Biosolids and Residuals Processing & Energy Management Workshop

December 12, 2013

HAZEN AND SAWYER
Environmental Engineers & Scientists

Overall Program Agenda

Time	Program Item
9:30 – 10:20	Biosolids Management / Regulatory Framework
10:20 – 10:30	Break
10:30 – 12:00	Biosolids Treatment Technologies
12:00 – 13:00	Lunch
13:00 – 13:30	Sidestream Treatment and Advanced Stabilization
13:30 – 14:30	Energy Management
14:30	Workshop Closure

Biosolids Management Seminar Expected Learning Outcomes

- Discuss the regulatory framework for management of sewage sludge;
- Discuss major residuals thickening and dewatering unit processes;
- Discuss sludge conditioning for thickening and dewatering;
- Discuss major residuals stabilization unit processes;
- Discuss side-stream treatment and post-dewatering advanced stabilization

Program Agenda

- Regulatory Framework
- Sludge Thickening
- Sludge Dewatering
- Sludge Conditioning
- Sludge Stabilization
- Side Stream Treatment
- Post-Dewatering Advanced Stabilization

THERE WILL BE ACTIVE LEARNING COMPONENTS TO THE SEMINAR

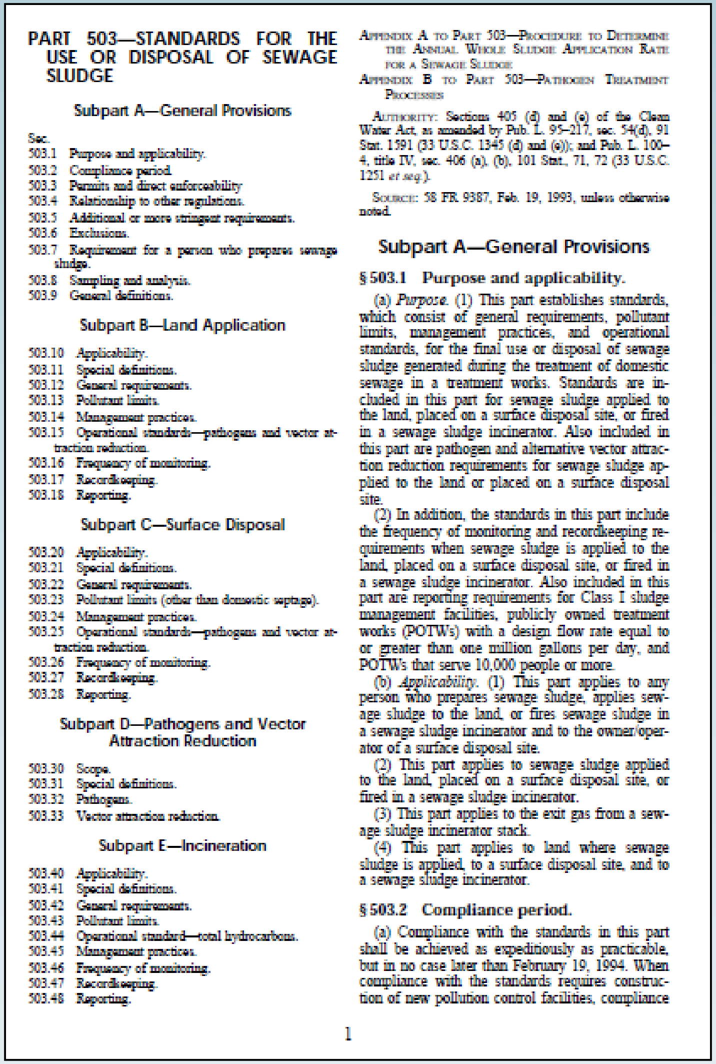
As my daughter says…

"If you snooze you lose"

REGULATORY FRAMEWORK & CONSIDERATIONS

Residuals regulation is governed at the federal level under 40 CFR 503

- Major Sections
  - General Provisions
  - Land Application
  - Surface Disposal
  - Pathogen & Vector Attraction Reduction
  - Incineration



PART 503—STANDARDS FOR THE USE OR DISPOSAL OF SEWAGE SLUDGE

Subpart A—General Provisions

Sec.
503.1 Purpose and applicability.
503.2 Compliance period.
503.3 Permits and direct enforceability
503.4 Relationship to other regulations.
503.5 Additional or more stringent requirements.
503.6 Exclusions.
503.7 Requirement for a person who prepares sewage sludge.
503.8 Sampling and analysis.
503.9 General definitions.

Subpart B—Land Application

503.10 Applicability.
503.11 Special definitions.
503.12 General requirements.
503.13 Pollutant limits.
503.14 Management practices.
503.15 Operational standards—pathogens and vector attraction reduction.
503.16 Frequency of monitoring.
503.17 Recordkeeping.
503.18 Reporting.

Subpart C—Surface Disposal

503.20 Applicability.
503.21 Special definitions.
503.22 General requirements.
503.23 Pollutant limits (other than domestic septage).
503.24 Management practices.
503.25 Operational standards—pathogens and vector attraction reduction.
503.26 Frequency of monitoring.
503.27 Recordkeeping.
503.28 Reporting.

Subpart D—Pathogens and Vector Attraction Reduction

503.30 Scope.
503.31 Special definitions.
503.32 Pathogens.
503.33 Vector attraction reduction.

Subpart E—Incineration

503.40 Applicability.
503.41 Special definitions.
503.42 General requirements.
503.43 Pollutant limits.
503.44 Operational standard—total hydrocarbons.
503.45 Management practices.
503.46 Frequency of monitoring.
503.47 Recordkeeping.
503.48 Reporting.

APPENDIX A TO PART 503—PROCEDURE TO DETERMINE THE ANNUAL WHOLE SLUDGE APPLICATION RATE FOR A SEWAGE SLUDGE

APPENDIX B TO PART 503—PATHOGEN TREATMENT PROCESSES

AUTHORITY: Sections 405 (d) and (e) of the Clean Water Act, as amended by Pub. L. 95–217, sec. 54(d), 91 Stat. 1591 (33 U.S.C. 1345 (d) and (e)); and Pub. L. 100–4, title IV, sec. 406 (a), (b), 101 Stat., 71, 72 (33 U.S.C. 1251 *et seq.*).

SOURCE: 58 FR 9387, Feb. 19, 1993, unless otherwise noted.

Subpart A—General Provisions

§ 503.1 Purpose and applicability.

(a) *Purpose.* (1) This part establishes standards, which consist of general requirements, pollutant limits, management practices, and operational standards, for the final use or disposal of sewage sludge generated during the treatment of domestic sewage in a treatment works. Standards are included in this part for sewage sludge applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator. Also included in this part are pathogen and alternative vector attraction reduction requirements for sewage sludge applied to the land or placed on a surface disposal site.

(2) In addition, the standards in this part include the frequency of monitoring and recordkeeping requirements when sewage sludge is applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator. Also included in this part are reporting requirements for Class I sludge management facilities, publicly owned treatment works (POTWs) with a design flow rate equal to or greater than one million gallons per day, and POTWs that serve 10,000 people or more.

(b) *Applicability.* (1) This part applies to any person who prepares sewage sludge, applies sewage sludge to the land, or fires sewage sludge in a sewage sludge incinerator and to the owner/operator of a surface disposal site.

(2) This part applies to sewage sludge applied to the land, placed on a surface disposal site, or fired in a sewage sludge incinerator.

(3) This part applies to the exit gas from a sewage sludge incinerator stack.

(4) This part applies to land where sewage sludge is applied, to a surface disposal site, and to a sewage sludge incinerator.

§ 503.2 Compliance period.

(a) Compliance with the standards in this part shall be achieved as expeditiously as practicable, but in no case later than February 19, 1994. When compliance with the standards requires construction of new pollution control facilities, compliance

1

For land application sewage sludge must meet certain requirements

- Non-Hazardous
- Criteria Pollutants
- Pathogen Content
- Vector Attraction Reduction

“Non-hazardous” sludge must meet the requirements of 40 CFR 261

- Ignitable
  - Flash Point < 140°F
- Reactive
  - Explosive
  - Reacts with water (fire, toxic gas, etc.)
- Corrosive
  - pH < 2.0 or pH > 12.5
- Toxic
  - TCLP extractable toxics

PART 261—IDENTIFICATION AND LISTING OF HAZARDOUS WASTE

Subpart A—General

Sec.
261.1 Purpose and scope.
261.2 Definition of solid waste.
261.3 Definition of hazardous waste.
261.4 Exclusions.
261.5 Special requirements for hazardous waste generated by conditionally exempt small quantity generators.
261.6 Requirements for recyclable materials.
261.7 Residues of hazardous waste in empty containers.
261.8 PCB wastes regulated under Toxic Substance Control Act.
261.9 Requirements for Universal Waste.

Subpart B—Criteria for Identifying the Characteristics of Hazardous Waste and for Listing Hazardous Waste

261.10 Criteria for identifying the characteristics of hazardous waste.
261.11 Criteria for listing hazardous waste.

Subpart C—Characteristics of Hazardous Waste

261.20 General.
261.21 Characteristic of ignitability.
261.22 Characteristic of corrosivity.
261.23 Characteristic of reactivity.
261.24 Toxicity characteristic.

Subpart D—Lists of Hazardous Wastes

261.30 General.
261.31 Hazardous wastes from non-specific sources.
261.32 Hazardous wastes from specific sources.
261.33 Discarded commercial chemical products, off-specification species, container residues, and spill residues thereof.
261.35 Deletion of certain hazardous waste codes following equipment cleaning and replacement.
261.38 Comparable/Syngas Fuel Exclusion.
APPENDIX I TO PART 261—REPRESENTATIVE SAMPLING METHODS
APPENDIX II TO PART 261—METHOD 1311 TOXICITY CHARACTERISTIC LEACHING PROCEDURE (TCLP)
APPENDIX III TO PART 261—CHEMICAL ANALYSIS TEST METHODS
APPENDIX IV TO PART 261—[RESERVED FOR RADIOACTIVE WASTE TEST METHODS]
APPENDIX V TO PART 261—[RESERVED FOR INFECTIOUS WASTE TREATMENT SPECIFICATIONS]
APPENDIX VI TO PART 261—[RESERVED FOR ETIOLOGIC AGENTS]
APPENDIX VII TO PART 261—BASIS FOR LISTING HAZARDOUS WASTE
APPENDIX VIII TO PART 261—HAZARDOUS CONSTITUENTS
APPENDIX IX TO PART 261—WASTES EXCLUDED UNDER §§260.20 AND 260.22

AUTHORITY: 42 U.S.C. 6905, 6912(a), 6921, 6922, 6924(y) and 6938.

SOURCE: 45 FR 33119, May 19, 1980, unless otherwise noted.

Subpart A—General

§261.1 Purpose and scope.

(a) This part identifies those solid wastes which are subject to regulation as hazardous wastes under parts 262 through 265, 268, and parts 270, 271, and 124 of this chapter and which are subject to the notification requirements of section 3010 of RCRA. In this part:

(1) Subpart A defines the terms "solid waste" and "hazardous waste", identifies those wastes which are excluded from regulation under parts 262 through 266, 268 and 270 and establishes special management requirements for hazardous waste produced by conditionally exempt small quantity generators and hazardous waste which is recycled.

(2) Subpart B sets forth the criteria used by EPA to identify characteristics of hazardous waste and to list particular hazardous wastes.

(3) Subpart C identifies characteristics of hazardous waste.

(4) Subpart D lists particular hazardous wastes.

(b)(1) The definition of solid waste contained in this part applies only to wastes that also are hazardous for purposes of the regulations implementing subtitle C of RCRA. For example, it does not apply to materials (such as non-hazardous scrap, paper, textiles, or rubber) that are not otherwise hazardous wastes and that are recycled.

(2) This part identifies only some of the materials which are solid wastes and hazardous wastes under sections 3007, 3013, and 7003 of RCRA. A material which is not defined as a solid waste in this part, or is not a hazardous waste identified or listed in this part, is still a solid waste and a hazardous waste for purposes of these sections if:

(i) In the case of sections 3007 and 3013, EPA has reason to believe that

1

40 CFR 503 regulates specific heavy metals as “criteria” pollutants

- Ceiling Concentrations
- “Exceptional Quality” Thresholds
- Cumulative Pollutant Loading Rates
- Annual Pollutant Loading Rates

Exceed ceiling levels then land application is not permitted!

TABLE 1 OF § 503.13.—CEILING CONCENTRATIONS

Pollutant	Ceiling concentration (milligrams per kilogram) [1]
Arsenic	75
Cadmium	85
Copper	4300
Lead	840
Mercury	57
Molybdenum	75
Nickel	420
Selenium	100
Zinc	7500

[1] Dry weight basis.

“Exceptional Quality” has lower criteria pollutant concentrations.

TABLE 3 OF § 503.13.—POLLUTANT CONCENTRATIONS

Pollutant	Monthly average concentration (milligrams per kilogram) [1]
Arsenic	41
Cadmium	39
Copper	1500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2800

Cumulative loading rate tracking required for "non-EQ" biosolids.

TABLE 2 OF § 503.13.—CUMULATIVE POLLUTANT LOADING RATES

Pollutant	Cumulative pollutant loading rate (kilograms per hectare)
Arsenic	41
Cadmium	39
Copper	1500
Lead	300
Mercury	17
Nickel	420
Selenium	100
Zinc	2800

Annual pollutant loading rate also applies for "non-EQ" biosolids.

TABLE 4 OF § 503.13.—ANNUAL POLLUTANT LOADING RATES

Pollutant	Annual pollutant loading rate (kilograms per hectare per 365 day period)
Arsenic	2.0
Cadmium	1.9
Copper	75
Lead	15
Mercury	0.85
Nickel	21
Selenium	5.0
Zinc	140

DON’T’ BE “NON-EQ”

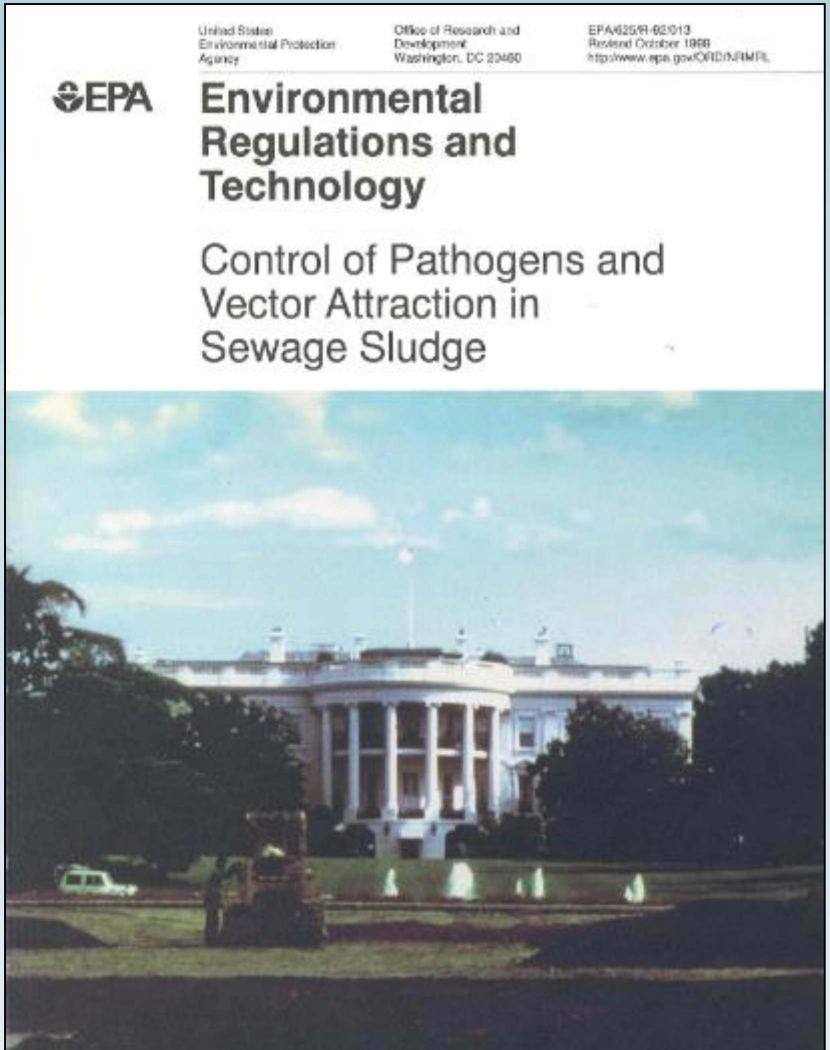
Save yourself a lot of regulatory headaches on cumulative and annual pollutant loading rates tracking

Active learning exercise…

What federal regulation establishes the standards for classification of materials as a hazardous or non-hazardous waste?

What are the four particular demonstrations that have to be made to show you are non-hazardous?

Pathogen reduction requirements are regulated under 40 CFR 503.32



<u>Pathogen Classifications</u>

- Class A
- Class B

<u>Class A</u>

- Lowest Pathogen Density
- < 1,000 MPN/gram fecal coliform density

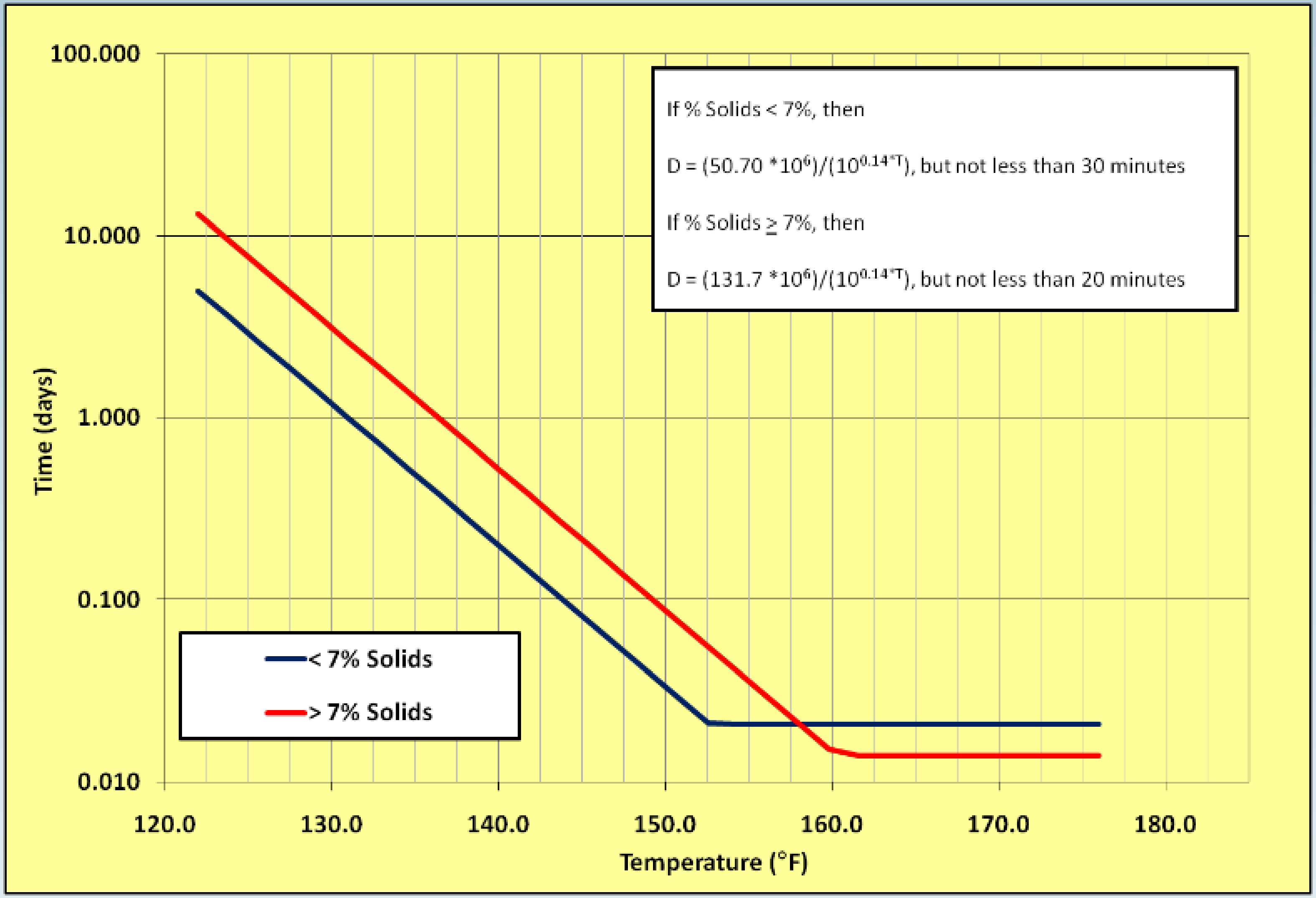
<u>Class B</u>

- Lower Pathogen Density
- < $2*10^6$ MPN/gram fecal coliform density

“Class B” pathogen reduction using PSRP unit processes

- Aerobic Digestion
  - > 40-days MCRT @ 20°C or > 60-days MCRT @ 15°C
- Anaerobic Digestion
  - > 15-days MCRT 35°C to 55°C or > 40-days MCRT @ 20°C
- Air Drying
  - > 3-months at > 0°C (above freezing)
- Composting
  - Windrow, aerated static pile, or in-vessel systems
  - > 40°C for at least 5-days AND > 55°C for at least 4-hours
- Lime Stabilization
  - pH > 12.0 standard units for > 2-hours

Class A pathogen reduction by “time and temperature”.



“Class A” pathogen reduction using PFRP unit processes.

- Composting
  - Aerated Static Piles and in-vessel systems temperature maintained at > 55°C for at least 3-days
  - Windrow systems temperature maintained at > 55°C for at least 15-days with at least 5-turnings
- Heat Drying
  - Dried to > 90% dry weight solids
  - Particles Heated to > 80°C (indirect dryers) or
  - Gas in contact with particles has a wet bulb gas temperature > 80°C (direct dryers)
- Heat Treatment
  - Liquid heated to > 180°C for > 30-minutes
  - Zimpro, Porteous, and/or CAMBI thermal lysis

“Class A” pathogen reduction using PFRP unit processes

- Thermophilic Aerobic Digestion
  - ATAD type systems
  - Heat generated from aerobic degradation of volatile solids
  - Sensitive to feed solids degradable VS content and %TS feed
  - Temperature maintained at > 55°C for 10-day MCRT
- Irradiation
  - Not commonly applied
  - Beta or Gamma Rays > 1.0 megarad at > 20°C
- Pasteurization
  - Sludge Temperature maintained at > 70°C for at least 30-minutes
  - Uncommon on “liquid” sludge due to heat demand
  - Common on dewatered cakes (e.g., RDP lime stabilization)

Vector attraction reduction is regulated under 40 CFR 503.33.

Table 2.3 Vector Attraction Reduction Methods

1. Volatile Solids Reduction by a minimum of 38 percent
2. Volatile Solids Reduction additional testing for anaerobic digestion
3. Volatile Solids Reduction additional testing for aerobic digestion
4. Specific Oxygen Uptake Rate (SOUR) equal to or less than 1.5 milligrams of oxygen per hour per gram of dry solids at 20 degrees Celsius (°C)
5. Aerobic process for a minimum of 14 days at a temperature of greater than 40°C and an average temperature greater than 45°C
6. pH of 12 or higher by alkaline addition, and the maintenance of at least pH 12 for two hours without addition of more alkaline material; then pH 11.5 or higher for an additional 22 hours
7. A total solids concentration equal to or greater than 75 percent for a material that does not include unstabilized solids generated in a primary treatment process prior to mixing with other materials
8. A total solids concentration equal to or greater than 90 percent for a material that contains unstabilized solids generated in a primary treatment process prior to mixing with other materials
9. Injection of liquid biosolids below the land surface
10. Incorporation of biosolids that have been surface applied or placed on a surface disposal site within 6 hours after application to or placement on the land
11. Biosolids placed in an active disposal unit shall be covered with soil or other material at the end of each operating day
12. The pH of domestic septage shall be raised to 12 or higher by alkaline addition and, without further alkaline addition, remain at 12 or higher for 30 minutes.

Active learning exercise…

What federal regulation establishes the standards management of sewage sludges by land application, land disposal, and incineration?

Active learning exercise…

Class B pathogen reduction can be achieved using a "process to _______________ reduce pathogens" and Class A pathogen reduction can be achieved using a "process to _________________ reduce pathogens"

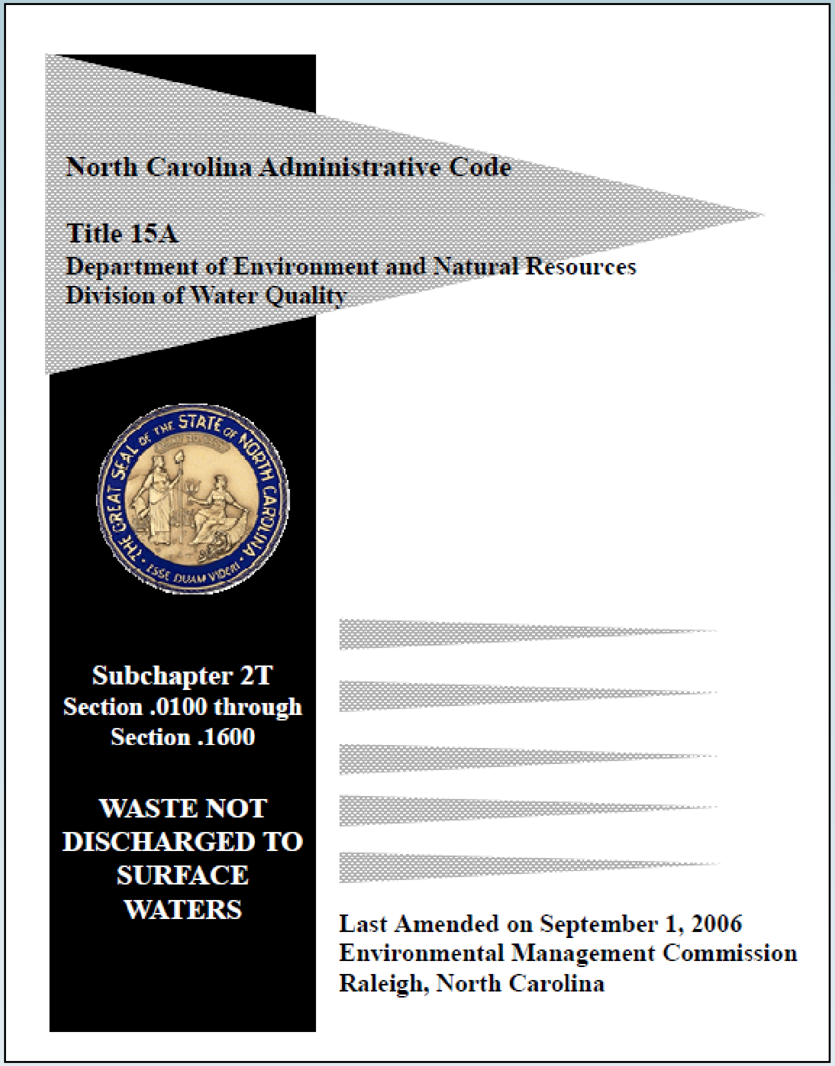
Discuss with a "neighbor" what process your utility uses for pathogen reduction.

Active learning exercise…

Discuss with a neighbor what FOUR criteria must be demonstrated in order to land apply biosolids:

1.
2.
3.
4.

State and local regulations may result in more stringent regulatory constraints.

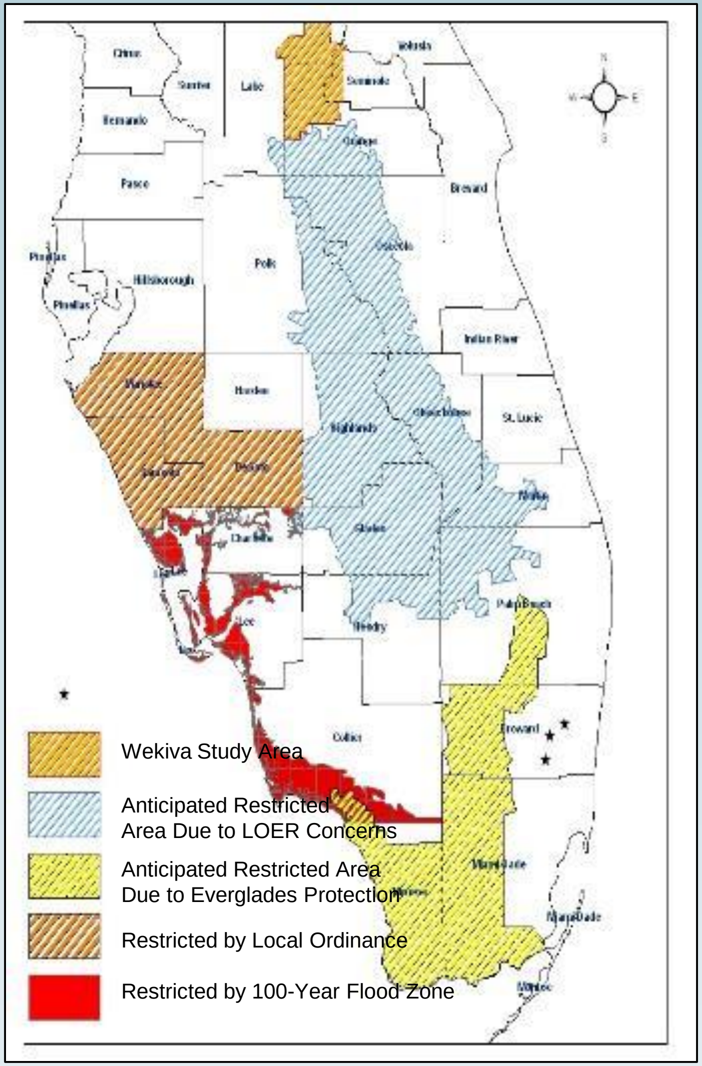

North Carolina Administrative Code

Title 15A
Department of Environment and Natural Resources
Division of Water Quality

Subchapter 2T
Section .0100 through
Section .1600

WASTE NOT
DISCHARGED TO
SURFACE
WATERS

Last Amended on September 1, 2006
Environmental Management Commission
Raleigh, North Carolina



In Virginia new biosolids management rules have recently been promulgated…

- 9VAC25 – 20
  - ➢ Fees
- 9VAC25 – 31
  - ➢ Regulations
  - ➢ VPDES Permitting
- 9VAC25 – 32
  - ➢ Regulations
  - ➢ VPA Permitting

Project 1248 - Final

STATE WATER CONTROL BOARD

Amendment of Regulations Pertaining to Biosolids After Transfer from the Department of Health

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State and local frameworks may raise the bar for management.

- Statewide Programs
  - Application Rates
  - Slope Restrictions
  - Buffer Restrictions
  - Soil pH Management
  - Nutrient Management Plans

- Local Government Programs
  - Local Oversight Function
  - Monitor Application at Sites
  - Additional Residuals Testing
  - Enforce State Regulations
  - Fee Supported Program

Will land application be viable or vulnerable over the long term?

- Regulatory Challenges
  - Federal Rules
  - State Ordinances
  - Local Ordinances

- Legal Challenges
  - Toxic Tort Claims
  - Personal Property
  - Public Nuisance Claims

Biosolids land application has been challenged in the trial courts.

Human Impact Claims

VA - Wyatt et. al. vs. Sussex Surry LLC and Synagro

TN – Jones vs. Erwin Utility District

FL – Bowen vs. American Water Services Residuals Management

PA – Pennock vs. Lenzi

Animal Impact Claims

GA – Boyce vs. Augusta-Richmond County

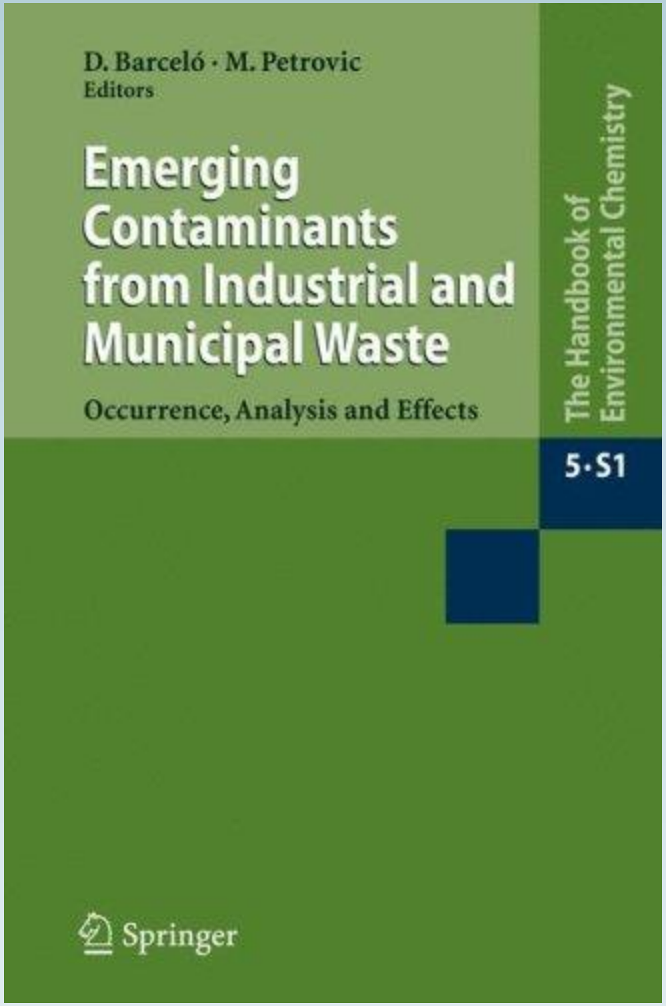
GA – McElmurray vs. Augusta-Richmond County

Pressure also exists for regulatory change on several fronts.

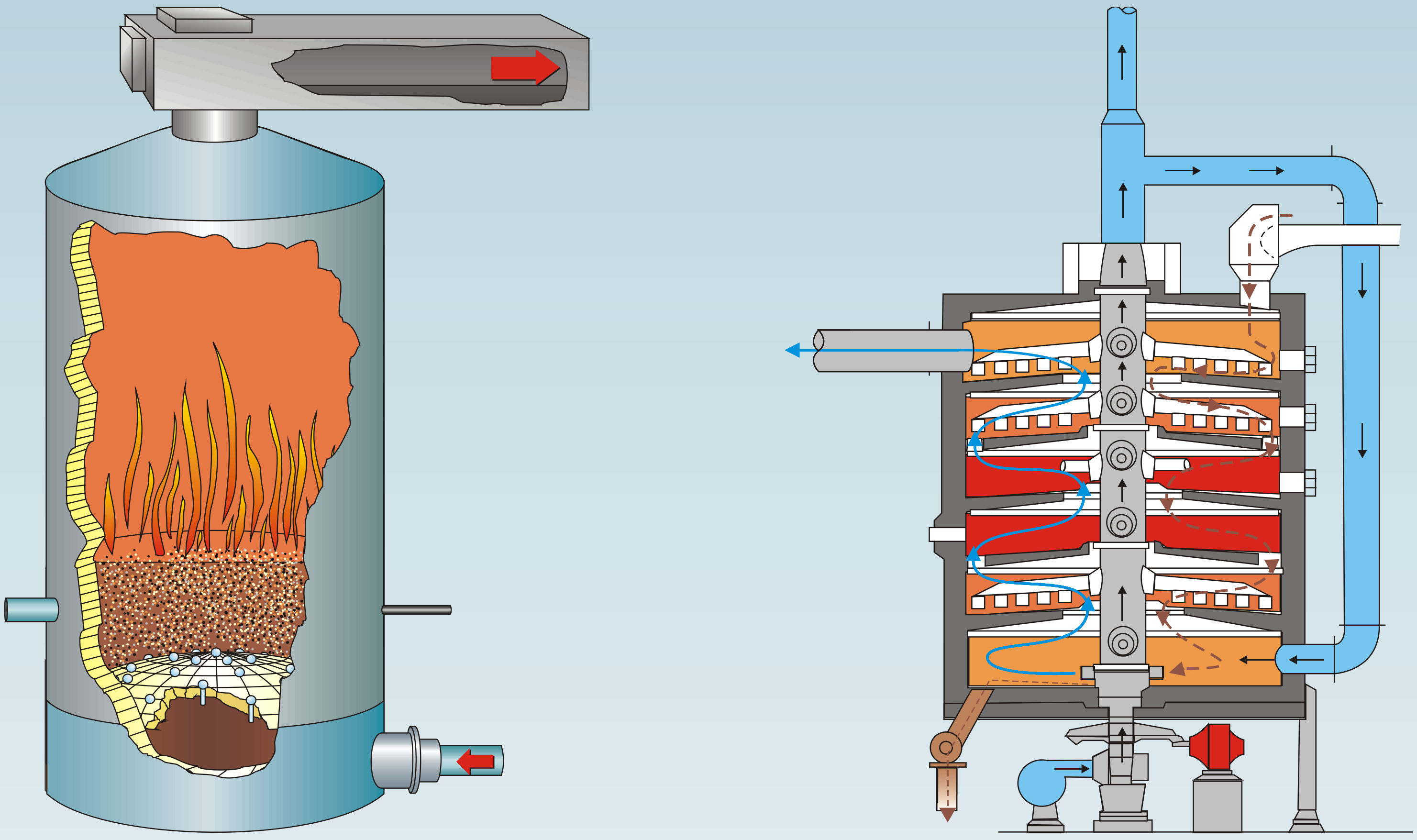
Emerging Contaminants
- Endocrine Disruptors
- Pharmaceuticals
- Personal Care Products
- Flame Retardants
- Dioxins

Pathogens
- Bacteria
- Virus

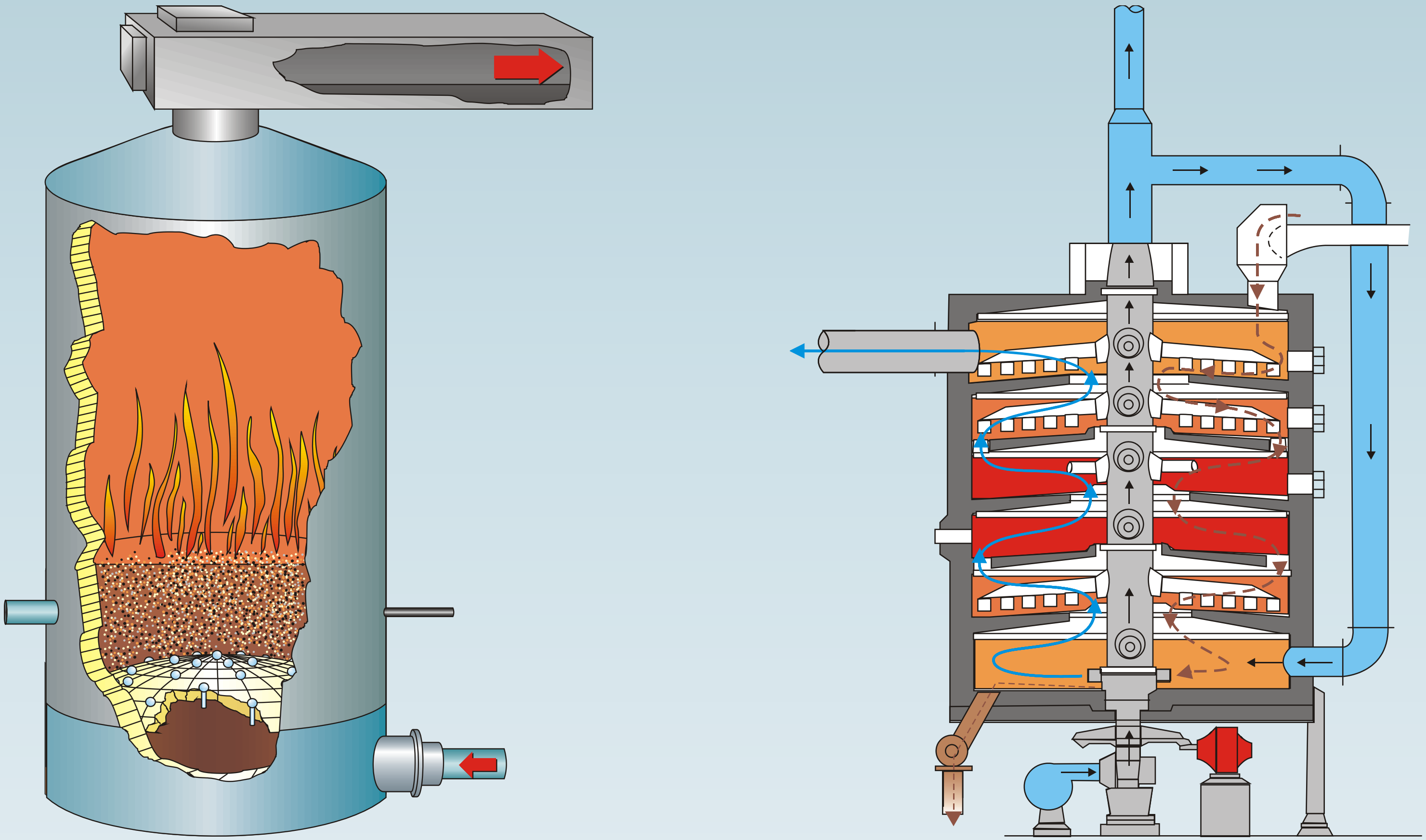
Odors & Bio-aerosols



An example of how regulatory changes can destabilize biosolids management.



The rules are changing for existing and new sewage sludge incinerators (SSI).



The former regulatory framework for sewage sludge incinerators.

- 40 CFR Standards of Performance for Sewage Treatment Plants
  - Particulate Matter
  - Opacity
- 40 CFR 61 National Emission Standards for Hazardous Air Pollutants (HAPS)
  - Mercury (Hg)
  - Beryllium (Be)
- Part 503 Regulations
  - Incorporate 40 CFR 61 for Be, Hg
  - Total Hydrocarbons/CO
  - Lead, Arsenic, Cadmium, Chromium, Nickel (Measured in Biosolids)

Regulations have been evolving based on an expanded waste definition

- Clean Air Act Established Emission Standards for Specific Categories of Solid Waste Incineration Units (70 FR 74870)
  - Municipal Waste > 250 TPD
  - Municipal Waste < 250 TPD
  - Hospital/Medical Waste
  - Commercial or Industrial Waste
  - Other Categories of Solid Waste

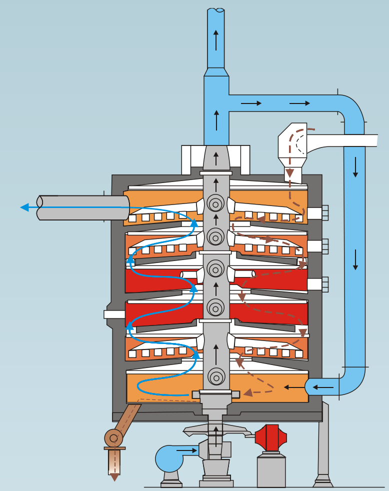
- EPA Established Emission Standards for other Solid Waste Incinerator Units – 12/2005
  - Did Not Include Emission Standards for SSI Units

Regulations have been evolving based on an expanded waste definition

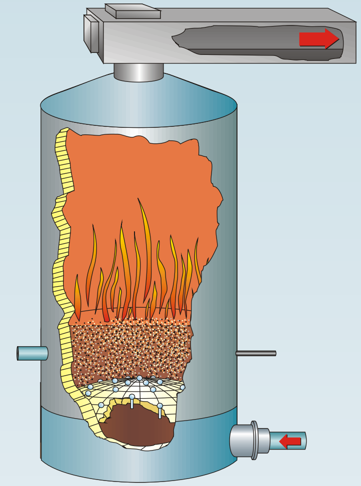
- Sierra Club Petitions EPA for SSI emission standards/litigates
  - Initial position of EPA – “no changes necessary to 70 FR 74870”
- EPA classifies sewage sludge as a solid waste and therefore regulated by CAA
- Rule promulgated to establish regulatory requirements for SSI units “new” and “existing”

Both FBTO and MHI will be regulated under the new rules

- Two Subcategories of SSI's:
  - Multiple Hearth (163 units)
  - Fluidized Bed (55 units)



- Regulated Pollutants:
  - Cadmium (Cd)
  - Dioxins/Dibenzofurons (CDD/CDF)
  - Carbon Monoxide (CO)
  - Hydrogen Chloride (HCL)
  - Mercury (Hg)
  - Oxides of Nitrogen (NOx)
  - Opacity
  - Lead (Pb)
  - Particulate Matter (PM)
  - Sulfur Dioxide (SO_2)



Emission limits were developed based on the best performing units sampled.

- Section 129A-CAA –“Emission limits for existing units cannot be less stringent that the average emission limitation achieved by the best performing 12% of units in a source category” – MACT Standards

- EPA’s interpretation is that emission levels for each pollutant should be used to define “best performing”.

- Therefore the proposed limits represent the average of the lowest 12% of emission levels for each pollutant and not the best performing 12% of installations.

What has been the response to a "sea change" in regulations…

Utility	Response
Asheville, NC	Stay with Incineration Upgrade APC System
Greensboro, NC	Stay with Incineration Upgrade APC System
High Point, NC	Stay with Incineration Upgrade APC System
Columbia, SC	Abandon Incineration Landfill / Class B Land Apply
North Charleston	Abandon Incineration Landfill Disposal

Active learning exercise…

Discuss the four potential challenges or regulatory changes which may impact biosolids and residuals management.

Discuss how your utility would respond to any one of these challenges if you lost the ability to manage biosolids as you do now.

Questions

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HAZEN AND SAWYER
Environmental Engineers & Scientists

Biosolids 101 - Program Agenda

- Sludge Thickening
- Sludge Dewatering
- Sludge Conditioning for Thickening and Dewatering

SLUDGE THICKENING

Dissolved Air Flotation Thickener

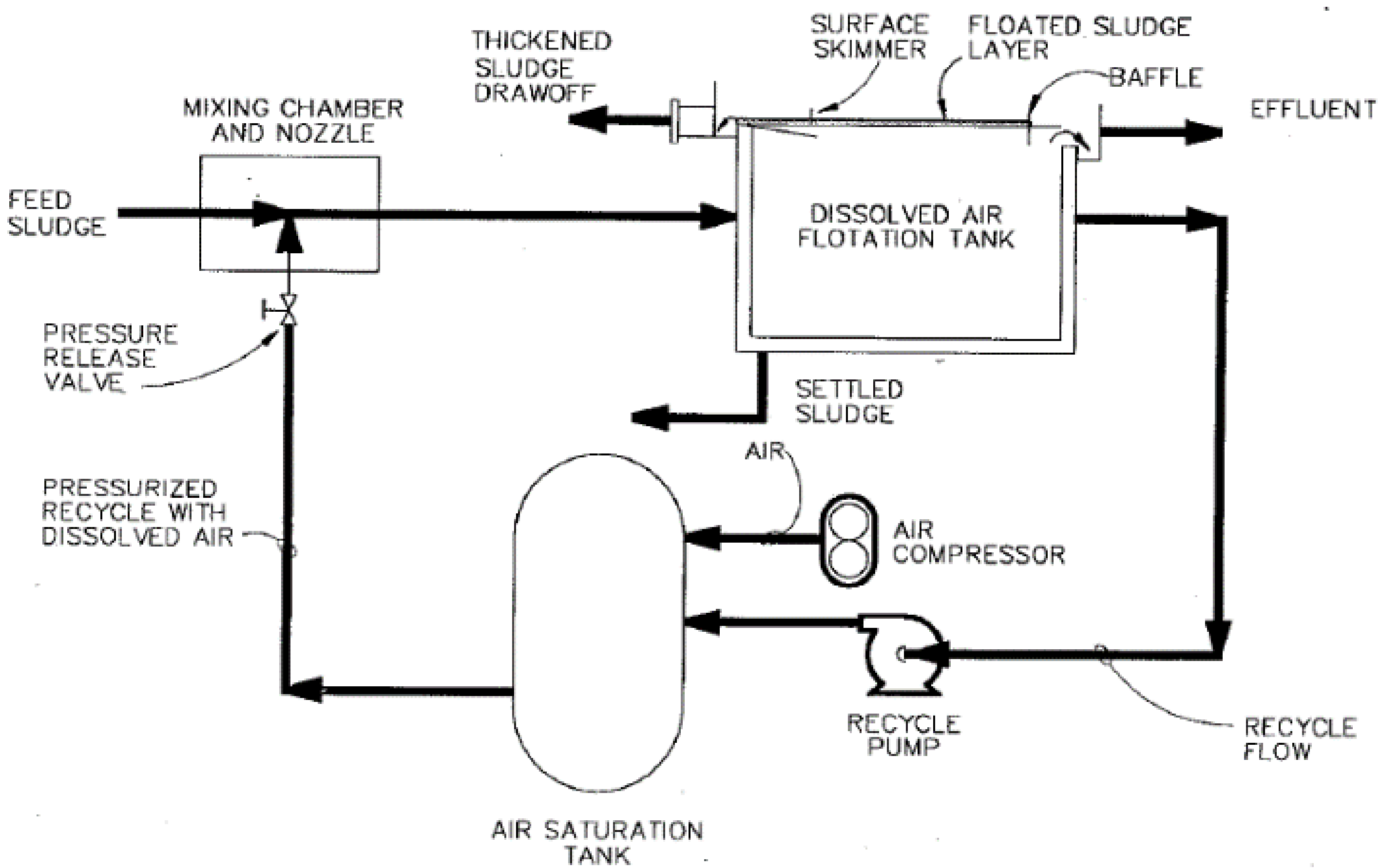


Figure 17.24 Schematic of dissolved air flotation thickener.

Source: WEF, MOP-8.

Dissolved Air Floatation Thickener

Image: Komline-Sanderson

Gravity Belt Thickener

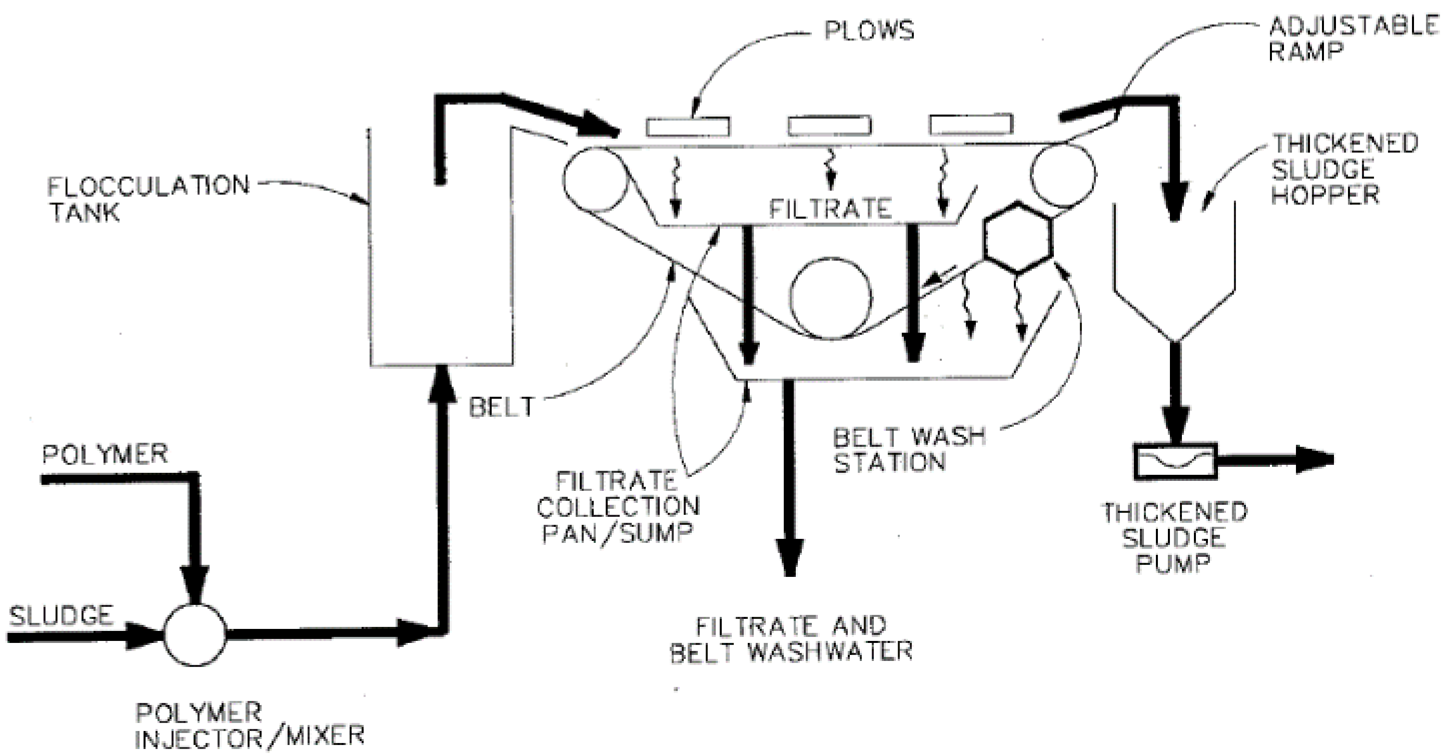


Figure 17.26 General schematic of a gravity belt thickener.

Source: WEF, MOP-8.

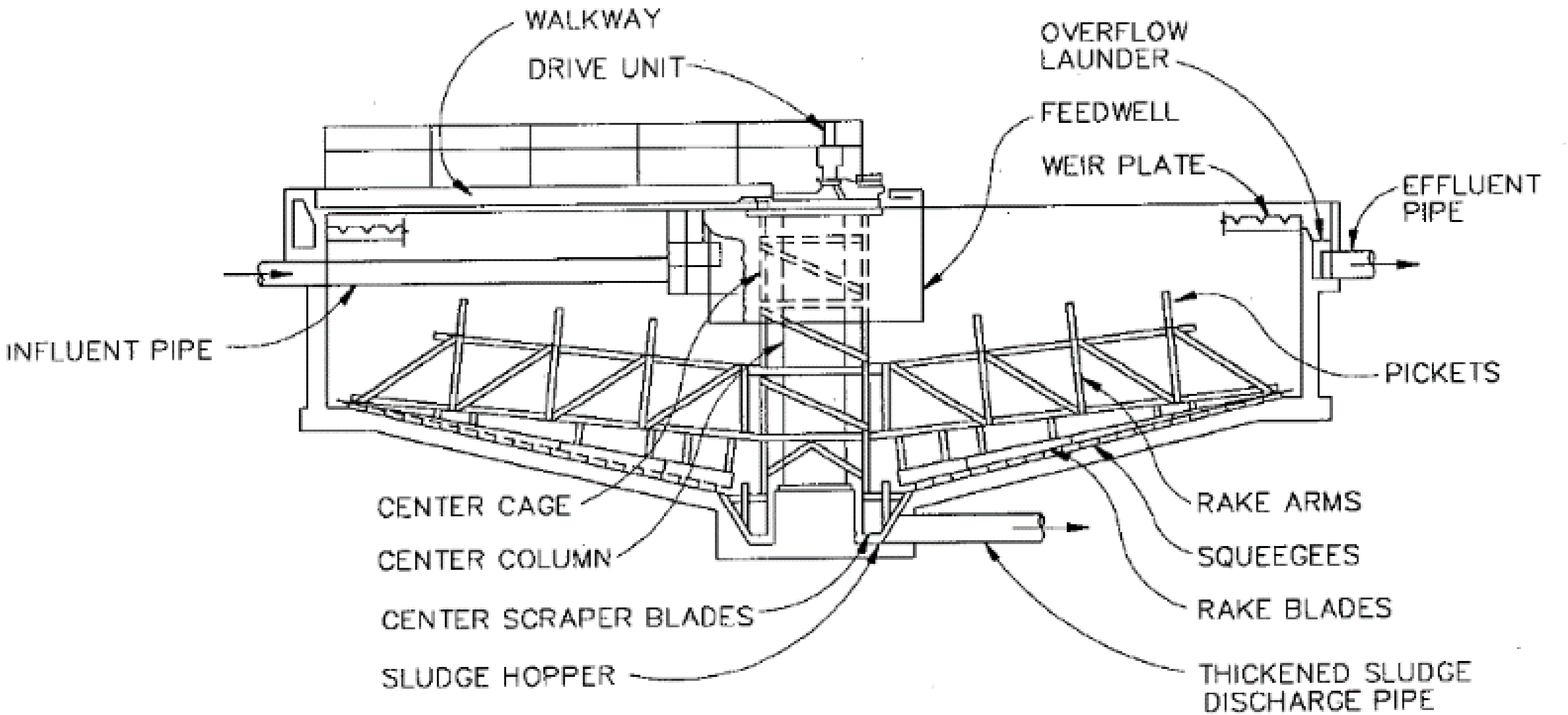
Gravity Belt Thickener

Some gravity belt thickener design characteristics for preliminary sizing.

Sludge Type	Primary	Waste Activated	Blended (50/50)
Feed Solids, %TS	2.0% - 4.0%	0.5% - 1.0%	1.0% - 2.0%
Thickened Solids, %TS	5.0% - 8.0%	4.5% - 5.5%	4.5% - 6.0%
Solids Loading Rate (lb/hr-meter)	750 – 1,000	600 - 750	750 - 900
Hydraulic Loading Rate (gallons/minute-meter)	75 – 100	200 – 250	150 - 200

Rotary drum thickener

Gravity Thickening



Source: WEF, MOP-8.

Figure 17.23 Typical gravity thickener.

Gravity sludge thickener

Image: Madison (WI) MSD @
http://www.madsewer.org/SolidWasteTreatment.htm

Some gravity sludge thickener design characteristics for preliminary sizing.

Sludge Type	Primary	Waste Activated	Blended (50/50)
Feed Solids, %TS	2.0% - 4.0%	0.5% - 1.5%	1.0% - 2.0%
Underflow Solids, %TS	5.0% -7.5%	2.0% - 3.0%	3.0% - 5.0%
Solids Loading Rate (lb/day-sft)	20-30	4-6	5-15
Hydraulic Loading Rate (gallons/day-sft)	400 – 750	100 – 200	250 - 450

Biosolids 101 - Program Agenda

- ~~Sludge Thickening~~
- Sludge Dewatering
- Sludge Conditioning for Thickening and Dewatering

SLUDGE DEWATERING

Belt Filter Press Dewatering

- Good
  - Simpler than centrifuge operation
  - Can be automated
  - High solids capture rate
  - Relatively low maintenance costs
- Not so Good
  - Odor control
  - High water requirements
  - Difficult for large roller and belt replacement
  - Large footprint requirements

Some belt filter press design loading characteristics for preliminary sizing.

Sludge Type	Digested Primary	Digested WAS	Digested Blend (50/50)
Feed Solids, %TS	3.0% - 4.0%	2.0% - 3.0%	2.0% - 4.0%
Cake Solids, %TS	24% - 30%	12%-18%	20% - 25%
Solids Loading Rate (lb/hr-meter)	800-1,200	400 – 600	600-750
Hydraulic Loading Rate (gallons/minute-meter)	60-75	40-60	60-75

High Solids Centrifuge

- Good
  - Generally higher solids content than belt press (1-2%?)
  - Compact footprint
  - Can generally be automated
  - High solids capture rate
  - Fully enclosed

- Not so Good
  - Specialized maintenance and operation
  - High rotational speeds
  - Higher power consumption
  - Higher noise
  - Wear and tear

Plate and Frame Filter Presses

- Good
  - High solids
- Not so Good
  - High pressure operation
  - Batch process
  - Difficult to automate
  - High operation and maintenance requirements
  - Skilled / trained labor requirements
  - High chemical costs (typically lime and ferric)

Image: WesTech Industries

Rotary Screw Presses

- Slow rotating screw presses solids into smaller and smaller area toward discharge
- Two types – inclined and straight
- Good
  - Low speed, low power
  - High solids capture rate
  - Low water requirements
  - Automated operations
  - Ease of maintenance
- Not so Good
  - Recent technology
  - Lower performance without primary solids

Image: Huber Industries

Rotary Fan Presses

- Slow turning internal disc, pressure creates cake
- Good
  - Low speed, low power
  - High solids capture rate
  - Low water requirements
  - Automated operations
  - Ease of maintenance
- Not so Good
  - Better with primary solids
  - Performance with WAS should be piloted

Biosolids 101 - Program Agenda

- ~~Sludge Thickening~~
- ~~Sludge Dewatering~~
- Sludge Conditioning for Thickening and Dewatering

SLUDGE CONDITIONING FOR THICKENING AND DEWATERING

Polymer Types

- Polymer is used for sludge conditioning and to enhance settling, thickening, and dewatering

- Electronic charge
- Charge density
- Molecular weight
- Molecular structure

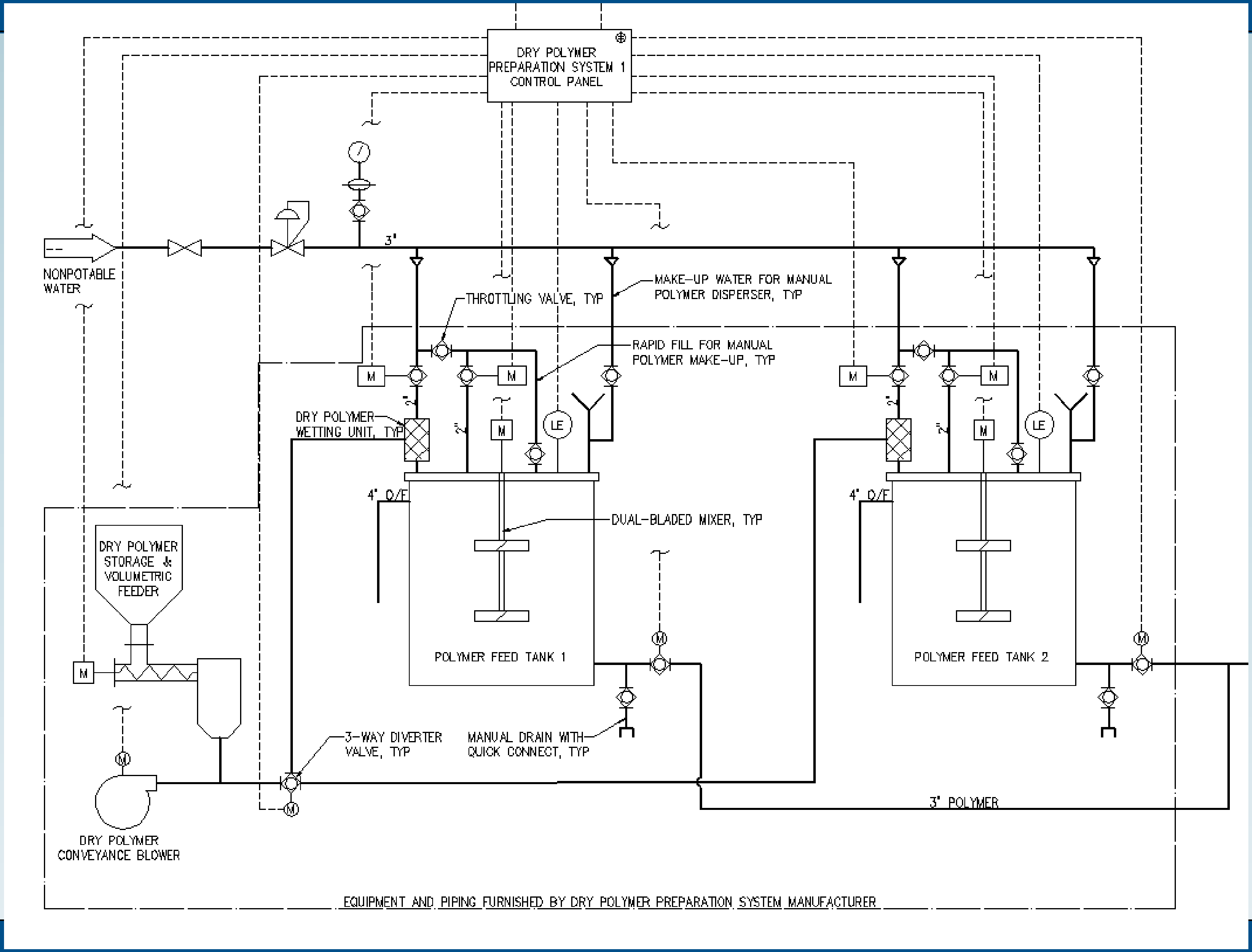
Emulsion Polymer

- Milky/cloudy liquid totes
- Higher concentration of active polymer
- Shorter self life than dry polymer
- Usually 25% to 60% active polymer

Dry Polymer

- Pellet or flake provided in large bulk bags
- Lower concentration of active polymer
- Longer shelf life than emulsion polymer

Dry Polymer


DRY POLYMER
PREPARATION SYSTEM 1
CONTROL PANEL
3"
NONPOTABLE
WATER
THROTTLING VALVE, TYP
MAKE-UP WATER FOR MANUAL
POLYMER DISPERSER, TYP
RAPID FILL FOR MANUAL
POLYMER MAKE-UP, TYP
DRY POLYMER
WETTING UNIT, TYP
LE
4" O/F
DUAL-BLADED MIXER, TYP
DRY POLYMER
STORAGE &
VOLUMETRIC
FEEDER
POLYMER FEED TANK 1
POLYMER FEED TANK 2
3-WAY DIVERTER
VALVE, TYP
MANUAL DRAIN WITH
QUICK CONNECT, TYP
3" POLYMER
DRY POLYMER
CONVEYANCE BLOWER
EQUIPMENT AND PIPING FURNISHED BY DRY POLYMER PREPARATION SYSTEM MANUFACTURER

Questions?

Laurissa Cubbage, PE

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Sludge Stabilization

HAZEN AND SAWYER
Environmental Engineers & Scientists

Sludge Stabilization - Outline

- Aerobic Digestion
- Anaerobic Digestion

AEROBIC DIGESTION

Aerobic Digestion – Overview

- Why *Aerobic* Digestion?
  - ➢Plant size (~< 5-mgd)
  - ➢Complexity
  - ➢Biosolids constraints
  - ➢Energy

Aerobic Digestion – Overview

GOAL

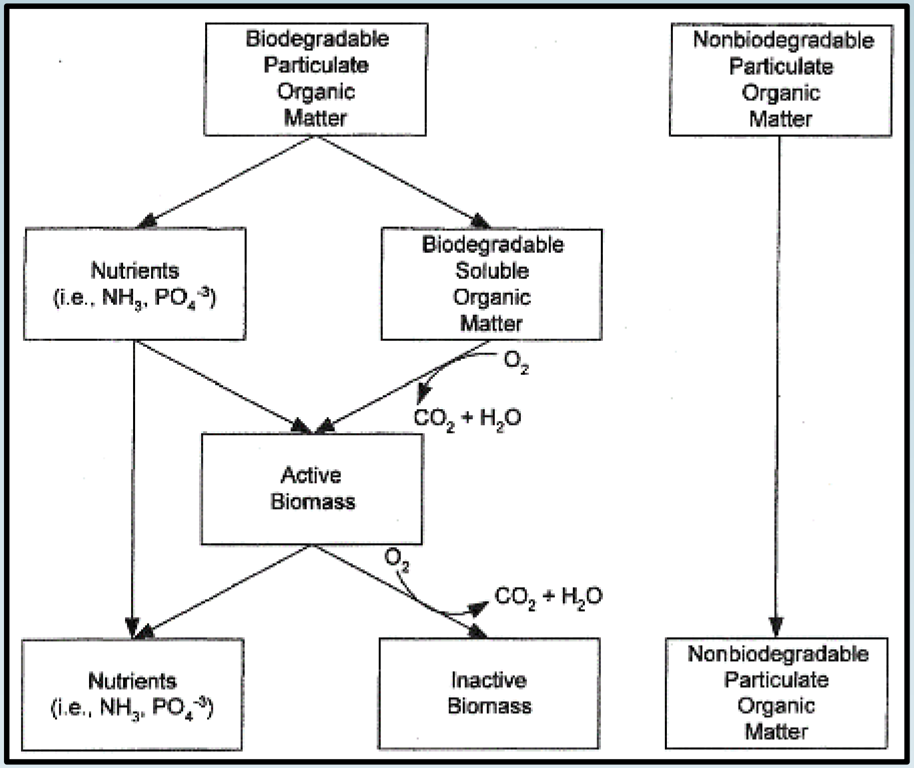
- Achieve desired volatile solids reduction (VSR) in an aerobic biological reactor.

INPUTS

- Primary sludge, WAS, or both (thickened or non-thickened)
- O_2 (via diffused air, mechanical aerator, draft tube, etc.)
- Mixing (aeration, or aeration + mixing)
- Alkalinity (naturally occurring HCO_3^-, or OH^- or CO_3^{-2} chemical addition)

OUTPUTS

- Red. sludge volume (e.g. VSR occurred)
- Supernatant



Grady, Daigger, and Lim, 1999

Aerobic Digestion – Overview

Biomass (input and food source)

Dissolved Oxygen (D.O.) from aeration

$$C_5H_7NO_2 + 7O_2 \longrightarrow 5CO_2 + 3H_2O + NO_3^- + H^+$$

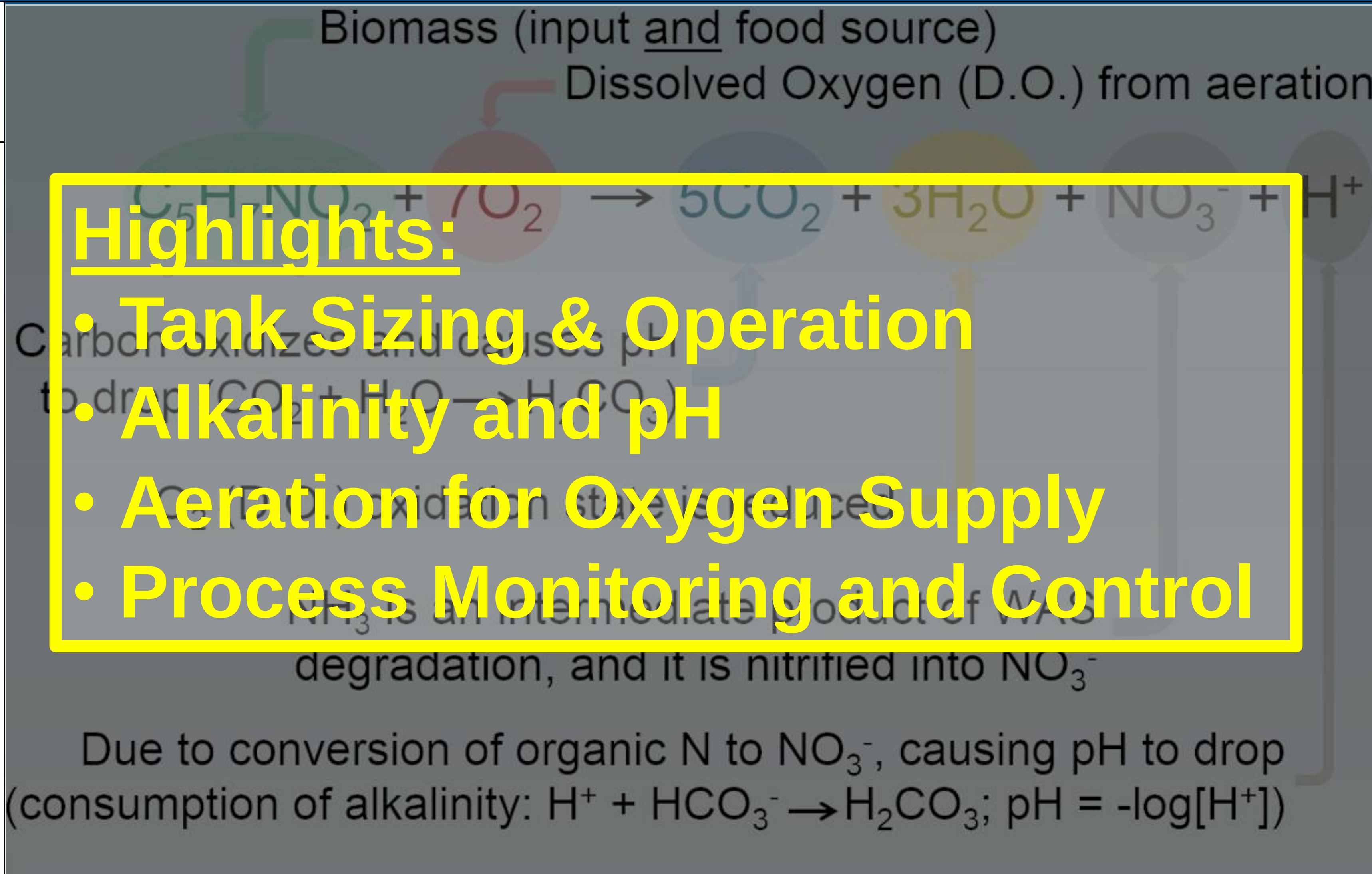
Carbon oxidizes and causes pH to drop ($CO_2 + H_2O \longrightarrow H_2CO_3$)

O_2 (D.O.) oxidation state is reduced

NH_3 is an intermediate product of WAS degradation, and it is nitrified into NO_3^-

Due to conversion of organic N to NO_3^-, causing pH to drop (consumption of alkalinity: $H^+ + HCO_3^- \longrightarrow H_2CO_3$; $pH = -\log[H^+]$)

Aerobic Digestion – Overview



Highlights:

- **Tank Sizing & Operation**
- **Alkalinity and pH**
- **Aeration for Oxygen Supply**
- **Process Monitoring and Control**

Aerobic Digestion – Tank Sizing

- Tank volume governed by solids retention time (SRT) necessary to achieve required volatile solids reduction (VSR)

$$\forall = \frac{Q(X_i + F_{PS})}{X(k_d P_v + 1/SRT)}$$

k_d at 10°C	0.02 d^{-1}
k_d at 15°C	0.06 d^{-1}
k_d at 20°C	0.10 d^{-1}
k_d at 25°C	0.14 d^{-1}

where $\forall$ = volume of aerobic digester, m^3
Q = average flowrate to digester, m^3/d
X_i = influent suspended solids, mg/L
F_{PS} = fraction of influent BOD that is raw primary solids
S = digester influent BOD, mg/L
X = digester suspended solids, mg/L
k_d = reaction rate constant, d^{-1}
P_v = volatile fraction of digester suspended solids
SRT = solids retention time, d

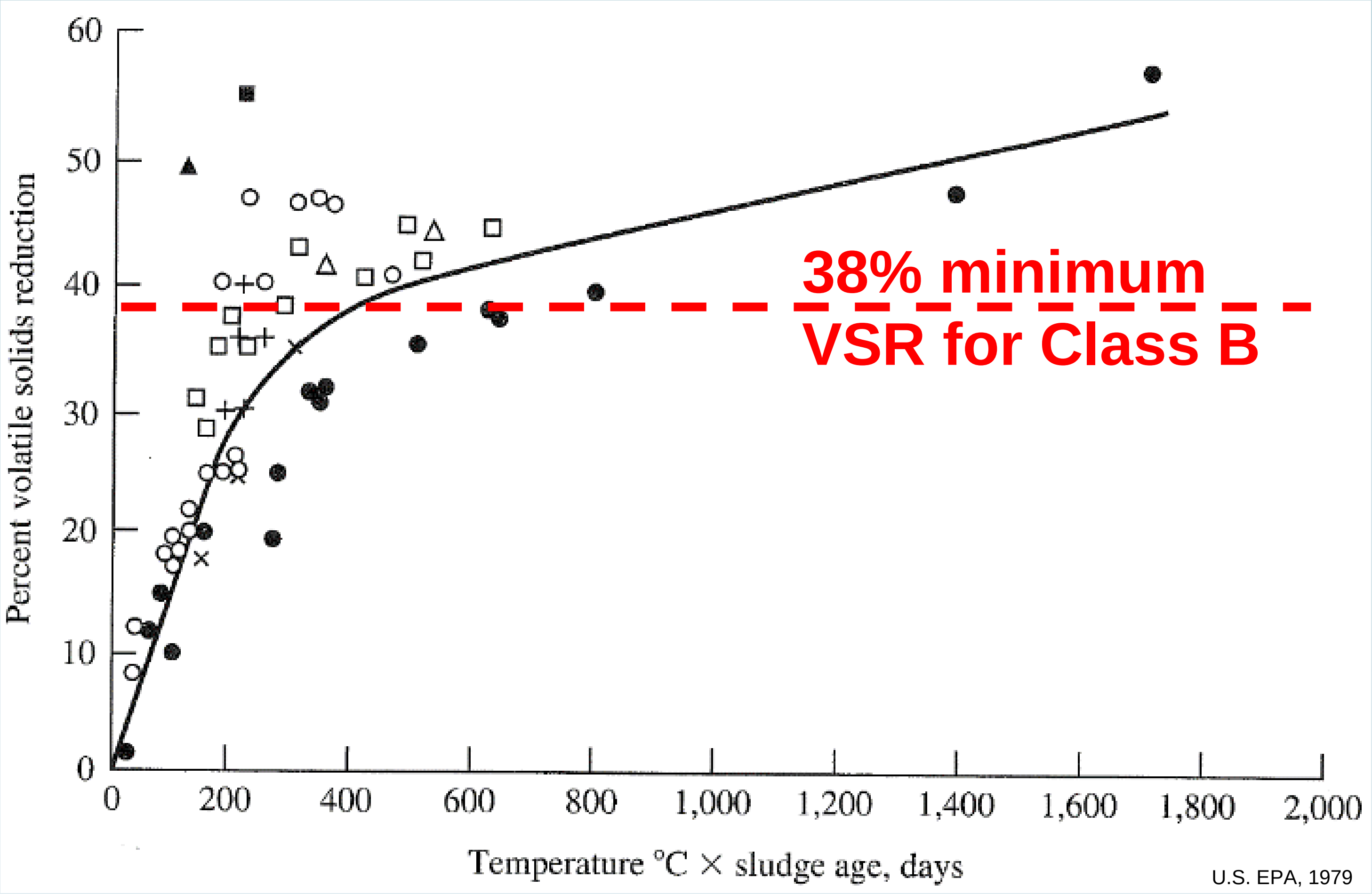
For Class B:

At 20°C	40 days
At 15°C	60 days

WEF, 1998

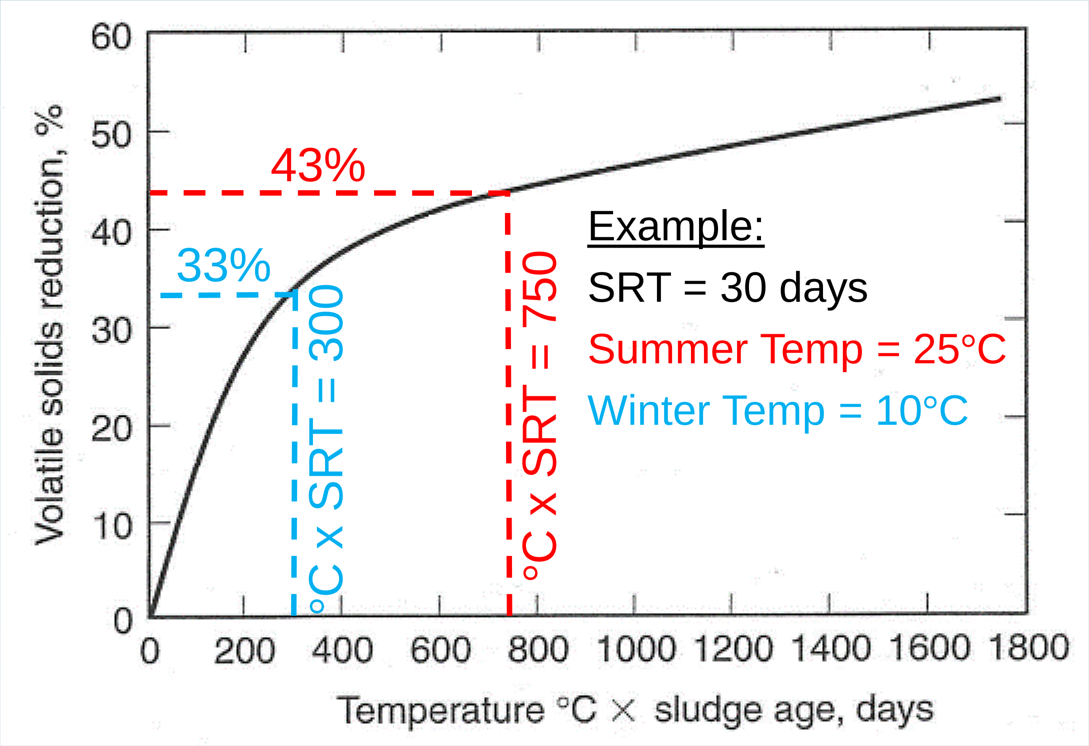
Aerobic Digestion – Tank Sizing

- VSR as function of temperature *and* SRT:



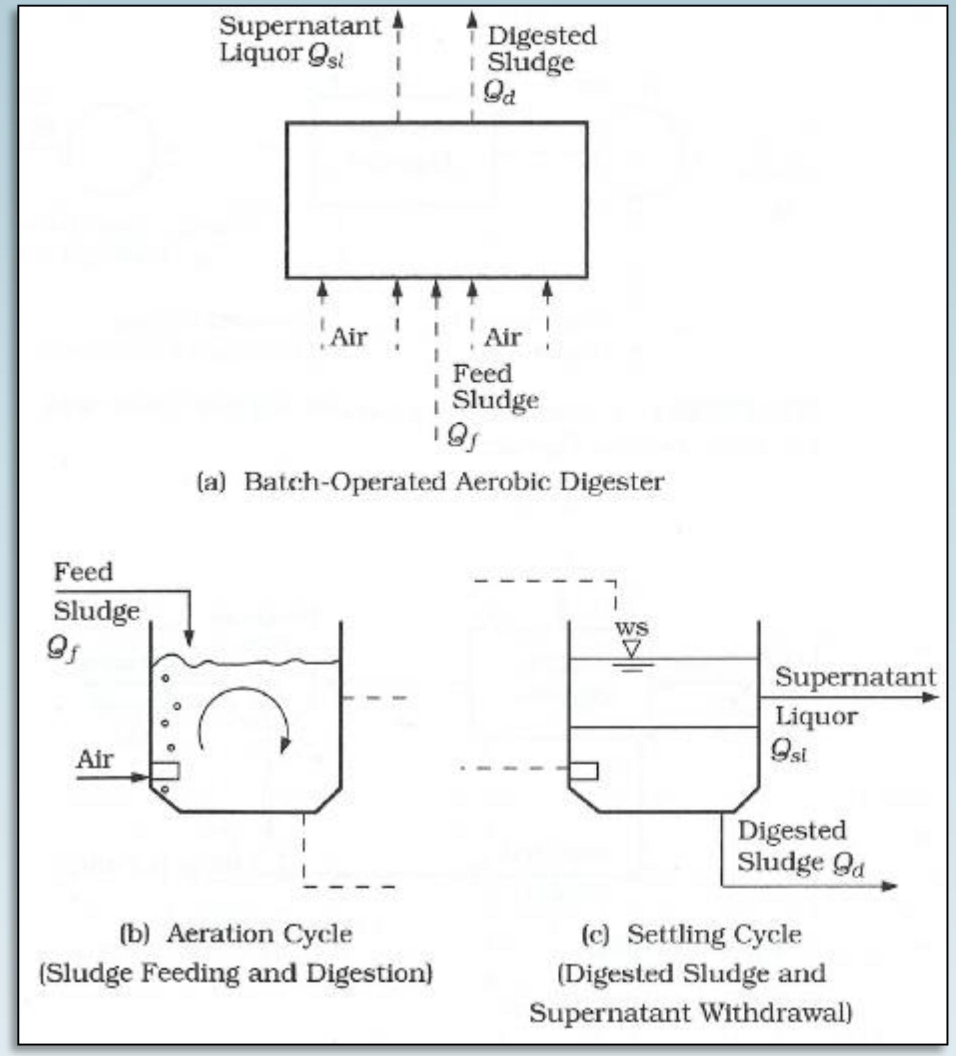
Aerobic Digestion – Tank Sizing

- VSR considerations at variable temperatures:



Aerobic Digestion – Operation

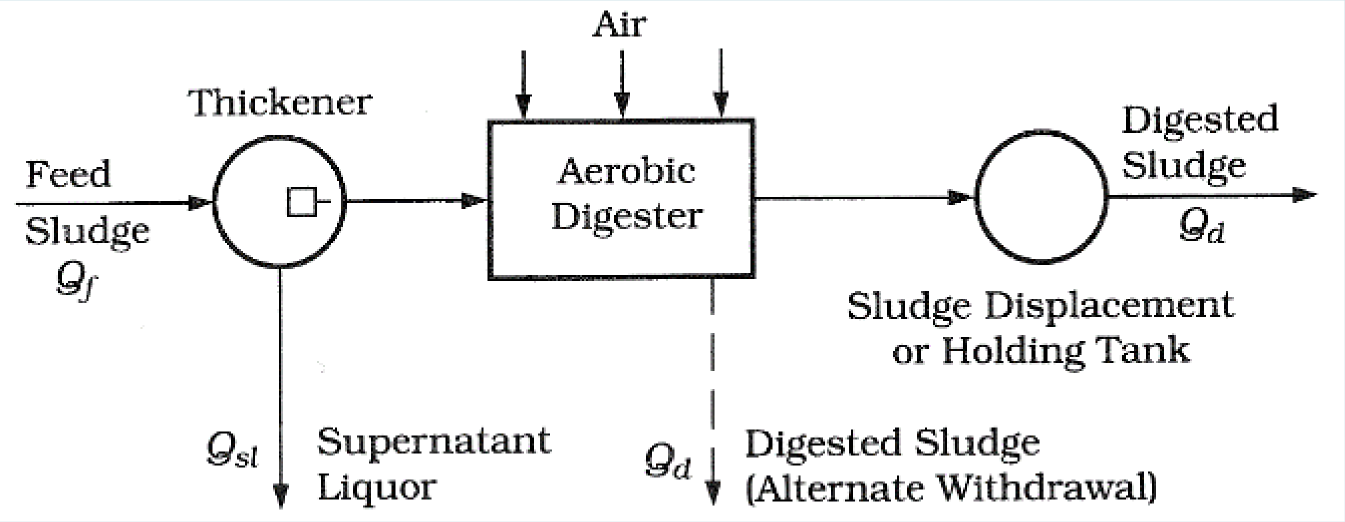
- Typical single stage batch operation
  - In-tank thickening
    - 0.5% - 1.5% TS (typ.)
  - Supernatant
    - Telescoping valve or floating decanter



Reynolds & Richards, 1996

Aerobic Digestion – Operation

- Typical single stage continuous operation
  - Upstream thickening
    - As discussed earlier in presentation
    - If thickened upstream, < ~3.5% - 4% TS for adequate tank mixing
  - Downstream thickening
    - As discussed earlier in presentation
  - Dewatered liquid from thickening



Reynolds & Richards, 1996

Aerobic Digestion – Alkalinity and pH

- Reactions during aerobic digestion (nitrif.)

$$C_5H_7O_2N + 5O_2 \rightarrow 4CO_2 + H_2O + NH_4HCO_3$$

Destruction of biomass in aerobic digestion

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

Nitrification of released ammonia-nitrogen

- Due to oxidation of ammonia
- 7 lb alkalinity cons. per lb ammonia conv.

- Reactions during aerobic/anoxic digestion (nitrif. and denit.)

$$C_5H_7O_2N + 4NO_3^- + H_2O \rightarrow NH_4^+ + 5HCO_3^- + 2N_2$$

Denitrification using nitrate-nitrogen as electron acceptor

Daigger et al. 1997

- Up to 50% recovery of alkalinity
- No aeration 25% - 50% of time
- Req. mech. mixing
- Will decrease VSR

- If pH < ~5.5, supplemental alkalinity addition required

Aerobic Digestion – Aeration for Oxygen Supply

- Maintain D.O. ≥ 1.0 mg/L during aeration
- ~2.3 lb O_2 per lb BOD oxidized
- Oxygen transfer efficiency will also dictate blower req.

Mechanical Aerator Type	Oxygen Transfer Efficiency (%)
Fine-bubble membrane diffusers (total floor coverage)[b]	20–39
Coarse-bubble diffusers[b]	10–15
Jet aerators[b]	22–27
Fixed mechanical aerators	10–18
Floating aerators	10–18
Rotor brush aerators	10–18

Typical for aerobic digestion (fine-bubble membrane diffusers and coarse-bubble diffusers)

Hammer & Hammer, 2008

Aerobic Digestion – Process Monitoring and Control

- Performance considerations:
  - VSR
  - SRT

- Monitoring considerations:

Monitoring parameter	Frequency	Operating range		
		Minimum	Nominal	Maximum
Temperature, °C	Daily	15	20	37
pH	Daily	6.0	7.0	7.6
Dissolved oxygen, mg/L	Daily	0.1	0.4 to 0.8	2.0
Alkalinity, mg/L as calcium carbonate	Weekly	100	>500	—
Ammonia-nitrogen, mg/L	Weekly	—	<20	40
Nitrate, mg/L	Weekly	—	<20	—
Nitrite, mg/L	As required	—	<10	—
SOUR, mg oxygen/h/g total solids	As required	—	<1.5	—
Phosphorus, mg/L	As required		<5	

Stege and Bailey, 2003

Sludge Stabilization - Outline

- ~~Aerobic Digestion~~
- Anaerobic Digestion

ANAEROBIC DIGESTION

Anaerobic Digestion – Overview

- Why *Anaerobic* Digestion?
  - ➢Plant size
  - ➢Biosolids constraints
  - ➢Energy

Anaerobic Digestion – Overview

GOAL

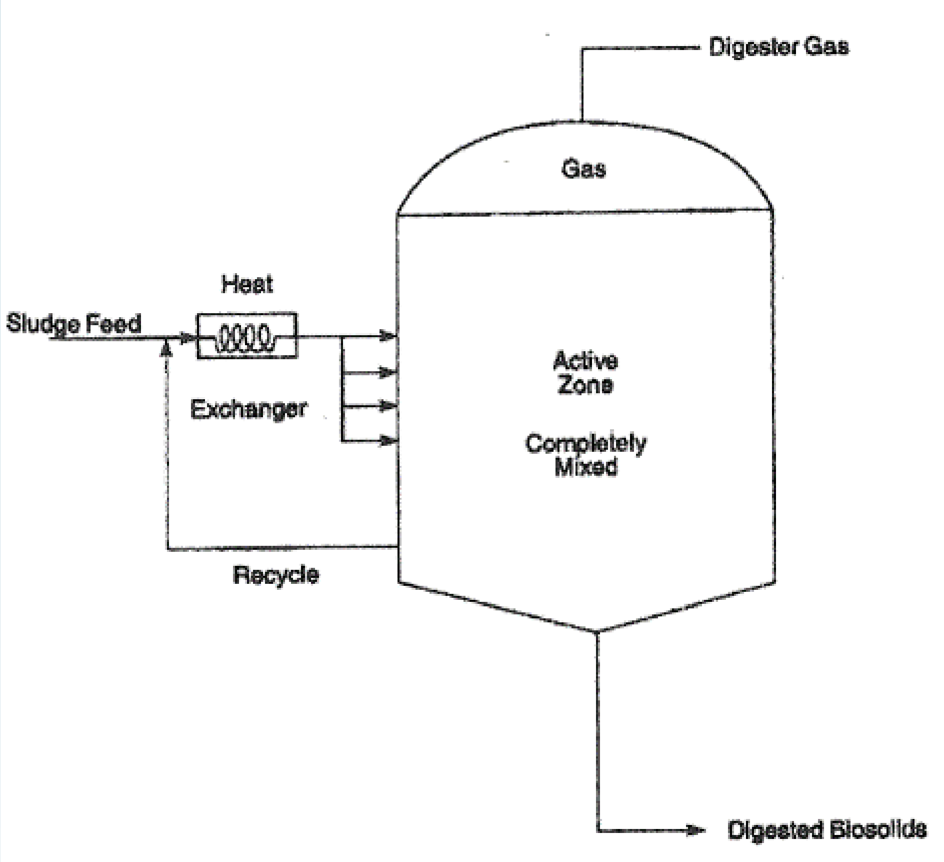
- Achieve desired VSR in an anaerobic biological reactor, and recover byproducts of process as valuable resources

INPUTS

- Primary sludge, WAS, or both (thickened)
- Heat (via heat exchanger)
- Mixing (biogas or mech. mixing)

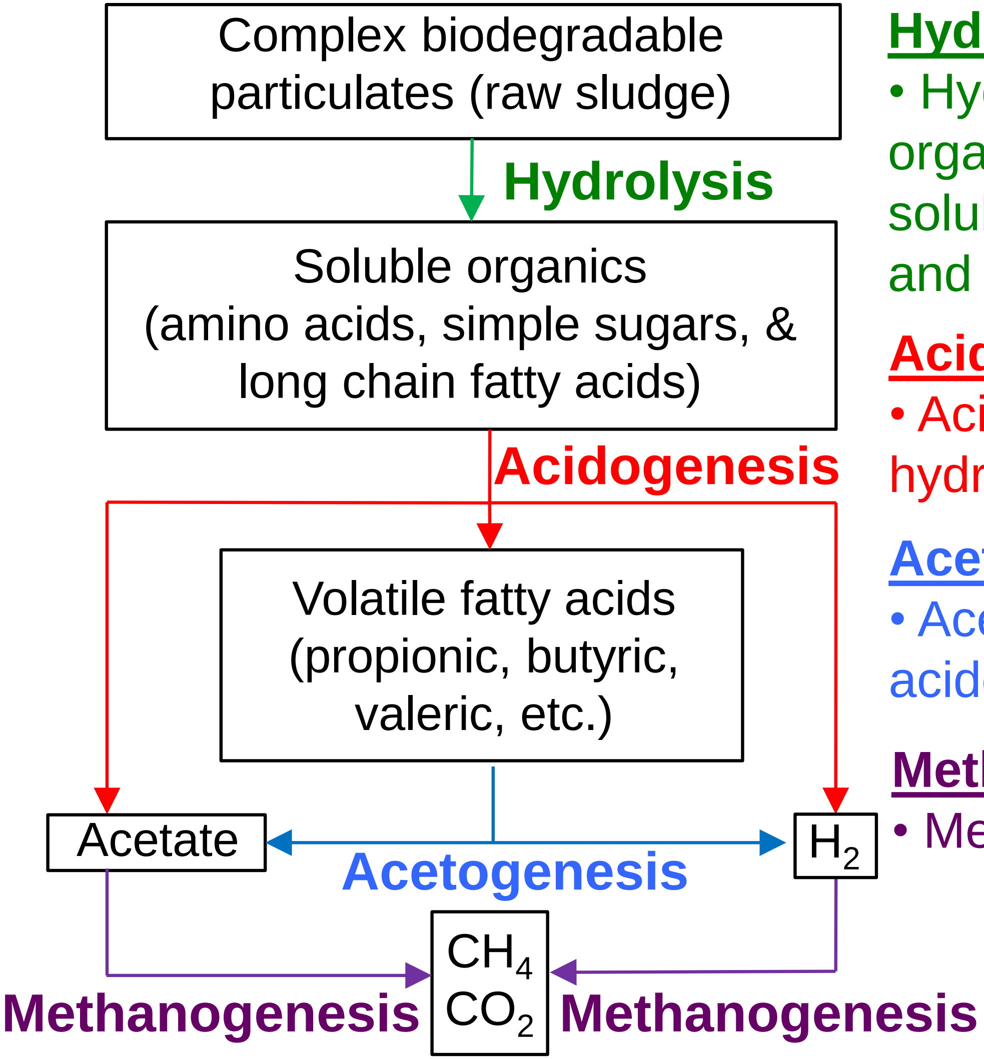
OUTPUTS

- Digested sludge w/ red. volume (e.g. VSR occurred)
- Dewatered liquid
- Methane rich biogas
- Nutrient rich biosolids



WEF, 2010

Anaerobic Digestion – Overview



Hydrolysis:

- Hydrolytic bacteria convert complex organics into smaller molecules, and solubilized to amino acids, simple sugars, and LCFA

Acidogenesis:

- Acidogenic bacteria convert products of hydrolysis into VFAs, acetate, and H_2

Acetogenesis:

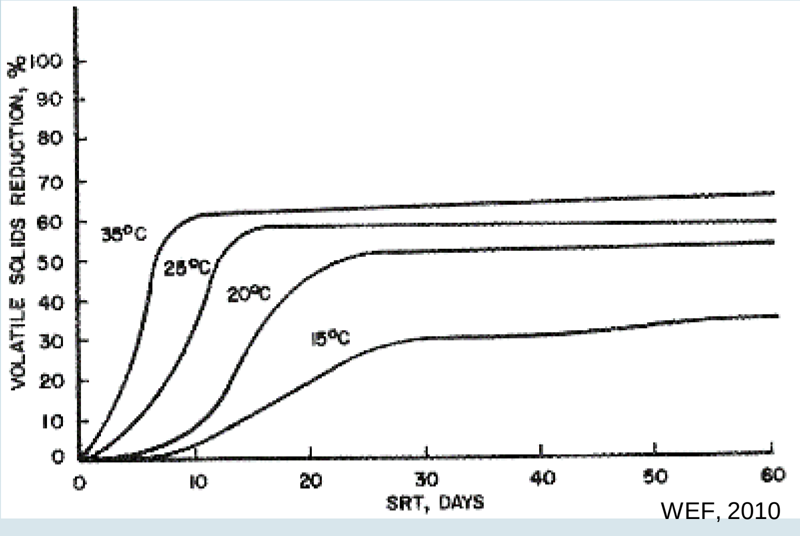
- Acetogenic bacteria convert products of acidogenesis into acetate & H_2

Methanogenesis:

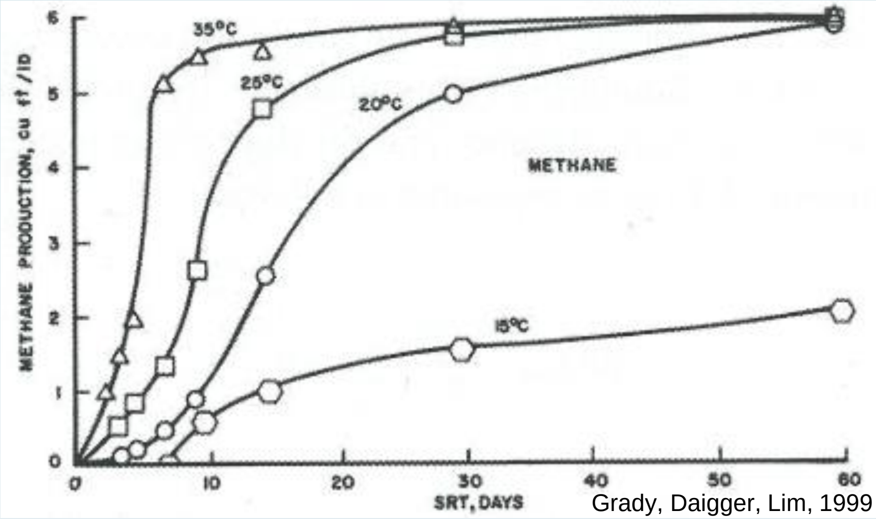
- Methanogenic Archae generate CH_4
  - Aceticlastic (acetate → CH_4 + CO_2)
  - Hydrogenotrophic (H_2 + CO_2 → CH_4)

Anaerobic Digestion – Temperature Regime

- Temperature impacts anaerobic digestion
  - ➢ VSR
  - ➢ Methane formation



WEF, 2010



Grady, Daigger, Lim, 1999

Anaerobic Digestion – SRT and Tank Sizing

- REMINDER → CFR 503 mandates:
  - Class B biosolids: SRT = 15-days
  - Class A biosolids:
    - If feed sludge < 7% TS: SRT (days) = $50{,}070{,}000/10^{0.14T}$
    - If feed sludge ≥ 7% TS: SRT (days) = $131{,}700{,}000/10^{0.14T}$

- SRT = HRT = Tank Volume / Q

  - **Tank Volume = SRT x Q**

Anaerobic Digestion – Mixing

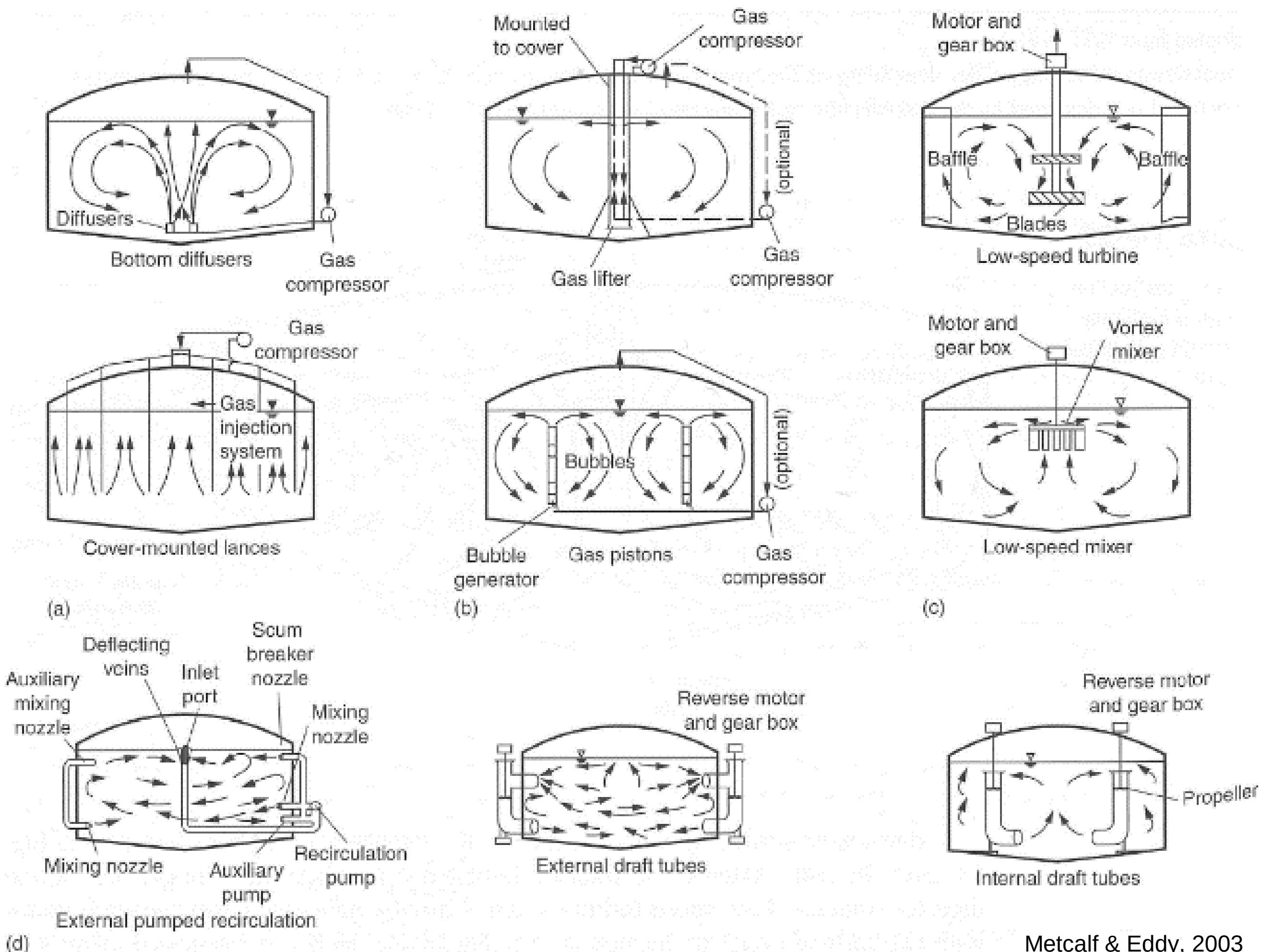
Digester mixing is vital for some of the following reasons:

- Reduction of thermal stratification
- Dispersion of "food"

<u>Primary methods:</u>

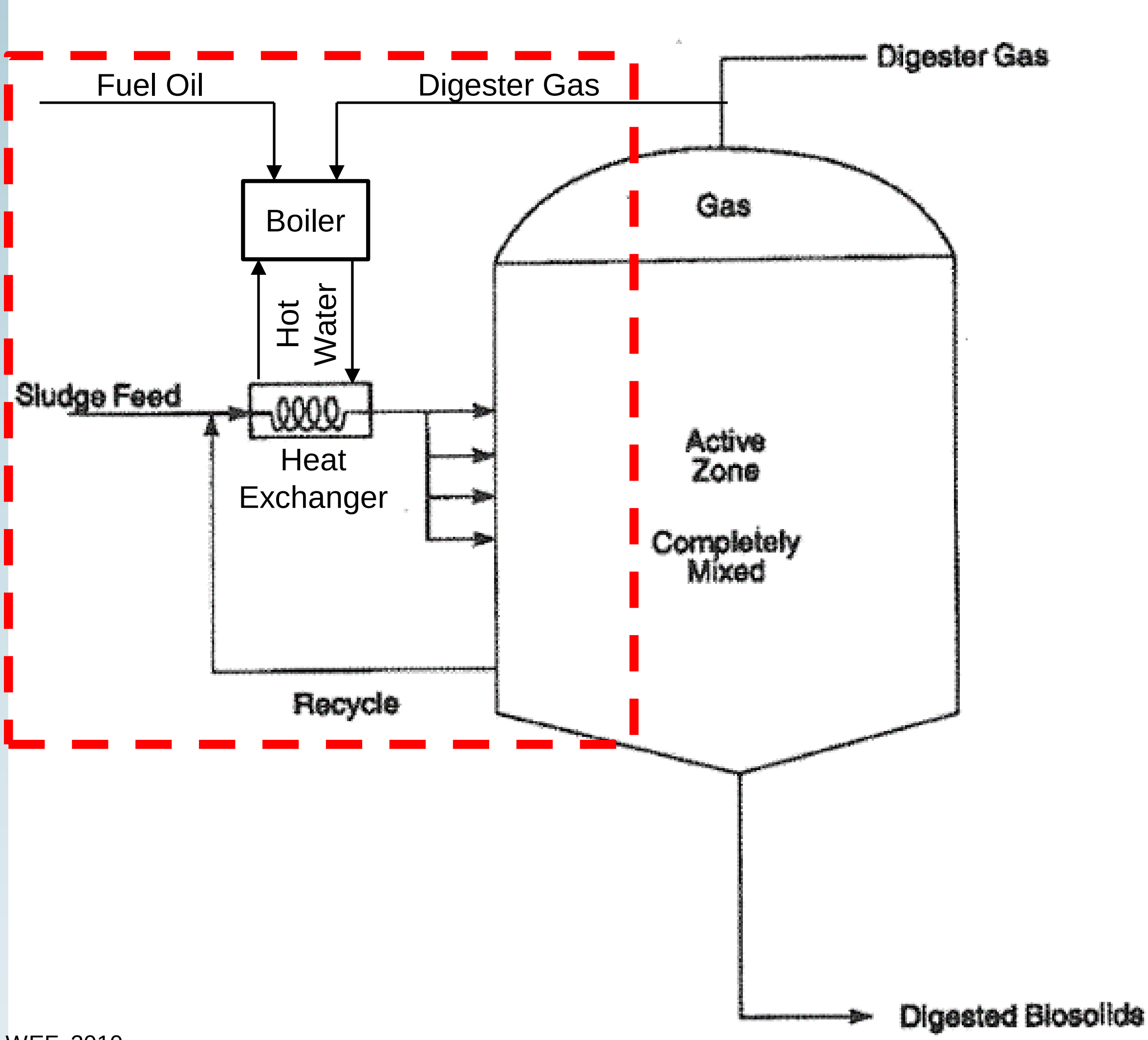
1. Mechanical
   - Pumped
   - Impeller, propeller, and turbine wheels

3. Gas recirculation
   - Tubes, lances, and diffusion



Metcalf & Eddy, 2003

Anaerobic Digestion – Heating and Temperature Control



WEF, 2010

Anaerobic Digestion – Heating and Temperature Control

Depending on desired operation, digester contents are heated to:

- Mesophilic temperatures (~35°C, ~95°F)
- Thermophilic temperatures (~55°C, ~131°F)

Heat is imparted to sludge via Heat Exchanger:

<u>Concentric Pipe</u>

www.hrs-heatexchangers.com

<u>Spiral Plate</u>

www.tranter.com

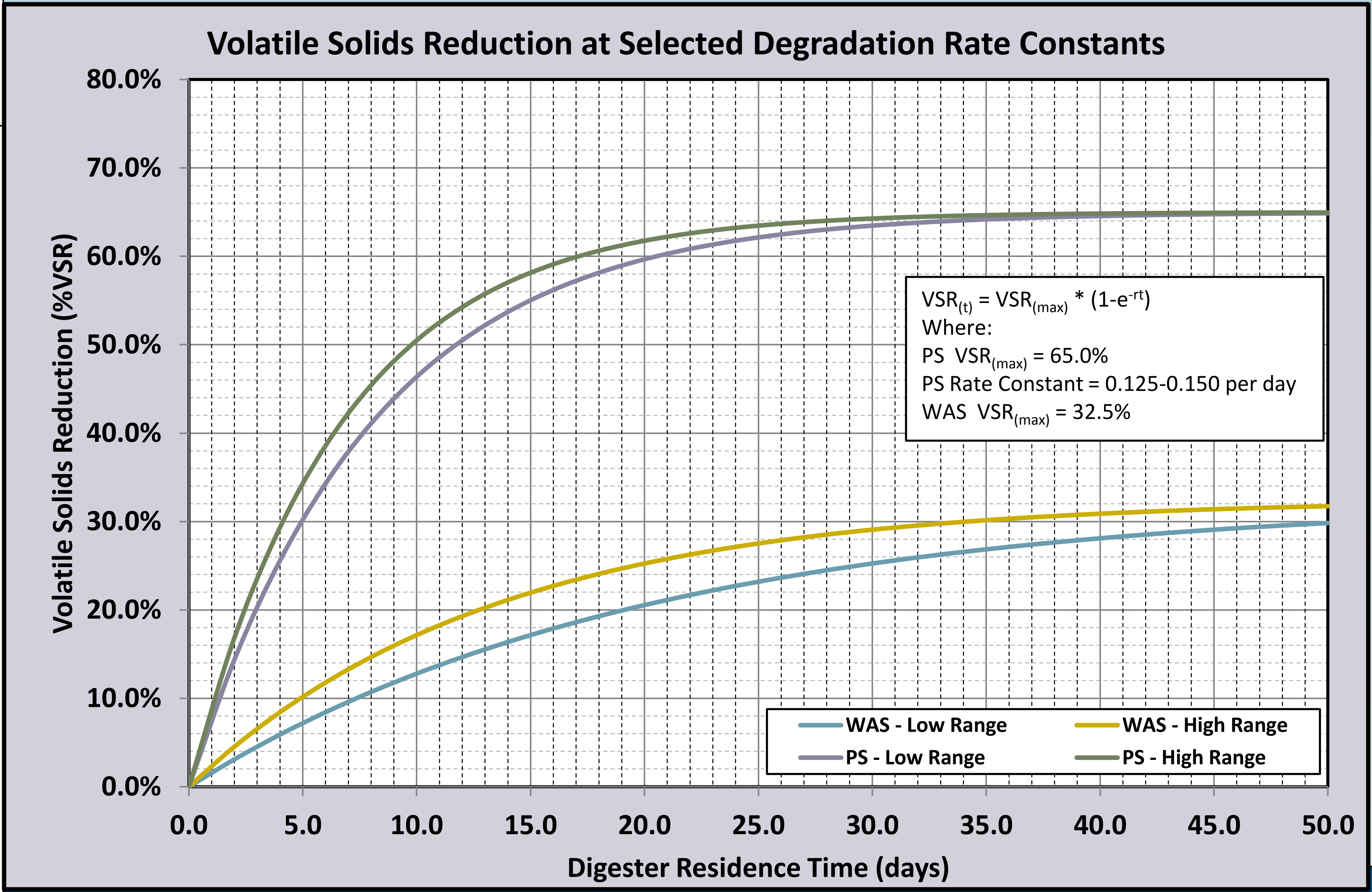
Typ. heat sources for Heat Exchangers from biogas combustion:

- Fired boilers (steam or hot water) from biogas or fuel oil combustion
- Cogeneration (AKA “CHP”, or combined heat and power)
- Water-source heat pump

Anaerobic Digestion – Monitoring and Control

- Temperature
  - ➢ Maintain mesophilic or thermophilic temperature range
  - ➢ Daily temperature deviation ≤ 0.6 °C (1 °F)
- pH
  - ➢ Desired operating range is 6.8 to 7.2, ideal for methanogens
    - At pH < 6, un-ionized volatile acids are toxic to methanogens
    - At pH > 8, un-ionized ammonia is toxic to methanogens
- Alkalinity
  - ➢ Ammonium bicarbonate (NH_4HCO_3), calcium, and magnesium
  - ➢ Desirable range: 1,500 – 5,000 mg/L and $CaCO_3$
- Volatile Acids
  - ➢ VA: ALK ratio = volatile acids (mg/L) / alkalinity as $CaCO_3$ (mg/L)
    - 0.3 – 0.4 corrective action needed; > 0.8 methane inhibition

Anaerobic Digestion – Implications of Sludge Feed Type



Anaerobic Digestion – Implications of Sludge Feed Type on Overall Mass Red.

Plant Type	No Primary Clarifiers	With Primary Clarifiers	
		Primary	Secondary
Feed Solids Rate (lbs/MG Treated)	1,780 0.77 VS/TS	1,250 0.80 VS/TS	970 0.82 VS/TS
Digester MCRT (days)	20	20	20
Volatile Solids Reduction (% VSR)	22.5%	62.5%	22.5%
Volatile Solids Destroyed (lbs VSR/MG Treated)	310	625	180
Post Digestion Solids (lb/MG Treated)	1,470	1,415	

Note: Sludge production estimate based on 250 mg/L influent BOD and TSS concentration, 10-day MCRT activated sludge process, 30% BOD removal and 60% TSS removal in primary clarifiers (where applicable), influent VS/TS fraction 0.80, 20% influent volatile solids un-degradable particulate solids.

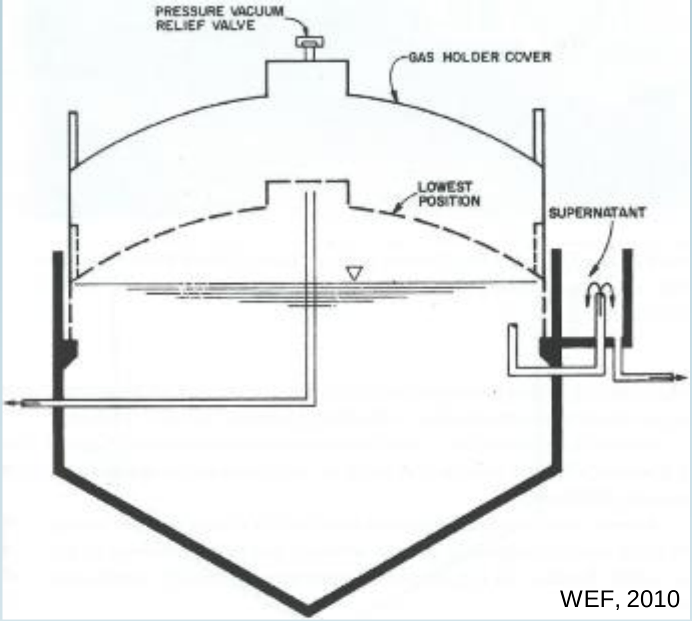
Anaerobic Digestion – Implications of Sludge Feed Type on Digester Gas Yield

Plant Type	No Primary Clarifiers	With Primary Clarifiers	
		Primary	Secondary
Feed Solids Rate (lbs/MG Treated)	1,780 0.77 VS/TS	1,250 0.80 VS/TS	970 0.82 VS/TS
Digester MCRT (days)	20	20	20
Volatile Solids Reduction (% VSR)	22.5%	62.5%	22.5%
Volatile Solids Destroyed (lbs VSR/MG Treated)	310	625	180
Gas Production (SCF/MG Treated)	4,700	12,100	

Note: Sludge production estimate based on 250 mg/L influent BOD and TSS concentration, 10-day MCRT activated sludge process, 30% BOD removal and 60% TSS removal in primary clarifiers (where applicable), influent VS/TS fraction 0.80, 20% influent volatile solids un-degradable particulate solids, gas production rate of 15 SCF/lb VSR.

Anaerobic Digestion – Tank Types

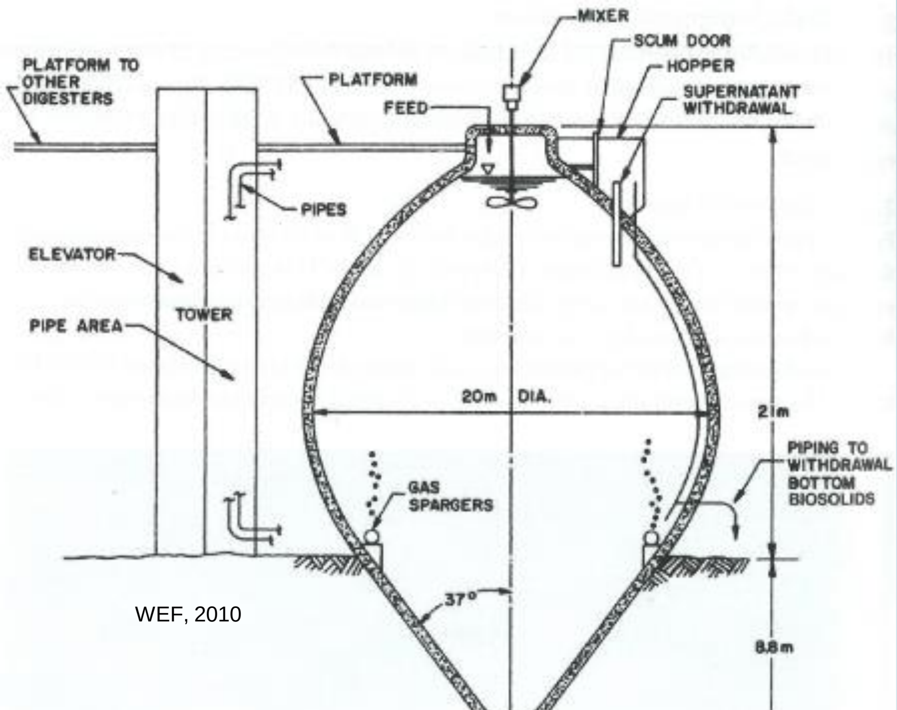
Cylindrical ("Pancake") Digester



- Most common configuration
- Easier & cheaper to construct
- Geometry permits operational flexibility
- Prone to dead zones, lower VSR, and grit deposition (frequent cleaning)
- Reinforced conc. w/ sloped bottom

Anaerobic Digestion – Tank Types

Egg-Shaped Digester



WEF, 2010

- Optimal shape for digestion (excellent mixing, higher active tank volume, low grit deposition)
- Specialty (expensive) construction
- Limited integral gas volume
- Reinforced conc. or steel

Anaerobic Digestion – Gas Production

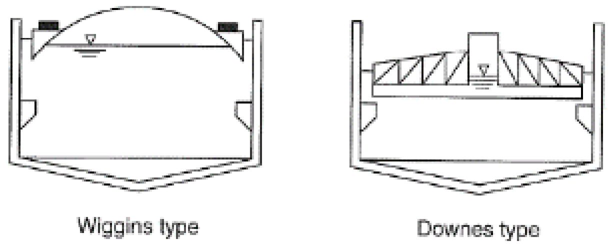
- Biogas yield = 12 – 18 ft^3/lb volatile solids destroyed

- Biogas Constituents
  - 65% - 70% CH_4 (by volume)
  - 25% - 30% CO_2 (by volume)
  - Remainder: N_2, H_2, H_2S, water vapor, other gases

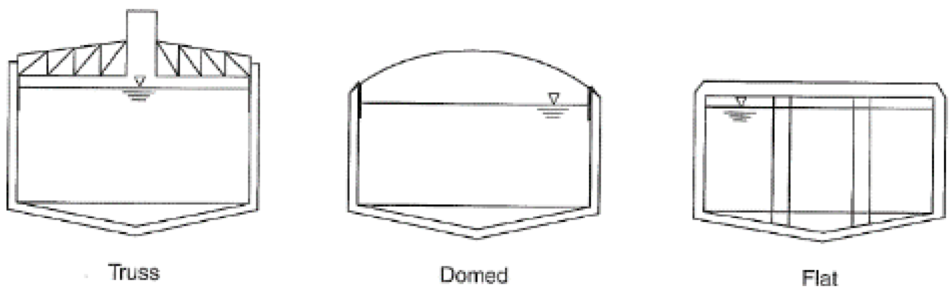
- Lower heating values:
  - Methane = 960 Btu/ft^3
  - Biogas = 600 Btu/ft^3
  - By comparison → Natural Gas = 1,000 960 Btu/ft^3

Anaerobic Digestion – Gas Storage

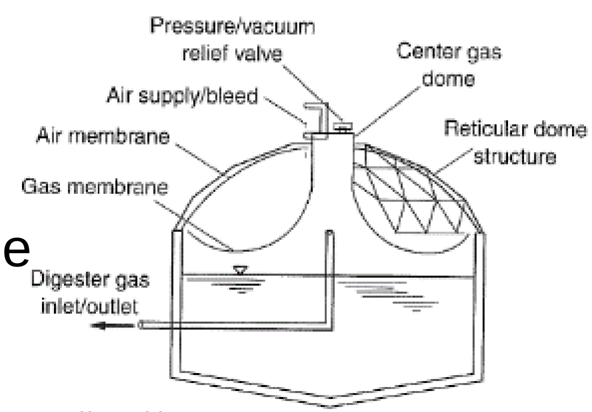
Floating



Fixed



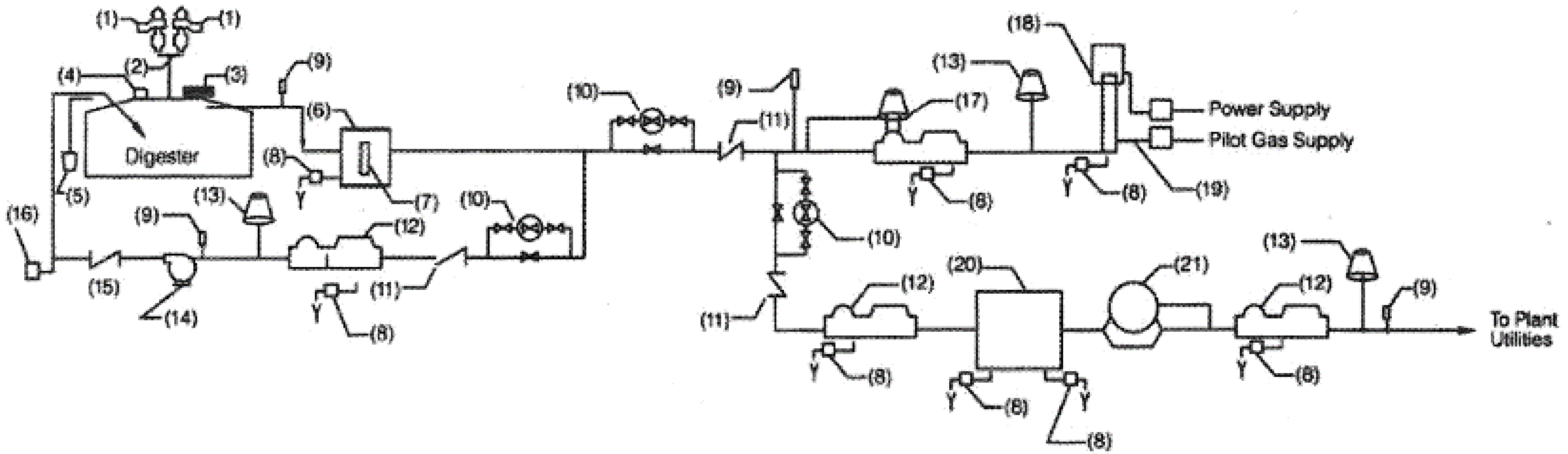
Membrane



Metcalf & Eddy, 2003

Anaerobic Digestion – Biogas Handling and Safety

Example Diagram: Single Digester w/ Gas Mixing System



Legend

Item	Description	Item	Description
1	Press/VAC Relief Valve with Flame Arrester	12	Flame Trap Assembly
2	Three-way Valve	13	Pressure (Explosion) Relief Valve
3	Manhole Cover	14	Blower/Compressor
4	Sampling Hatch Cover	15	High-Pressure Check Valve
5	Cover Position Indicator (for Floating Roof)	16	High-Pressure Drip Trap
6	Condensate and Sediment Trap	17	Pressure Relief and Flame Trap Assembly
7	Sight Glass	18	Waste Gas Burner and Ignition System
8	Low-Pressure Drip Trap	19	Flame Check
9	Manometer	20	Gas Purifier
10	Flowmeter	21	Double Port Regulator
11	Check Valve		

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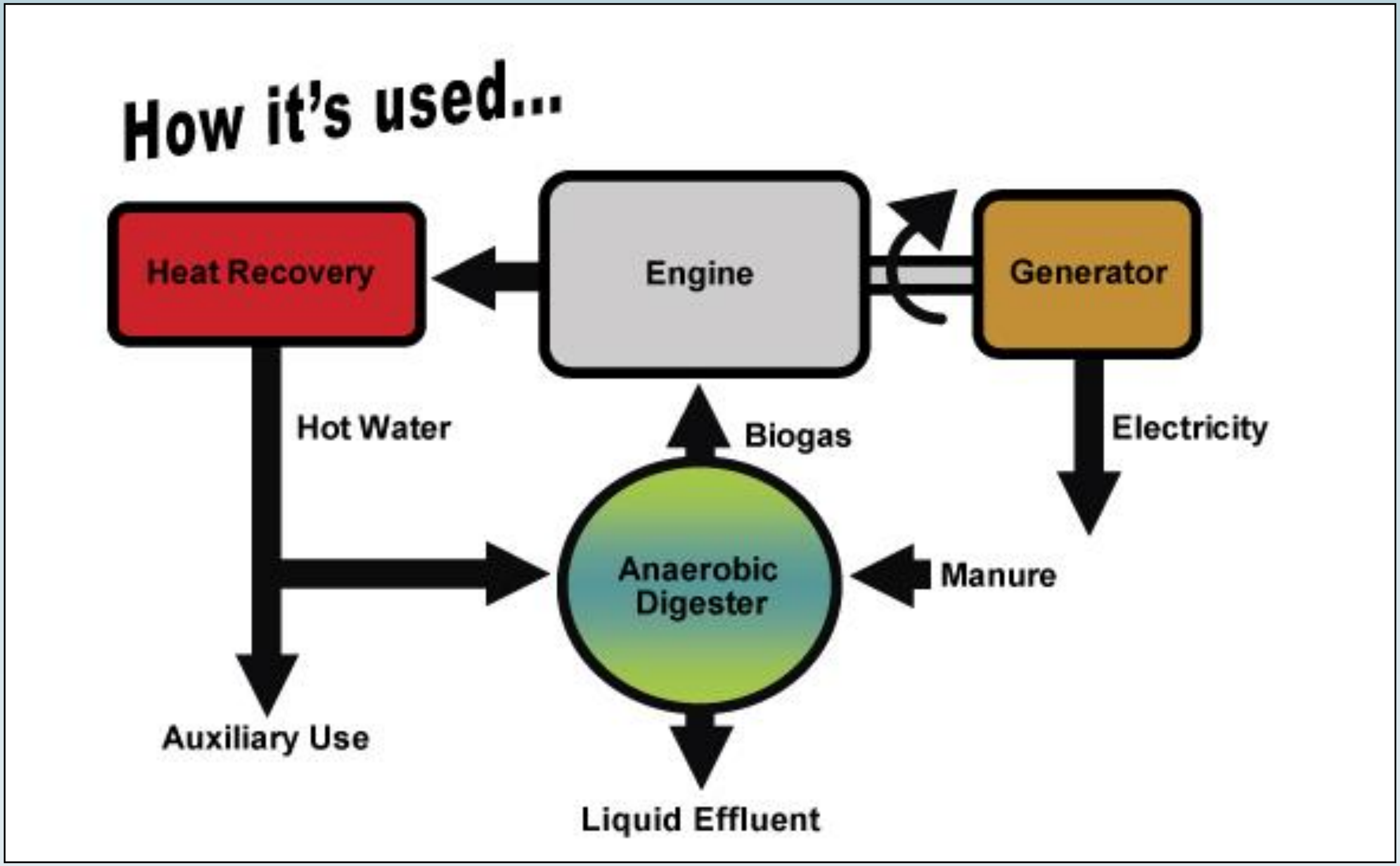
Anaerobic Digestion – Biogas Handling and Safety

Anaerobic Digestion – Biogas Utilization

Combined Heat and Power



Anaerobic Digestion – Biogas Nuisance Issues and Treatment

Hydrogen Sulfide

How is it primarily generated?

1. Presence of sulfate (SO_4^{-2}) in sludge

$$SO_4^{-2} \xrightarrow[\textit{bacteria}]{\textit{sulfate reducing}} S^{-2} \xrightarrow{H^+} HS^- \xleftrightarrow[\textit{pH and temp.}]{\textit{conc. dep. on}} H_2S$$

2. Degradation of proteins in sludge

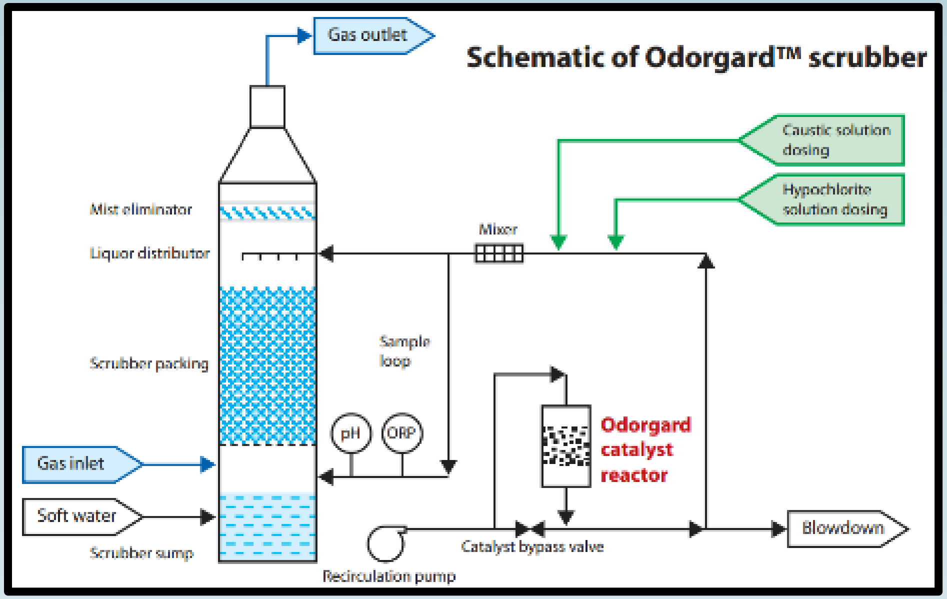
$$\text{Proteins} \xrightarrow[\textit{hyd.}]{\textit{enz.}} \text{Cysteine} \xrightarrow[\textit{deg.}]{\text{bac.}} S^{-2} \xrightarrow{H^+} HS^- \xleftrightarrow[\textit{pH and temp.}]{\textit{conc. dep. on}} H_2S$$

What sorts of problems does H_2S cause?

- Diminished methane production (due to bacterial competition and sulfide toxicity to methanogens)
- Corrosion & acidification
- Criteria pollutant (SO_X) when combusted

Anaerobic Digestion – Biogas Nuisance Issues and Treatment

Hydrogen Sulfide Removal



Iron Sponge

- Iron oxide impregnated wood chips
- Converts H_2S to elemental iron & sulfur, and water

Chemical Scrubber

- Uses high pH liquid (e.g. caustic) for H_2S absorption to packed media
- Requires oxidant (e.g. sodium hypochlorite) to manage adsorbent disposal issues & extend media life

Anaerobic Digestion – Biogas Nuisance Issues and Treatment

Siloxanes and SiO_2 (Sand) Deposition

How is it primarily generated?

- Siloxane compounds volatilize from sludge during digestion
  - Enters WWTP influent due to heavy use in commercial cosmetic and hygienic products (e.g. shampoo, deodorant)
- Siloxane compounds are combusted with biogas, become SiO_2

WERF, 2011

What sorts of problems does SiO_2 cause?

- Decreased efficiency of energy recovery equipment
- Voiding of equipment warranties
- Catastrophic failure of energy recovery systems

WERF, 2011

Anaerobic Digestion – Biogas Nuisance Issues and Treatment

Siloxane Removal

Carbon Adsorption

- Gas-phase siloxane compounds adsorbed onto activated carbon
- Requires upstream H_2S and moisture removal

Cryogenic Condensation

- Most biogas chilled to -25°C (or lower), gas-phase siloxanes condensed and removed.
- Developing technology, mixed successes

Questions?

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