operational flexibility you have

Troubleshooting Discussion

- Poor VSS Destruction
- Odor Issues
- Poor Settling

Most aerobic digester problems can be traced back to volume, aeration capacity and alkalinity.

Digestion Accessory Equipment

- Piping
- Valves
- Air Piping
- Covers
- Decanters
- Instrumentation

Piping

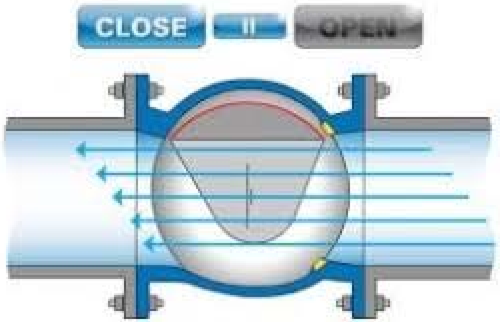
- Pipe selection is based on maintaining a fluid velocity of 2.0 fps to minimize settling in the pipe
- Pipe interior should be smooth to avoid sludge adherence and build up
- Ductile iron pipe (Class 52 or 53) glass lined (ESPECIALLY UNDER TANKS AND CLARIFIERS)
- SDR 21 PVC piping
- HDPE? and/or special lining?

Valves

- Plug valve is the most utilized valve on solids handling
- Plug is ¼ turn nearly full port
- Solids are not readily captured in the seating
- Resilient seated gates are sometimes applied
- Solids can settle in a gate seat
- Consideration when mounting in the vertical

Plug Valve

SOURCE: https://azvalves.com/product-overview/lined-plug-valves/iso-standard-ca/



SOURCE: http://www.dezurik.com/products/product-line/plug-valves/eccentric-plug-valves-pec-pef/1/115/

Gate Valve

SOURCE: https://www.indiamart.com/proddetail/resilient-seated-gate-valve-15203825848.html

Air Piping

- Growing use of stainless steel schedule 10s
- Similar pricing to DIP
- DIP
- High temperature gaskets (i.e. viton)
- Fiberglass
- Careful using CPVC and PVC

Covers

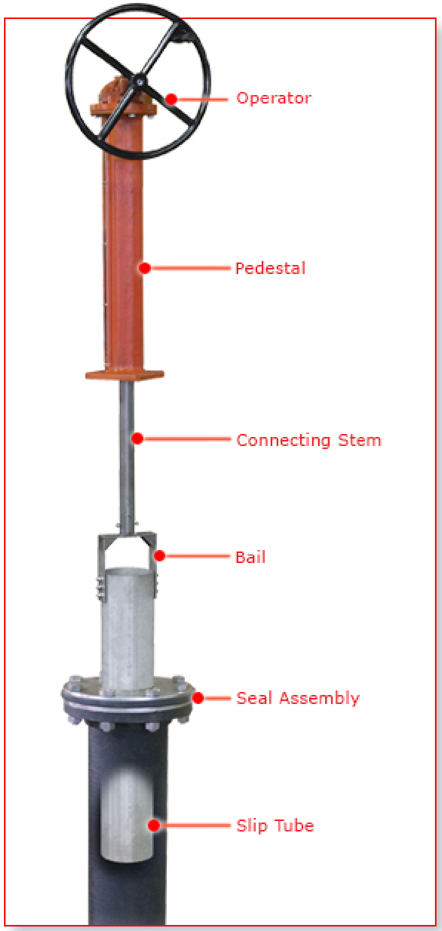
- Keep consistent environment and increase VSS destruction through the winter (considerable benefit)
- Can create thermophilic conditions in the summer
- Depending on the type of cover they can significantly increase the cost of construction

Decanters

Most common methods of decanting include telescoping valves and swivel joint-type decanters.

- Telescoping are more expensive but can be automated
- Swivel less expensive but labor intensive

Decanters



SOURCE: http://watermanusa.com/products/water-treatment-specialties/telescoping-valves

SOURCE: http://www.trumbull-mfg.com/products/valves-valve-accessories-treatment-plant-products/telescoping-valves/

Decanter

SOURCE: http://www.heumannenviro.com/portfolio/hec-decanter/

Instrumentation

Aerobic digestion has seen an increase in instrumentation

Most common forms of instrumentation:

- D.O. probe-proportional response
- pH probe-nitrification/denitrification
- Temperature-historical recording
- Orp-not as popular but used

Most instrumentation used to control blowers

Thank You and Questions

Questions?

QUIZ No. 3

Please complete Quiz No. 3.

Thank You!

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