Conventional Aerobic Digestion – the Basic Process

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MWH

OUTLINE

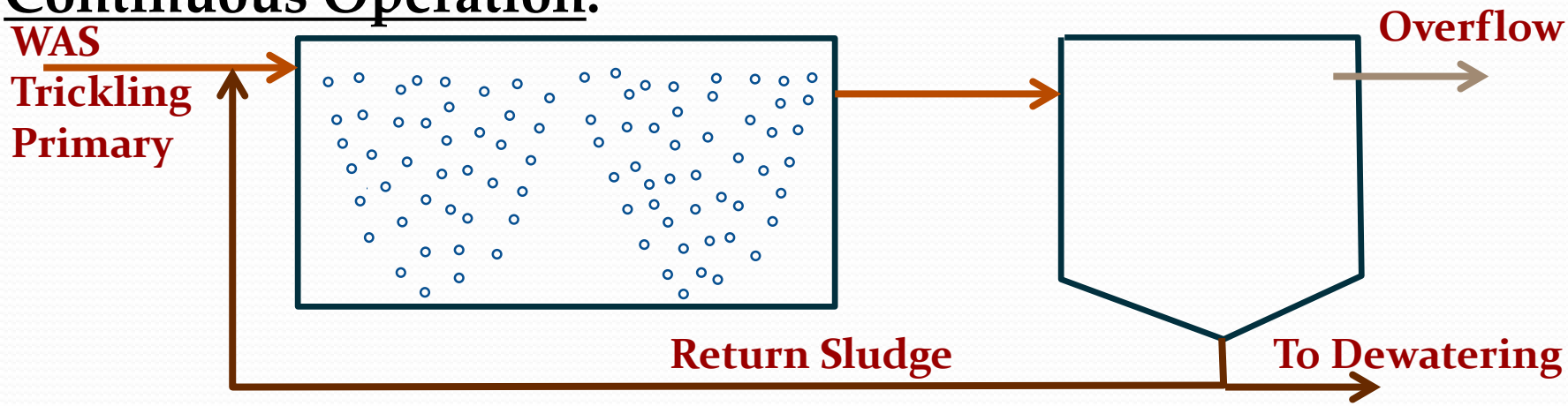
- Process Description
- Regulatory Requirements
- Design Parameters
- Operational Considerations
- Design Example / Expected Performance
- Summary

Aerobic Digestion

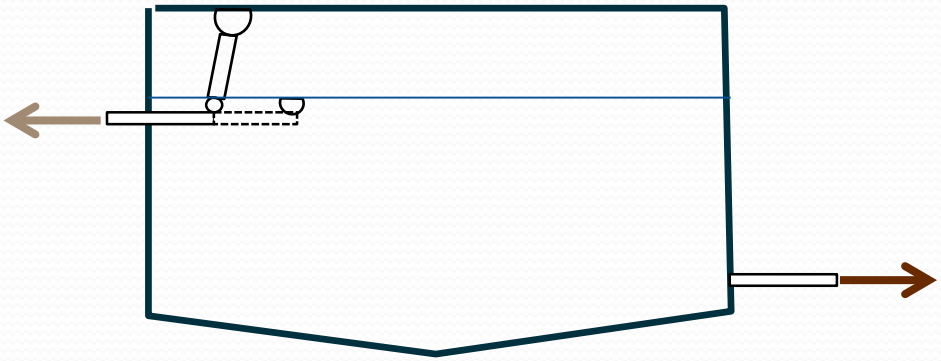
- **Definition:**
  - Biological stabilization process in which aerobic reactions biologically destroy degradable organic components of biosolids removed from wastewater treatment processes
- **Objectives:**
  - Generation of a stable product by oxidation of biosolids organisms and other biodegradable organics
  - Reduction of the biosolids mass (and volume after settling)

Configurations

Continuous Operation:



Batch Operation:



Process Theory

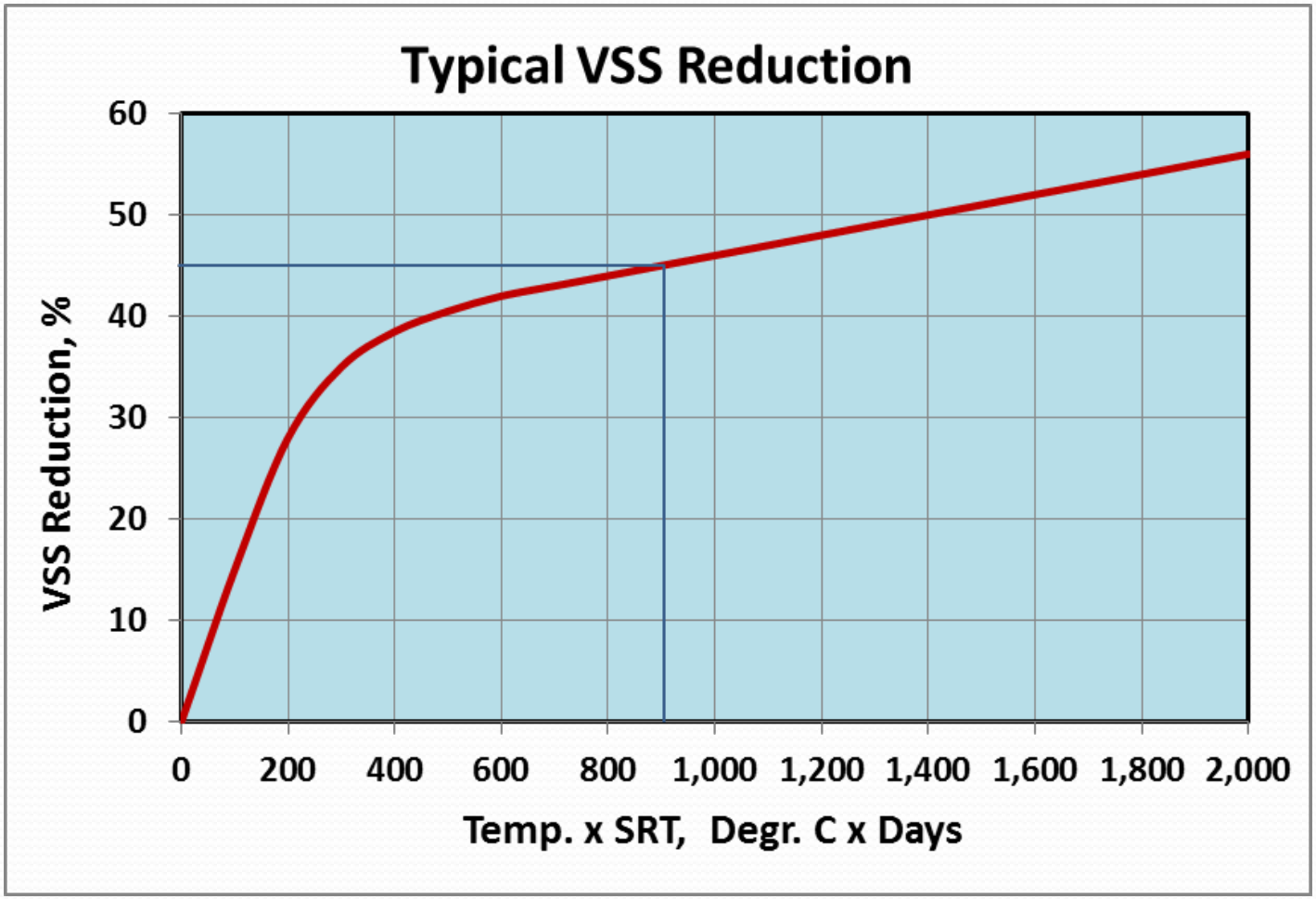
- **Aerobic biological process**
- **Similar to complete mixed activated sludge process in the endogenous phase of cell growth**
- **Energy is obtained from biodegradable organic matter, including microorganism cells**
- **Basic process chemistry:**
  - $C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3$
  - $C_5H_7NO_2 + 7O_2 \rightarrow 5CO_2 + {}_3H_2O + NO_3^- + H^+$
- **pH, Alkalinity drop – Lime, caustic or sodium bicarbonate might have to be added if insufficient alkalinity**

Process Theory

- **Oxygen requirements:**
  - **Carbonaceous: 1.4 lbs O_2/lb organic matter oxidized**
  - **Nitrogenous: 4.6 lbs O_2/lb NH3-N oxidized**
  - **Total: 2 lbs O_2/lb organic matter oxidized**

Process Theory

Typical VSS Reduction (MOP-8)



Process Theory

- **Actual VSS reduction depends on:**
  - **Prior sludge processing (e.g., activated sludge type, SRT, etc.)**
  - **Sludge characteristics (e.g., portion of primary and secondary sludge, coagulant/polymer addition, volatility, etc.)**
  - **Digester operating conditions**

Regulatory Requirements

- **U.S. EPA's 40 CFR Part 503 Standards for the Use or Disposal of Sewage Sludge**
- **Adapted by the State of Ohio under Chapter 3745-40 of the OAC**

<u>Subpart B - Land Application of Aerobically Digested Biosolids</u>

- **Pathogen reduction requirements, and**
- **Vector attraction reduction requirements**

Regulatory Requirements

- **<u>Class A</u> (Exceptional Quality in Ohio)**
  - **Compliance with one of seven pathogen reduction alternatives (P-8 to P-16) – NOTE: Aerobic Digestion does not qualify**
  - **Certain Fecal coliform or Salmonella densities**
  - **Compliance with one of eight vector attraction reduction options**
    - **VAR-1: 38 % reduction in volatile solids (VS) content**
    - **VAR-3: When the 38 % VS reduction cannot be met, additional 30-day aeration at 20 °C of digester sludge reduces VS by less than 15%**
    - **VAR-4: The specific oxygen uptake rate (SOUR) at 20 °C for digested sludge is less than 1.5 mg O_2 / hour / gram of dry total solids**

Regulatory Requirements

- **Class B**
  - **Compliance with one of pathogen reduction alternatives P-1 to P-16**
    - **P-1: Fecal coliform density less than 2,000,000 MPN / gram of dry solids, or less than 2,000,000 cfu / gram of dry solids**
    - **P-2: Aerobic digestion – Mean CRT between 40 days at 20 ^{o}C and 60 days at 15 ^{o}C, minimum temperature always > 15 ^{o}C**
  - **Compliance with one of ten vector attraction reduction options**
    - **As for Class A (VAR-1, VAR-3 or VAR-4)**
    - **VAR-9: Subsurface injection**
    - **VAR-10: Incorporation into the soil within 6 hours of delivery**

Regulatory Requirements

- **<u>Metal concentration limits</u> (for both Class A and Class B)**
  - **Metal ceiling concentration limits**
  - **Pollutant cumulative load rates**

- **<u>Ohio EPA</u>**
  - **120 days of storage or alternative method**

Design Parameters

10-State Standards

- **Aerobic sludge digestion system provisions:**
  - **Digestion,**
  - **Supernatant separation,**
  - **Sludge concentration, and**
  - **Any necessary sludge storage**
- **Multiple tanks (for avg. WWTP Q > 0.1 MGD)**
- **High-level emergency overflow**

Design Parameters

10-State Standards

- **Volume req'd based on Equivalent Population:**
  - **15,000 – 34,000 gal/1,000 people**
  - **25% greater if solids separation in same tanks**
- **Minimum air supply: 30 cfm/1,000 ft^3 (D.O. = 1-2 mg/L)**
- **Minimum range of 120 to 180 days storage, unless a different period is approved by the reviewing authority**

Design Standards

- **Aeration / Mixing System:**
  - **Diffused aeration (fine and coarse bubble)**
  - **Mechanical aeration (surface, submerged turbine)**
  - **Jet aeration**
  - **Combined systems**

- **Diffused aeration is preferable in cold climates**

Operational Considerations

- **Recycle streams: Could be high in total P and total N**
- **Alkalinity depletion: Addition of lime or caustic might be required**
- **Digested sludge thickening:**
  - **By gravity: 2 - 3.5%**
  - **Mechanically: up to 6 %**
- **Digested sludge dewatering:**
  - **Inconsistent**
  - **Better dewatering if includes primary solids**
- **Foaming**
  - **Foam removal, Spray, Antifoaming chemicals**

Advantages and Disadvantages

- **Advantages**
  - **Low capital cost**
  - **Easy to operate**
  - **No nuisance odors**
  - **Good supernatant quality**
- **Disadvantages**
  - **Not very good dewatering characteristics**
  - **High energy cost**
  - **Significant influence by climate**

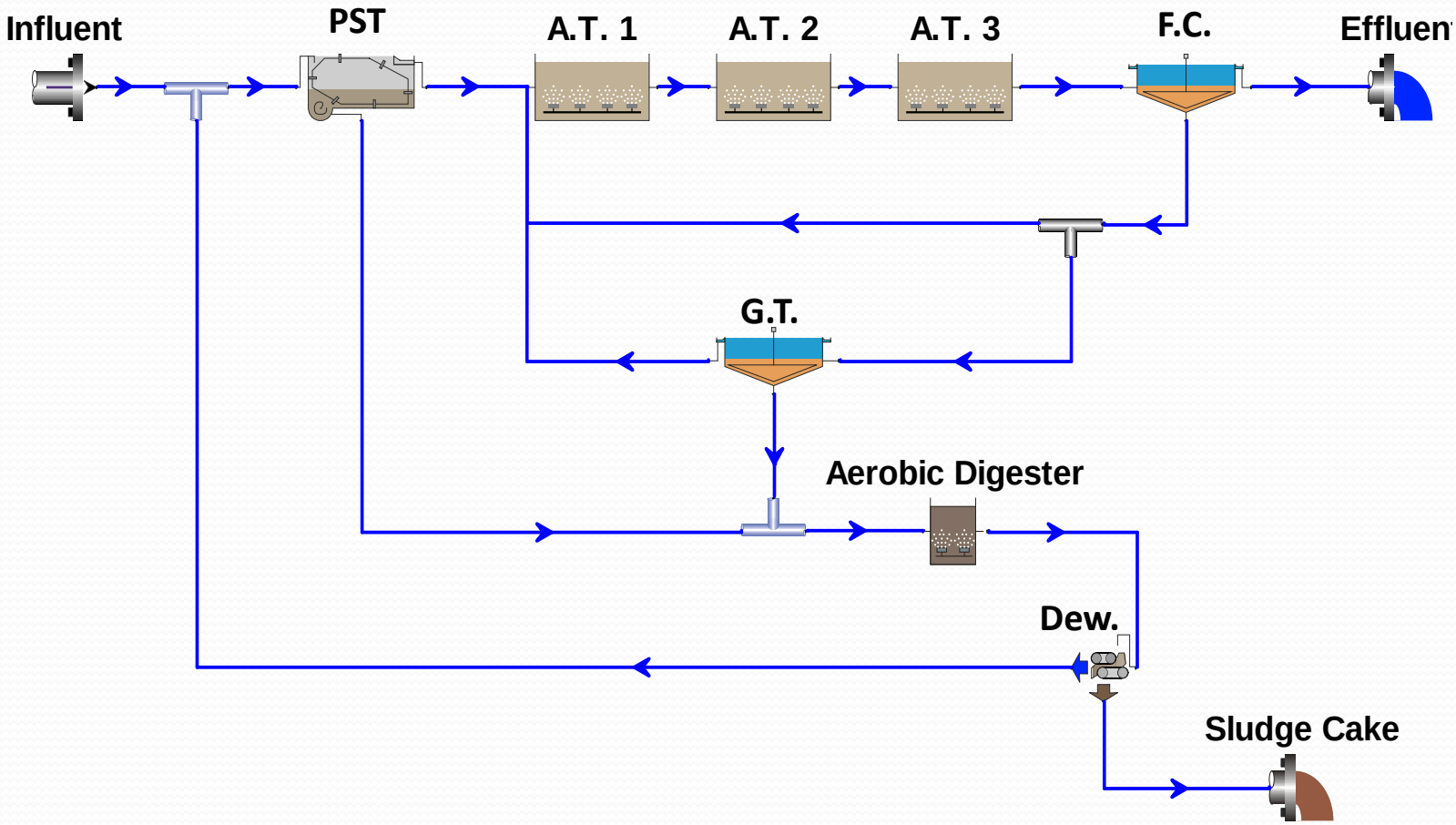
Aerobic Digester Design Example

Design Parameters:

- **Digester Influent**
  - **Q = 0.036 MGD**
  - **TSS = 2%**
  - **VSS = 78%**
- **HDT = 60 days (SRT = 60 days)**
  - **Volume = HDT x Q = (60 days)x(0.0162 MGD) = 2.16 MG**
- **Oxygen requirements:**
  - **1 lb O2/lb COD removed**
  - **4.6 lbs O2/lb ammonia-N removed**
- **Mixing: 30 cfm/1,000 cf**

Aerobic Digestion Modeling

Using BioWin^{R}



Aerobic Digestion Modeling

Elements	Infl.	Prim. Infl.	Prim. Effl.	Prim. Sludge	RAS	WAS	A.D. Infl.	A.D. Effl.	Dewat. Filtrate	Sludge Cake	Final Effl.
Flow [MGD]	5	5.03	5.01	0.02	2.0	0.032	0.036	0.036	0.035	0.0015	5
TSS (mg/L)	150	152	61	22,955	8,611	8,611	20,177	11,572	362	269,391	7
VSS (mg/L)	121	121	49	18,329	6,457	6,457	15,750	7,219*	226	168,057	5
CBOD5 (mg/L)	150	149	101	12,212	2,748	2,748	9,154	574	19	13,330	3
COD (mg/L)	305	305	190	29,296	9,465	9,465	24,430	10,880	357	252,909	24
TKN (mg/L)	26	27	24	802	580	580	945	731	178	13,447	2
NH4-N (mg/L)	17	18	18	18	1	1	11	158	158	158	<1
Total P (mg/L)	5	6.4	5.1	335	322	322	472	472	203**	6,667	3.0
Alk. (mg/L)	4	4	4	4	2	2	3	0	0	0	2
pH	8	7	7	7	7	7	7	4	4	4	7
Temp. (deg. C)	15	15	15	15	15	15	15	15	15	15	15

* 54% VSS reduction

** Approximately 30% TP increase due to recycles

Aeration Requirements

Process:

- **178 lbs O2 /Hr**
- **1,160 scfm**

Mixing (based on 30 cfm/1,000)

- **8,860 cfm for a 2.16-MG digester (60-day SRT/HDT)**
- **4,430 cfm for a 1.08-MG digester (60-day SRT)**

Aerobic Digester System

A. No Decant

- **Tanks: (Min. digester volume req'd = 2.16 MG)**
  - **Four tanks 45' x 95' x 17' swd**

    Volume (each) = 0.54 MG

    Total volume = 2.16 MG
- **Blowers: (Min. air requirements 8,860 scfm)**
  - **Three 5,000-cfm each air blowers**
  - **Blower type: Screw positive displacement**
  - **Blower HP: 300 HP each**
- **Diffusers: Membrane tube diffusers, 10 cfm each**
  - **Number of diffusers per tank: 220**

Aerobic Digester System

B. <u>With Decant</u>

- **Tanks: (Min. digester volume req'd = 1.08 MG)**
  - **Two tanks 45' x 95' x 17' swd**

    Volume (each) = 0.54 MG

    Total volume = 1.08 MG
- **Blowers: (Min. air requirements 4,430 scfm)**
  - **Three 2,500-cfm each air blowers**
  - **Blower type: Screw positive displacement**
  - **Blower HP: 150 HP each**
- **Diffusers: Membrane tube diffusers, 10 cfm each**
  - **Number of diffusers per tank: 220**

Summary

- **Simple and easy to operate process**
- **High energy requirements**
- **Not very effective in N.E. Ohio**
- **Requires large digestion tank volume and 120-days of storage if biosolids have to be land applied**
- **More suitable for small systems**