Wastewater Treatment
Biosolids and Sludge Handling

1

Wastewater Treatment

Objectives

2

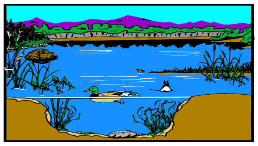
Management Objectives for Wastewater Systems

1. Collect and accept waste from the generator (residential, commercial, industrial) and dispose of it in a cost-effective and efficient manner that protects public health and safety.
2. Return the waste and the water used to transport it back to the environment in an acceptable form.

3

Why Collect and Treat Wastewater from Homes, Businesses, and Industries?

…to reduce the threat of water pollution in nearby waterways; the Potomac River and the Chesapeake Bay



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Clean Water Act (CWA)

- The 1972 Clean Water Act:
  - Set the basic structure for regulating point source discharges of pollutants into US waterways
  - Gives EPA authority to set **water quality standards** for contaminants:
    - Attain water quality levels that make surface waters safe to fish and/or swim in
    - Restore and maintain the chemical, physical, and biological integrity of the nation's waterways

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Clean Water Act (CWA)

- The CWA makes it unlawful for any person to discharge any pollutant from a point source into navigable waters unless a NPDES discharge permit is obtained
- NPDES - National Pollutant Discharge Elimination System
- WWTPs are self-monitored
  - Monthly "Discharge Monitoring Reports" (DMRs)
- EPA has delegated monitoring responsibility to states

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Wastewater Collection and Treatment

- Suspended Solids – the quantity of solid materials floating in the water column
- BOD – a measure of the amount of oxygen required to aerobically decompose organic matter
- TN – NH_3 + NO_2 + NO_3 + Org-N (Soluble and Particulate)
- TP – PO_4 + Org-P + Poly-P (Soluble and Particulate)
- pH – an expression of the intensity of basic or acidic conditions, 0 (most acidic) to 14 (most basic); 7 neutral
- Alkalinity – capacity of wastewater to neutralize acids, as $CaCO_3$

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Goals of Wastewater Treatment

- Removal of:
  - **Suspended solids and organic matter** (cBOD and nBOD) to limit pollution
  - **Nutrients** (TP and TN) to limit eutrophication
  - **Microbiological contamination** to eliminate infectious diseases
- Required levels of treatment are based on NPDES regulations as prescribed in issued discharge permits

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Wastewater Treatment (Effluent)

Pollutant	*Removal*
Suspended Solids	>90%
Pathogens	>99.9%
BOD	>90%
Nutrients	>90%
Organics/Metals	trace

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Wastewater Collection and Treatment

1. Industrial Pre-treatment Program
2. Collection system
3. Plant Laboratory
4. Preliminary treatment
5. Primary treatment
6. Secondary (Biological) treatment
7. Advanced (Tertiary) treatment (Filtration/ nutrient removal)
8. Disinfection
9. **Sludge (biosolids) handling and disposal**
10. Maintenance

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Biosolids

Overview

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Purpose of Today's Class

- To discuss biosolids/sludge sources, dewatering characteristics, and the importance of removing biosolids/sludge daily
- To focus on technologies for biosolids/sludge handling – thickening, stabilization, dewatering, and post-dewatering

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Learning Objectives

Participants will be able to:

- Discuss the federal regulatory framework for management of sewage sludge
- Discuss major sludge thickening unit processes
- Discuss major sludge stabilization unit processes
- Discuss major sludge dewatering unit processes
- Discuss post-dewatering and disposal options

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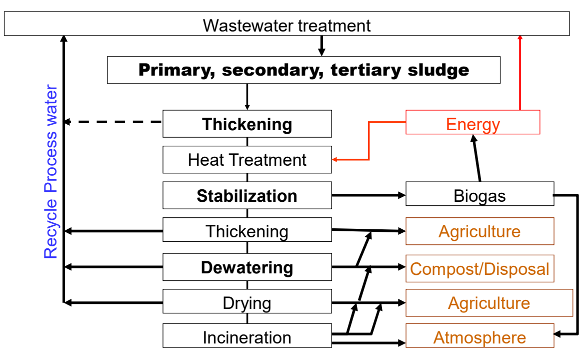
Overview



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Goals of Sludge Treatment

Volume reduction
- Thickening
- Dewatering

Elimination of pathogenic germs
- If used in agriculture as fertilizer or compost

Stabilization of organic substances
- Gas production
- Reduction of dry content
- Improvement of dewatering
- Reduction of odors

Recycling of substances
- Nutrients, fertilizer
- Humus
- Biogas

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Agenda/Focus

1. Sludge Characteristics
2. Regulatory Framework
3. Sludge Thickening
4. Sludge Stabilization
5. Sludge Dewatering
6. Post-dewatering Treatment
7. Disposal

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Participant Focus

- What information can you use at your work location?
  - About the current technology
  - About best practices
  - About sludge handling problems
- What information can you contribute to the discussion?
  - Thickening
  - Stabilization – Anaerobic Digestion
  - Dewatering
  - Post-dewatering

17

Introduction

Definitions and Acronyms

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Microorganisms

- **Aerobic** (Oxic) - Organisms requiring, or not destroyed, by the presence of free oxygen
- **Anoxic**: Organisms requiring , or not destroyed, by the absence of free oxygen; nitrates (NO_3) are present.
- **Anaerobic** - Organisms requiring, or not destroyed, by the absence of free oxygen and NO_3
- **Facultative** - Organisms able to function both in the presence or absence of free oxygen
- **Heterotrophic** - Organisms that use organic materials as their source of cell carbon
- **Autotrophic** - Organisms able to use carbon dioxide and other inorganic matter as their source of carbon
- **Filamentous** – Bulking organisms that grow in thread or filamentous form

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Sludge Stabilization and Dewatering

Stabilization – Converting sludge to a form that resists change. Typically, organic fraction of sludge is reduced such that organic matter will not give off obnoxious odors.

Dewatering – Separating water from sludge, with or without chemical or thermal conditioning. Typically, sludge is considered dewaterable if water will drain readily from it.

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Sludge Stabilization and Dewatering

Stabilization

- Reduces Volatile Solids
- Reduces Odor Potential
- Reduces Pathogens
- Variable Effect on Disposal Costs

Dewatering

- Reduces Water Volume
- Returns Fines Back to Head of Plant
- Major Effect on Disposal Costs

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Sludge Characteristics

Organic (Volatile) Portion – Volatile matter in sludge lost on ignition of dry solids at 550 degrees Celsius.

Inorganic Portion – Nonvolatile matter which is not lost on ignition of dry solids at 550 degrees Celsius.

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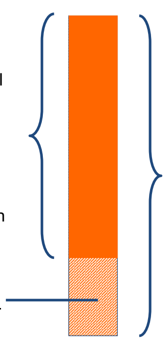
Organic Solids and Inorganic Solids

Volatile solids (VS)
- "Organic solids"
- Fraction of the total solids burnt off (volatilised) in the muffle oven at 520°C
- Only the volatile solids can be broken down by anaerobic digestion



Inorganic or inert solids

Total solids (TS)
- = (organic solids + inorganic solids)
- Measured after drying at 105°C
- "Dry solids" is another word for total solids

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Sludge Characteristics

Specific Gravity – Weight of a particle, substance, or chemical solution relative to water. Water has a specific gravity of 1.0. Sludge particles have a specific gravity of ~0.5 (Scum) to 2.5 (Sand)

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Sludge Characteristics

- Solids Concentration: 1% = 10,000 mg/L
- Volatile solids reduction is NOT total solids reduction.
- Dewatering: Doubling the solids' concentration reduces the sludge volume by half
- Hauling water is the Major Component of Sludge Disposal Costs

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Introduction

WWTP Biosolids

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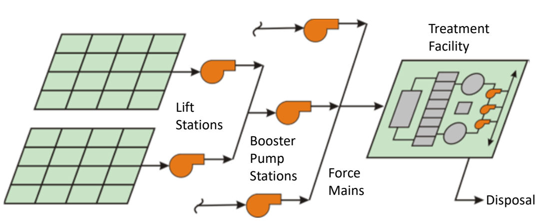
Wastewater Collection and Treatment



Gravity/Low Pressure Collection

Lift Station/ Booster Station

Wastewater Treatment

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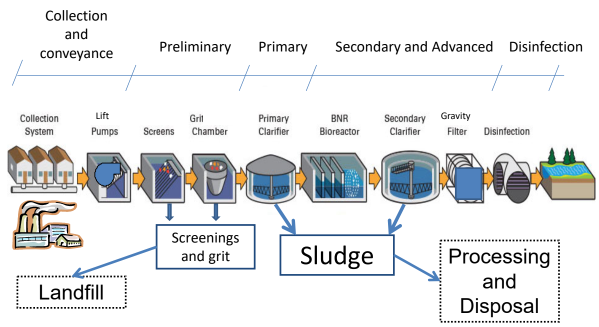
Wastewater Treatment - Sludge



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Types of Sludge

- **Primary**
- **Biological**
- **Chemical**
- **Mixed or Blended Sludge**

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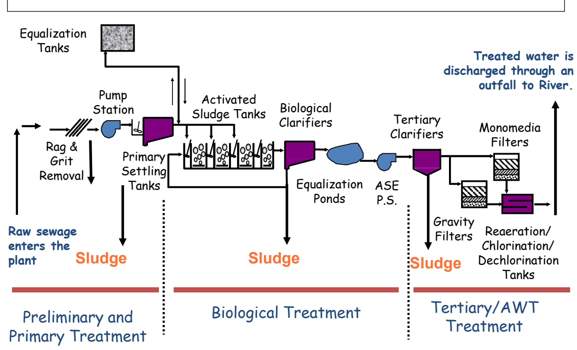
Wastewater Treatment Process



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Primary Treatment

Physical Treatment

- Suspended solids removal
- Sedimentation
  - >65% TSS removal
  - >25% BOD removal
- Disposal of sludge/scum
  - TSS removed
  - Sludge = TSS_{in} - TSS_{out}

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Primary Sludge

- Sludge from Primary Clarifiers:
  - Consists of organic solids, fine grit, and inorganic fines
  - Easy to settle solids
  - Readily thickens by gravity
  - Stored sludge (sludge blanket)
- Typically pumped to gravity thickeners for additional thickening and storage

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Secondary Treatment

Biological Treatment

- Purpose –
  - BOD removal
  - Nitrification
- Processes
  - Activated sludge (suspended growth)
  - Fixed film (attached growth)
- Disposal of sludge/scum
  - Growth of biomass – 0.5 to 0.8 lbs/lbs BOD_r

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Biological Sludge

- Biological sludge conversion products from soluble wastes in the primary effluent
- Particles escaping primary treatment
- Wasted continuously
- Typically, secondary sludge is more difficult to thicken than primary sludge

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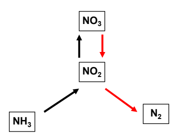
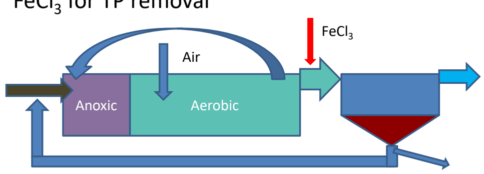
Nutrient Removal

- Nitrification (*Nitrosomonas* and *Nitrobacter*)
  $NH_3 + O_2 \rightarrow NO_2^- \rightarrow NO_3^-$
- Denitrification
  $NO_3^- + \text{organics} \rightarrow CO_2 + N_2$
- Process adaptation – MLE
- $FeCl_3$ for TP removal





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Chemical Sludge

- Sludge from the addition of either aluminum or iron salts or lime to:
  - Remove phosphorus
  - Improve suspended solids removal
- Typically blended with either primary or secondary sludge.
- Pumped to a thickening process for additional thickening and storage

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Sludge Types

Sludge Type	% Solids	% Volatile	Thickened %TS	Dewater-ability
Primary	3-6%	65-75%	5-10%	Good
Biological	0.5-1.5%	70-80%	2-4%	Moderate
Chemical	0.5-1.0%	0-50%	2-4%	Difficult

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Sludge Handling Process

- Thickening
- Stabilization
- Dewatering
- Post-dewatering and Disposal

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Thickening

- Technologies
  - Gravity
  - DAF
  - Gravity Belt
  - Centrifuges
- Widely applied
- Multiple applications
- Ancillary systems
  - Thickened sludge pumping
  - Polymer conditioning

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Sludge Stabilization

- Technologies
  - Anaerobic Digestion
  - Aerobic Digestion
- Widely applied
- Multiple applications
- Ancillary systems
  - Digester mixing and aeration
  - Digester heating
  - Gas collection & treatment
  - Gas utilization

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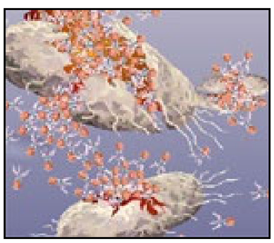
Cell Lysis - Enhancing Digestion

- Thermal Cell Lysis
  - CAMBI™
  - Excelys™
- Mechanical Cell Lysis
  - MicroSludge™
- Electrical Cell Lysis
  - OpenCel™
  - BioCrack™
- Ultrasonic Cell Lysis
  - Sonolyzer™



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Sludge Dewatering

- Technologies
  - Belt Filter Presses
  - High Solids Centrifuges
  - Rotary Presses
  - Screw Presses
- Widely accepted
- Multiple applications
- Ancillary systems
  - Cake conveyance
  - Polymer conditioning

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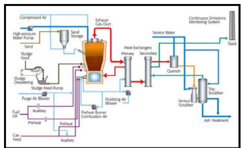
Post Dewatering Technologies

- Technologies
  - Incineration
  - Composting
  - Alkaline Stabilization
  - Thermal Drying
- Multiple applications
- Not as widely utilized
- Driver - Class A beneficial use



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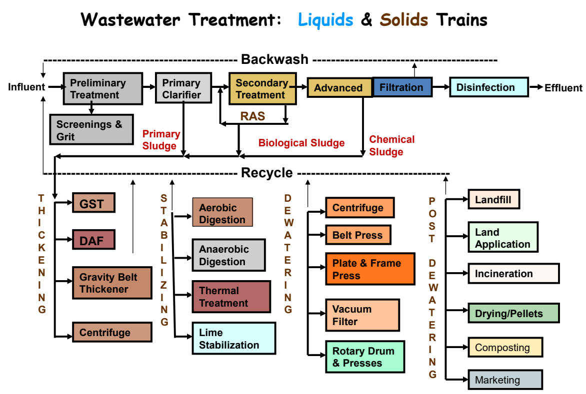

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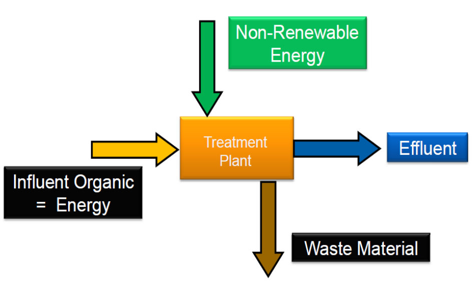
The old paradigm: "Wastewater is a waste…"



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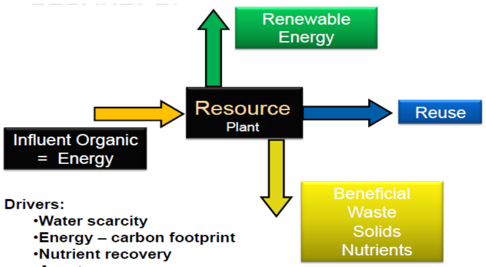
The new paradigm: Wastewater is a (valuable) resource



Drivers:
- Water scarcity
- Energy – carbon footprint
- Nutrient recovery
- Asset recovery

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Regulations

40 CFR 503 and 261

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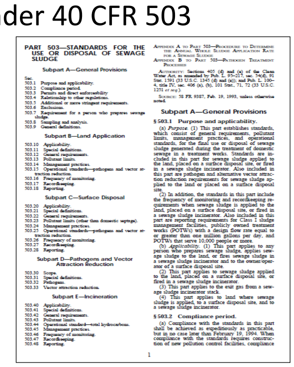
Residuals regulation is governed at the federal level under 40 CFR 503

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

Subpart B—Land Application

Subpart C—Surface Disposal

Subpart D—Pathogens and Vector Attraction Reduction

Subpart E—Incineration

Subpart A—General Provisions

§ 503.1 Purpose and applicability.

§ 503.2 Compliance period.

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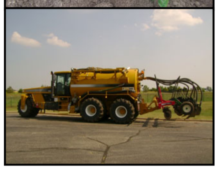
land application sewage sludge must meet certain requirements:

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

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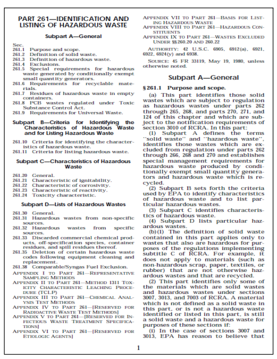
"Non-hazardous" sludge must meet the requirements of 40 CFR 261

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

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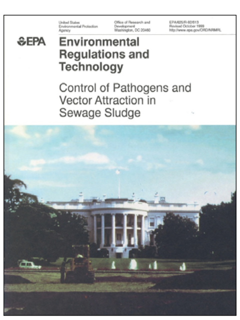
Pathogen reduction requirements are regulated under 40 CFR 503.32



Pathogen Classifications
- Class A
- Class B

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

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

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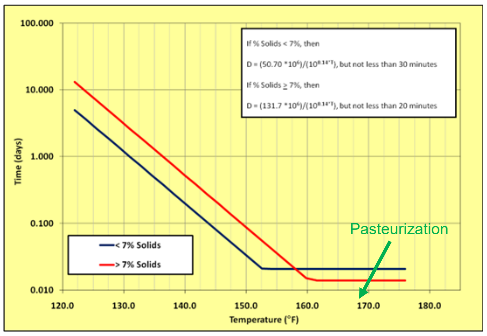
Class A pathogen reduction can be achieved by “time and temperature”.



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Regulations

- Land and Landfill Applications
  - Sludge
    - Class A – Pathogen-free
    - Class B – Contains detectible levels of pathogens
  - Ash (mono-fills)
- Air Emissions
- Odors, noise, and transportation

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“Class A” pathogen reduction can be achieved using PFRP unit processes

- PFRP – Processes to Further Remove Pathogens
- 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)

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“Class A” pathogen reduction can be achieved 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

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“Class B” pathogen reduction can be achieved using PSRP unit processes

- PSRP – Processes to Significantly Reduce Pathogens
- 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

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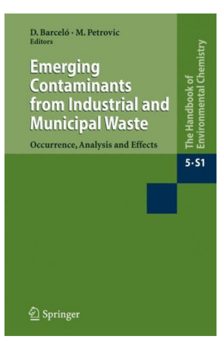
Continuing pressure also exists for regulatory change on several fronts.

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

Pathogens
- Bacteria
- Virus

Odors & Bioaerosols



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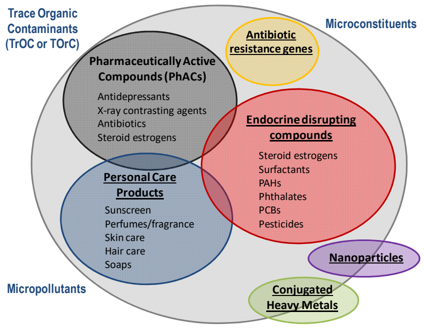
Contaminants of Emerging Concern (CECs)



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Solids Handling

Thickening Options

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Sludge Thickening

The primary functions of sludge thickening are to:

- Reduce the sludge volume to be handled in subsequent processes
- Equalize sludge flows
- Blend sludge
- Store sludge

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Thickening Options

- Gravity Sludge Thickening
- Dissolved Air Flotation
- Gravity Belt Thickeners
- Thickening Centrifuges – Rotary Drum

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Gravity Sludge Thickening

- Operating Principles: Gravity
- Optimum Sludge Type (s): Primary
- Operational Factors: Temperature, Chemical Addition, Retention Time
- Advantages: Storage Capacity, Minimal Attention, Low Maintenance
- Disadvantages: Septic and odor conditions possible, requires large land area

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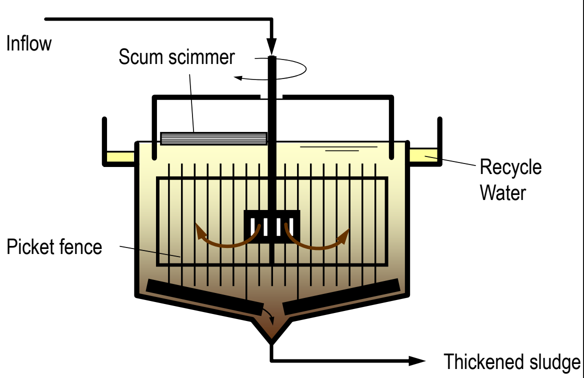
Gravity Thickener



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Gravity Thickeners

- Solids retention time within a gravity thickener and peak performance of a thickener is controlled by:
  - The size of the solids particles
  - Loading Rates
  - The speed of the sludge collection mechanism
  - The depth of the sludge blanket
  - Adjusting the sludge withdrawal rate
  - Chemical coagulants/flocculants

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Gravity Thickening

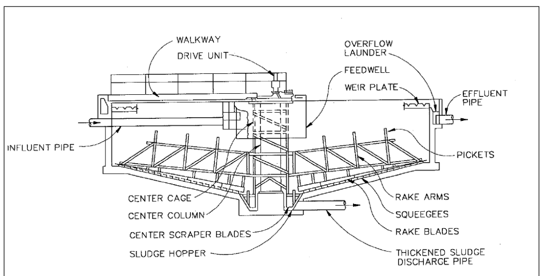

Figure 17.23 Typical gravity thickener.

Source: WEF, MOP-8.

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Gravity Sludge Thickener

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

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Types of Settling

- Type I settling (free settling)
- Type II settling (settling of flocculated particles)
- Type III settling (zone or hindered settling)
- Type IV settling (compression settling)

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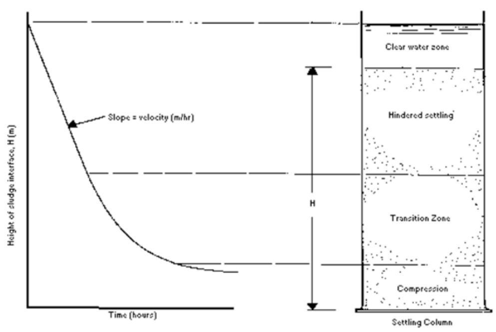
Types of Settling



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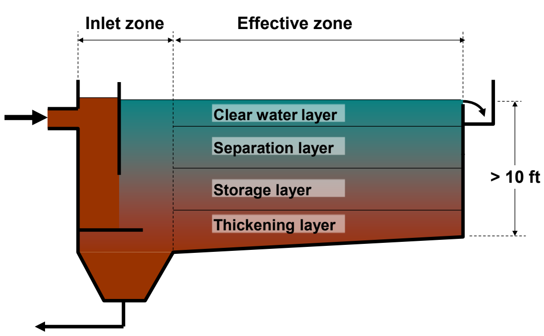
Thickener



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Process Components

- Influent distribution box
- Sludge collection rake mechanism
- Vertical "pickets" allow water and gases to release from the sludge
- Overflow weirs
- Scum removal

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Factors Affecting Gravity Thickener Performance

- Sludge Characteristics
  - Type of Sludge
  - Age of sludge
  - Sludge temperature
- Operational Controls
  - Primarily sludge blanket depth
  - Hydraulic and solids detention times
  - Hydraulic and solids loadings

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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

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Process Operating Criteria

- Retention time – 1 to 2 days
- Sludge blanket depth – 2 to 6 feet
- Loading Rates:
  - Hydraulic – 400 to 800 gpd/sf
  - Solids loading, lbs/sf/day:
    - Primary = 20 to 30
    - Trickling Filter = 8 to 10
    - Activated Sludge/Chemical = 4 to 8
    - Blended = 6 to 12
- Thickened sludge performance:
  - Primary, 8 – 10%
  - Trickling Filter, 7 – 9%
  - Activated sludge, 2-4%
  - Blended, 4-8%
- Solids capture efficiency – 85 to 95%

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Trouble Shooting

- Gasification
  - Increase withdrawal rate to reduce solids retention time
- Low solids concentrations in sludge underflow:
  - Check sludge blanket levels:
    - If high, increase collector speed and withdrawal rates to reduce solids detention time
    - If low, decrease withdrawal rate to increase blanket level and solids concentration

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Dissolved Air Flotation Thickener-DAF

- Operating Principles: Gravity-Buoyancy, Particle Formation and Air Entrainment
- Optimum Sludge Type (s): Secondary and BNR
- Operational Factors: Filamentous, Polymer Addition, Air/Solids Mix (0.02-0.04), Flight Speed, Recirculation (1/3), Air Compressor
- Advantages: Good Equalization Control, Minimal Odors, Removes Some Grease
- Disadvantages: Higher O&M Costs, Minimal Storage Capacity, Typically In-Doors.

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Process Components

- Rectangular or circular tanks
- Surface skimmers and float trough
- Recycle flow saturated with air
- Sludge feed at bottom of tank w/polymer
- Pressurization system
  - Recirculation pump
  - Air compressor
  - Air saturation tank
  - Pressure release valve
- Overflow baffles with level controllers
- Bottom sludge collector

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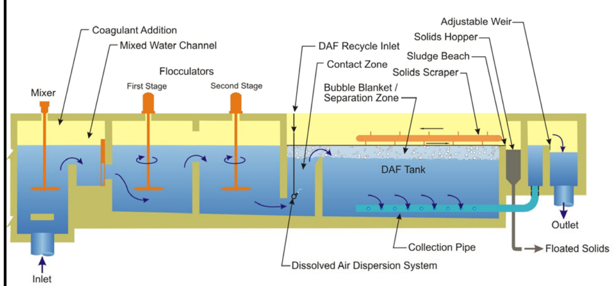
Dissolved Air Flotation Schematic



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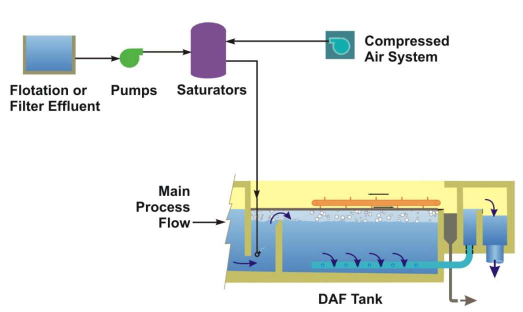
DAF Recycle System Schematic



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Dissolved Air Flotation Thickener

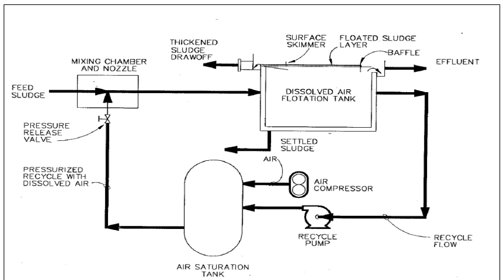

Figure 17.24 Schematic of dissolved air flotation thickener.

Source: WEF, MOP-8.

79

Dissolved Air Floatation Thickener

80

Process Operating Criteria

- Loading Rates:
  - Solids loading, lbs/sf/day:
    - WAS, w/o polymer = 0.4 to 1.0 lb/ft^2/hour
    - With polymer = 0.8 to 2.0 lb/ft^2/hour
    - Polymer dose = 4 to 12 lbs/dry ton
- Air-to-solids ratio
  - 0.02 to 0.04 lb air:lb solids ratio
- Solids content in float:
  - WAS, 4% to 5%
  - Blends, 6% to 8%
  - Very dependent on sludge SVI
    - High SVI = poor performance
    - Low SVI = good performance
- Solids capture efficiency – 85 to 99%

81

Trouble Shooting

- Float sludge too thin:
  - Check skimmer speed and polymer dosage; decrease skimmer speed or increase polymer dosage.
- Effluent solids too high:
  - Check sludge loading rates, polymer dosage, and air-to-solids ratio:
    - Decrease sludge feed rate or increase polymer dosage
    - If air-to-solids ratio low, increase air flow to pressurization system

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Pros and Cons - DAF

Pros

- Compact – high loading rates > 6 gpm/ft^2
- Low flocculation HDT >5 min – compact
- Can be positioned over filter; now extremely compact
- Very suited to reservoir water
- Very good at removing algae
- Fast start up – low HDT
- Not sensitive to water temperature or gradients

Cons

- Needs to be covered in any climate
- Not good with "silty" water
- Energy use from DAF recycle about 5 kW/mgd
- High rate being "over-sold" e.g. 20 gpm/ft^2 – high failure risk

83

Gravity Belt Thickener

- Operating Principles: Gravity Dewatering Through Belt
- Sludge Type (s): Secondary, BNR
- Operational Factors: Polymer, Belt Speed & Loading Rate, Belt Alignment, Sludge Distribution, Belt Wash
- Advantages: High Loading Rates
- Disadvantages: High O&M Costs, Grease Clogging

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Gravity Belt Thickener

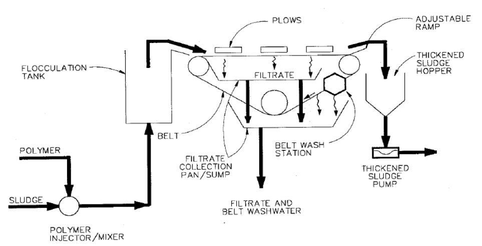

Figure 17.26 General schematic of a gravity belt thickener.

Source: WEF, MOP-8.

85

Gravity Belt Thickener

86

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

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Solids Handling - Stabilization

Overview

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Stabilization Options

- ➢ Aerobic Digestion
- ➢ Anaerobic Digestion
- ➢ Thermal (Wet Oxidation) Treatment
- ➢ Lime Stabilization
- ➢ Composting
- ➢ Heat Drying/Incineration

89

Aerobic Digestion

- ➢ Operating Principles: Aerobic Processes
- ➢ Sludge Type (s): Secondary
- ➢ Operational Factors: Temperature, DO, pH, Mixing, DT,
- ➢ Advantages: Minimal Operational Attention, Meets 503 Regulation for Class B Sludge
- ➢ Disadvantages: Filamentous Farm, Energy Requirements High, Variable VS Reductions

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Aerobic Digestion

Class B – PSRP
- > 40-days @ >20°C
- > 60-days @ >15°C

Aeration Rates
- Mixing Controlled
- Oxygen Demand Controlled

Aeration Systems
- Fine Bubble
- Coarse Bubble
- Mechanical

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Intensity (time and temperature) impacts digester volatile solids reduction.

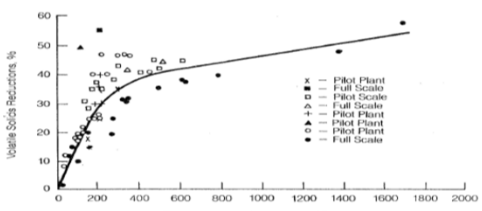

Figure 18.31 Typical volatile solids reductions as a function of digester liquid temperature and digester sludge age.[37] VS reduction depends on many variables, including prior processing, sludge characteristics, and digester operating conditions.[37]

92

Conventional "pancake" Style Anaerobic Digestion Tank (low SWD/DIA ratio)

93

Egg-shaped Digesters Utilized as an Alternative to "Conventional" Tanks

94

Anaerobic Digestion

- Operating Principles: No Oxygen
- Sludge Type (s): Primary, Secondary
- Operational Factors: Heating, pH, Mixing, Alkalinity, Gas Production & Collection (Two phases: Acid and Gas Formers), Uniform Feed Rate
- Advantages: Produces Own Energy Source
- Disadvantages: Easily Upset, High O&M Costs, Foaming (CO2:CH4), Filamentous

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Anaerobic Digestion

Anaerobic digestion is a biological process carried out in the absence of O_2 for the stabilization of organic materials by conversion to CH_4 and inorganic end-products such as CO_2 and NH_3

$$\textit{Organic materials + Nutrients} \xrightarrow{\text{Anaerobic microbes}} CH_4 + CO_2 + NH_3$$

Anaerobic processes

→ Anaerobic fermentation

→ Anaerobic respiration

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TWO-STEP REPRESENTATION

ORGANIC MATTER

↓ Fermentation

VOLATILE FATTY ACIDS

↓ Methanization

BIOGAS

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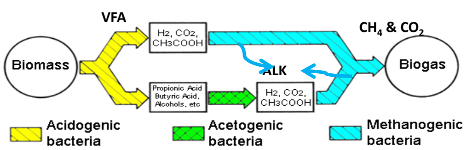
Anaerobic Digestion

- Acid Forming Bacteria
  - Produce Organic or Volatile Acids
  - Can depress pH
- Methane Forming Bacteria
  - Produce CH_4 and CO_2
  - Produce alkalinity; increase pH



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Anaerobic Digestion

- Biological conversion of degradable particulate mass into gas
  - Methane (CH_4)
  - Carbon dioxide (CO_2)
- Four separate steps
  - Hydrolysis
  - Acidogenesis or Fermentation
  - Acetogenesis
  - Methogenesis

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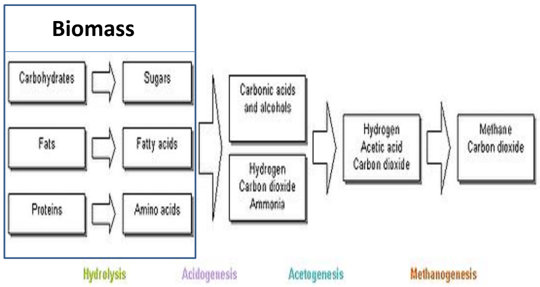
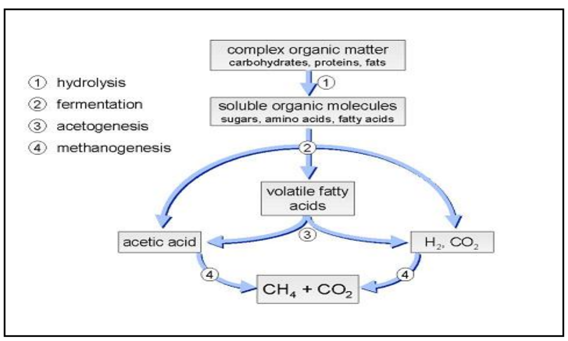
Anaerobic Digestion – Four Step Process



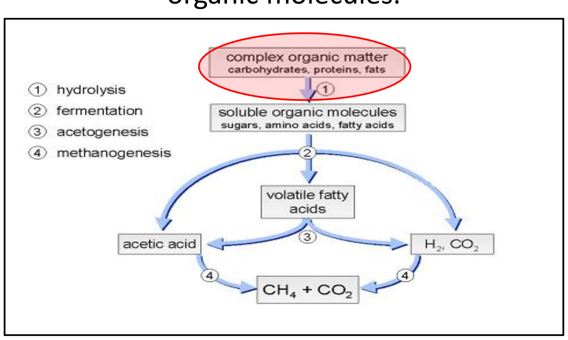
100

Anaerobic Digestion – Four Step Process



101

Complex solids are hydrolyzed into soluble organic molecules.



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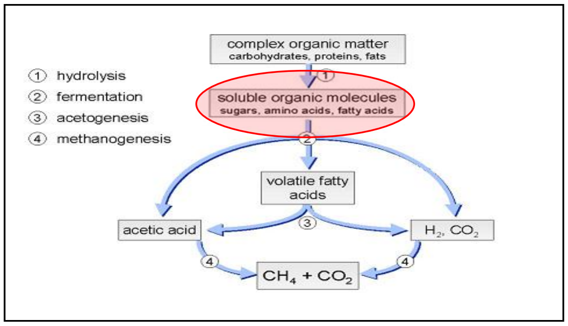
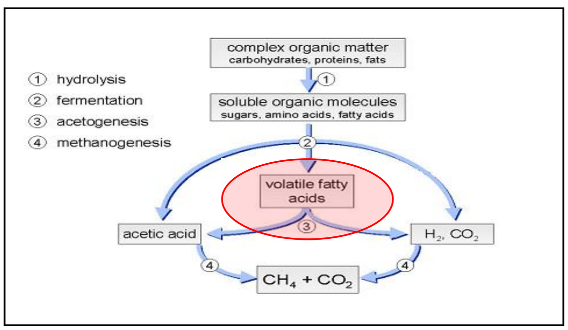
Soluble organics are fermented into volatile fatty acids (VFAs).



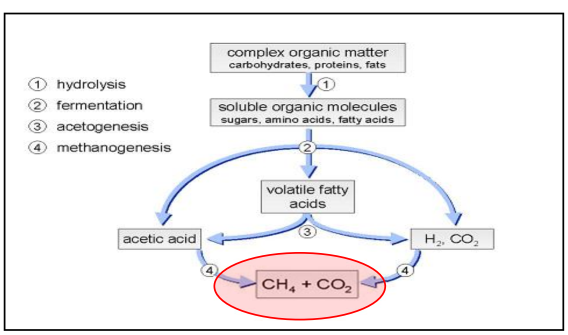
103

VFAs are converted to acetic acid (simplest form of VFA) in acetogenesis.



104

Acetic acid and hydrogen are converted to methane via methanogenesis.



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Benefits of Anaerobic Digestion

- Mass and volume reduction
  - Reduce downstream processing costs
  - Reduce disposal costs
- Reduction of pathogens
- Stabilization of organics to reduce odor potential
- Production of energy containing biogas
  - Process heating demands
  - Power generation and thermal drying

106

Factors Affecting Anaerobic Digestion Performance

- Sludge Characteristics
  - Type of Sludge
  - Age of sludge
  - Sludge temperature
- Operational Controls
  - Solids residence times
  - Digester temperatures
  - Mixing

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Implications of different sludge feeds to digestion

- Volatile solids from different types of sludge need to be “tracked” and quantified separately into the digester
- Aggregated (lumped) loading calculations that don’t consider the different degradable fractions may not provide good guidance on performance expectations
- “Blended” sludge sources affect volatile solids reduction and gas production

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Volatile Solids Reductions

- Not all volatile solids degrade equally
- Some volatile solids are more degradable than others:
  - Extent of VS destruction
  - Rate of VS destruction reaction
- SRT and degradation rate determine VS destruction

109

Typical Digester Operating Conditions

Operating Parameter	Typical Range	Extreme Range
Temperature, (°F)	95 - 98	90 - 100
pH (std. units)	7.0 to 7.2	6.8 to 7.4
ORP (mV)	-520 to -530	-490 to -550
VFA (mg/L as acetic acid)	50 to 400	> 2,000
ALK (mg/L as $CaCO_3$)	1,500 to 3,000	1,000 to 5,000
Hydraulic Retention Time (Days)	15 to 20	10 to 30
VS Loading (Lbs VS/Day/ft^3)	0.15 to 0.3	0.1 to 0.35

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Typical Digester Performance Results

Performance Parameter	Typical Range	Extreme Range
Volatile Solids Reduction (%)	45 to 60	40 to 65
Moisture Reduction (%)	45 to 60	40 to 65
VFA-to-ALK ratio (Fraction)	0.1 to 0.2	0.05 to 0.3
Biogas Production (Ft^3/lb VSR)	12 to15	10 to 20
Biogas (%CH_4 by volume)	60% to 65%	55% to 70%
Biogas (Btu/ft^3)	575 to 625	550 to 650
Biogas (%CO_2 by volume)	35% to 40%	30% to 45%

111

Digester Performance

Creating the right operating environment
will be critical to maintaining
stable digester operations

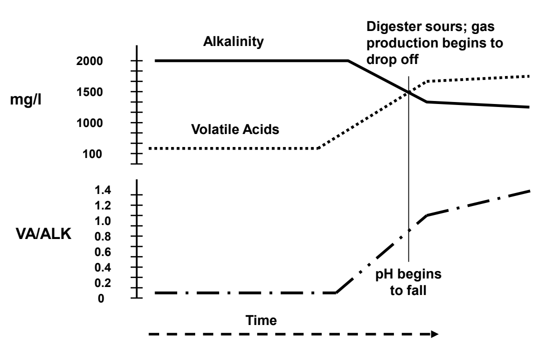
112

VFA/ALK Ratio

- Typical VFA/ALK = 0.01 to 0.03 (1% to 3%)
- High VFA/ALK = 0.05 to 0.7 (5% to 7%)
- If VFA/ALK gets to high:
  - VFA production exceeds VFA consumption
  - Organic overloading risk
  - Buffering capacity may be compromised
  - pH could drop in the reactor below 6.8
  - pH shift can further compromise methanogenesis

113

Alkalinity/Volatile Acid Ratio



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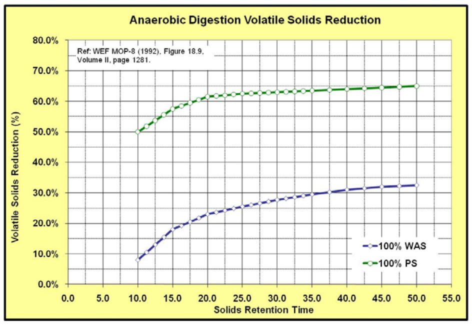
Volatile Solids Reduction in Digester



115

Elements can be both stimulatory and inhibitory to methanogenesis.

Compound	Stimulatory (mg/L)	Moderate Inhibition (mg/L)	Strong Inhibition (mg/L)
Sodium	100 to 200	3,500 to 5,500	> 8,000
Potassium	200 to 400	2,500 to 4,500	> 12,000
Calcium	100 to 200	2,500 to 4,500	> 8,000
Magnesium	75 to 150	1,000 to 1,500	> 3,000
Ammonia (as N)	**50 to 200**	**1,500 to 3,000**	**> 3,000**
Sulfide	N/A	200	200

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Digester Performance

Evaluation of existing digester systems needs to consider residence time and organic loading rates

117

Hydraulic retention time is an important factor in digester sizing.

$$HRT = \frac{Digester\ Tank\ Volume}{Volumetric\ Feed\ to\ Digester}$$

Where:

Volumetric Feed to the Digester= gallons/day

Digester Tank Volume = gallons

HRT = Hydraulic Retention Time, days

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Typical Hydraulic Retention Times for Mesophilic Digesters

Plant Type	AVG365	MAX30	MAX07
All Digester Tanks in Service, days	25.0	20.0	15.0
One (Largest) Digester Tank out of Service, days	20.0	15.0	12.5

119

VS organic loading rate (VSLR) is one measure to track digester loading.

$$VSLR = \frac{Volatile\ Solids\ Feed\ to\ Digester}{Digester\ Tank\ Volume}$$

Where:

Volatile Solids Feed to the Digester = lb(VS)/day

Digester Tank Volume = 1,000 cubic feet

VSLR = Volatile Solids Loading Rate, lb(VS)/day-1000ft^3

120

Typical and Maximum VSLR for Well Heated and Mixed Digesters

	Metric Units (kg/m³-day)	English Units (lb/1000ft³-day)
Typical VSLR	< 2.4	< 150
Range VSLR	1.6 to 6.2	100 to 400
Reference: WEF Manual of Practice #11 (MOP-11), Fifth Edition, Volume 3, pg 1069.		

121

Volatile solids reduction effectiveness can be using the Van Kleek Equation.

$$\%VSR = \frac{\%VS_{raw} - \%VS_{digester}}{\%VS_{raw} - \left(\%VS_{raw} \times \%VS_{digester}\right)}$$

Where:

%VSR = Volatile Solids Reduction Rate

$\%VS_{raw}$ = Feed Volatile Solids Fraction

$\%VS^{digester}$ = Digested Sludge Volatile Solids Fraction

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Process Monitoring

- Daily Volumetric Feed Rate (gallons/day)
- Raw Feed Total Solids (mg TSS/L or %TS)
- Raw Feed Volatile Fraction (VS/TS Ratio)
- Raw Feed Temperature (°F)

123

Process Monitoring

- Blended Volumetric Feed Rate (gallons/day)
- Blended Feed Total Solids (mg TSS/L or %TS)
- Blended Feed Volatile Fraction (VS/TS Ratio)
- Digester Temperature (°F)
- Digester VFA (mg/L as acetic acid)
- Digester Alkalinity (mg/L as $CaCO_3$)
- Digester VFA/ALK Ratio
- Digester Volume (gallons)

124

Process Monitoring

- Primary Hot Water Loop Temperature
- Secondary Loop Temperature(s)
  - HEX Sludge Inlet Temperature
  - HEX Sludge Outlet Temperature
  - HEX Hot Water Supply (Inlet) Temperature
  - HEX Hot Water Return (Outlet) Temperature
- Digester Gas Consumption to Boilers
- Natural Gas Consumption to Boilers

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Process Monitoring

- Total Digester Gas Production
  - Digester Gas to Hot Water Boilers
  - Digester Gas to Thermal Dryer
  - Digester Gas to Waste Gas Flares
- Digester Gas Pressure
  - Operating pressure under digester cover

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Process Monitoring

- Volatile fatty acids (VFA) concentration increases rapidly
- Bicarbonate alkalinity decreases rapidly
- Reactor pH declines below 6.8 std. units
- Gas production rate decreases relative to the volatile loading to the reactor
- Carbon dioxide in the digester gas increases significantly

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Typical Causes of Process Failure in Anaerobic Digestion Systems

- Mechanical failure
- Hydraulic overload
- Organic overload
- Toxic overload

128

System Failures

- Heating system
  - Decrease in digester operating temperature
  - Imbalance between hydrolysis, acetogenesis, and methanogenesis
  - Temperature induced stress to digester system
- Mixing system
  - Inability to disperse raw feed in digester
  - Inability to maintain homogeneous solids and temperature in reactor

129

System Failures

- Dilute feed sludge results in low digester HRT and wash-out of methanogens.
- Dilute feed and low feed temperature results in heating system ability to maintain temperature.
- Grit and scum accumulation reduces active volume and lowers HRT
- Dilute feed shifts the VFA/ALK balance in the reactor due to ALK washout

130

System Failures

- Increase in volatile solids loading to the digestion system
- Change in sludge characteristics (e.g., addition of primary sludge, change in PS/TWAS ratio)
- Slug loading to the reactor (e.g., change from continuous to intermittent feeding)
- Addition of highly degradable materials (e.g., FOG, high strength organics, etc.) to reactor

131

System Failures

- Heavy metals (Cd, Cr, Cu, Ni, Zn, etc.)
- Chlorinated organic chemicals
- Ammonia buildup in reactor
- Sulfide buildup in reactor
- Some cations (Na, K, Ca, Mg, etc.)
- Oxygen
- Inorganic acids

132

UNIFORMITY and CONSISTENCY will aid operations significantly.

- UNIFORMITY
  - Strive for uniform loading rates across time
  - Avoid intermittent slug load feeding
  - Continuous feed or near continuous feed
  - Mixing helps provide uniformity in the reactor
- CONSISTENCY
  - Strive for consistent blend of sludge feedstocks
  - Maintain temperature with minimal variation in reactor.

133

Digester foaming can create a number of operational issues.

134

Digester foaming can create a number of operational issues.

135

Foaming can be caused by a number of factors working alone or together…

- Digester Operational Stress
  - Temperature fluctuations
  - Loading fluctuations
  - Mixing interruptions
- Digester Feedstock
  - Loading fluctuations
  - *Nocardia* (foaming organisms)
  - Fats, Oils, Greases (organic and/or surfactant)

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Two basic types of foaming have been reported in anaerobic digester systems…

- “Nuisance” Foaming
  - Low level foaming
  - Transient condition
- “Rapid Rise” Foaming
  - aka Rapid Volume Expansion
  - Rapid increase in gas production rate
  - Gas hold-up in liquid sludge matrix
  - Reduction in sludge bulk density
  - Increase in sludge volume

137

Digester Mixing Systems

- Draft Tubes
- Pumped Mixing Systems
- Gas Mixing Systems
- Linear Motion Mixer

138

Effective Digester Mixing

- Elimination of temperature stratification and maintenance of homogeneous mixture in the digester tank.
- Rapid dispersion of raw feed sludge with the active biomass within the digester tankage.
- Mitigation of formation of excessive floating scum layers or deposition of heavy silt, grit and inert solids in digester

139

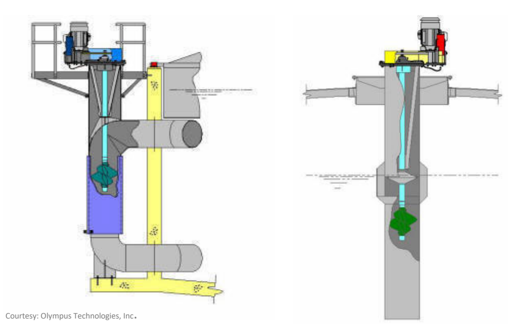
Typical Design Criteria for Digester Mixing Systems

Mixing Criteria	Type of Mixing System	Process Value
Unit Power, HP/1000cft	Mechanical, Pumped	0.2 to 0.3
Unit Gas Flow, CFM/1000cft	Gas – Unconfined	4.5 to 5.0
Unit Gas Flow, CFM/1000cft	Gas - Confined	5.0 to 7.0
Velocity Gradient "G", 1/sec.	All Types	50 to 80
Turnover Time, minutes	Confined Gas / Mechanical Systems	20 to 30

Adapted from "Anaerobic Digester Mixing Systems", JWPCF, Vol. 59, No. 162, 1987.

140

Draft tube mixers can be side mounted or cover mounted.



Courtesy: Olympus Technologies, Inc.

141

Pumped Mixing Systems Using Nozzles

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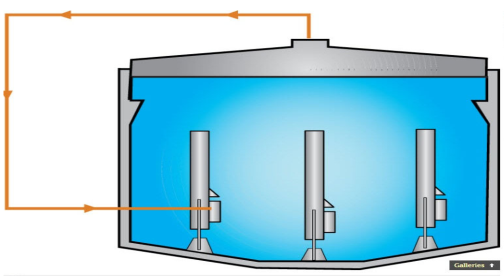
"Cannons" are floor mounted inside the digester.



Courtesy: Infilco Degremont Industries

143

Heating

- Heat Exchangers
- Hot Water Boilers
- Combination Boiler / HEX Systems

144

Tube-in-Tube heat exchangers are most common.

145

Dual fuel capable Scotch Marine style boilers can be used.

146

Combination hot water boiler and heat exchanger units are around.

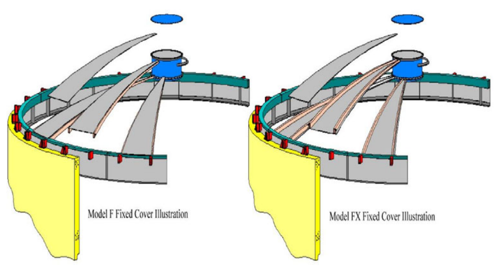
147

Covers

- Fixed Covers
- Gas Holder Covers
- Steel Truss Floating Covers
- Membrane

148

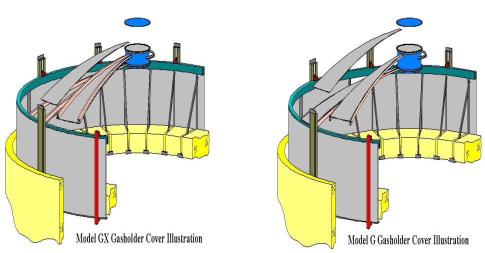
Fixed covers are the least costly.



Courtesy: Olympus Technologies, inc.

149

Floating covers are ballasted and can provide some gas storage.



Courtesy: Olympus Technologies, inc.

150

Membrane covers can provide high gas storage volume.

151

Different cover types have different advantages and disadvantages.

	Drawdown	Gas Holding	Odor Control
Fixed Cover	No	No	Excellent
Floating Cover	Yes	No	Moderate
Floating Gas Holder	Yes	Yes	Moderate
Membrane	Yes	Yes	Excellent

152

Waste gas flare for burning excess digester gas.

153

Lime Stabilization

- Operating Principles: Raise pH to Attenuate Micro-Organisms
- Sludge Type (s): Primary, Secondary
- Operational Factors: Lime Addition Pre or Post Dewatering, pH 12 for 2 Hours + pH 11.5 for Additional 22 Hours.
- Advantages: Low Cost, Enhances Dewaterability, Meets Class B regulations, Reduces Odors to Disposal Site
- Disadvantages: Lime Handling.

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Alkaline stabilization can be used to meet both “Class A” and “Class B” standards.

- Calcium Oxide (Lime) is blended with dewatered cake
- Elevated pH can result in high ammonia odors release
- “Class A” achieved by:
  - pH + Temperature
  - Time + Temperature
- Finish Product used as Soil Conditioner

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Solids Handling - Conditioning

Coagulation and Flocculation

156

Sludge Conditioning

- Coagulation – the clumping together of very fine particles (floc) into larger particles using chemicals (coagulants).
- Flocculation – The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing.
- Polymers – Coagulant chemicals used in binding small suspended particles to larger chemical flocs for their removal from water.

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Conditioning Options

- Chemicals
  - Iron salts
  - Aluminum salts
  - Lime
  - Polymer
- Heat Treatment

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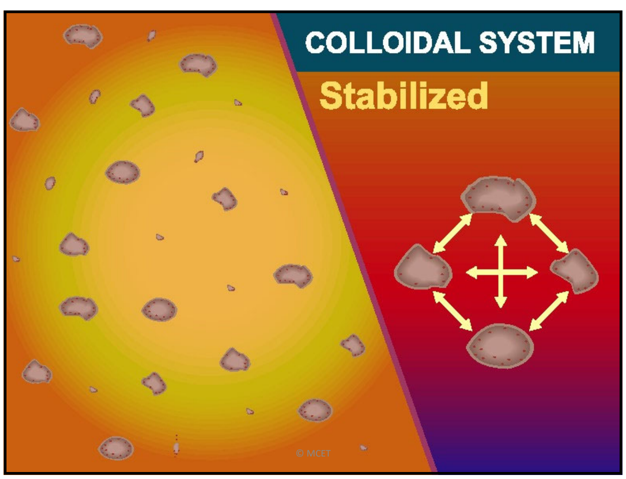

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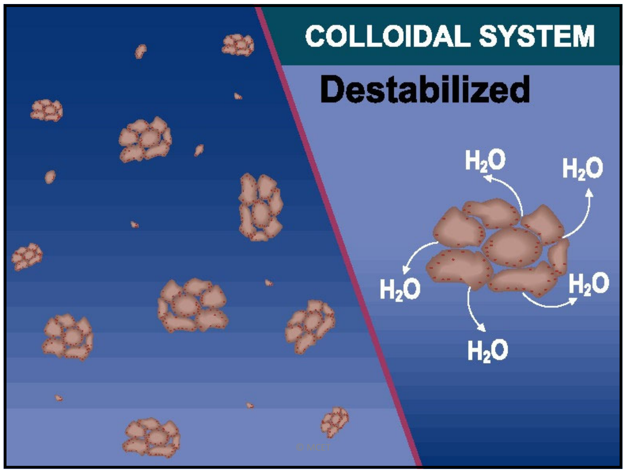

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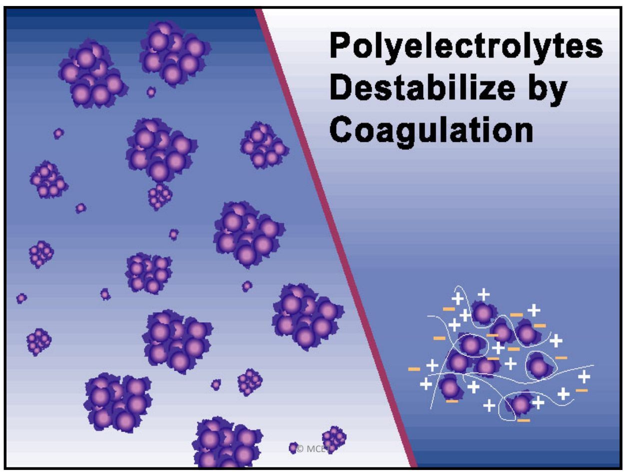

161

Chemical Conditioning

- Optimum chemicals, type, and dosages for a particular sludge are highly dependent on the characteristics of that sludge.
- Calculation of chemical requirements is usually based on on-site experimentation and trial and error procedures (chemical trials).
- One of the keys to successful chemical conditioning is the preparation of the chemical solutions.

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Chemical Use Calculations

- $w = Q \times C \times 8.34$ (@ 100%)
  - w = Weight of pure chemical, Lb/day
  - Q = Flow rate, MGD
  - C = Chemical dose concentration, mg/L
- $w = \frac{Q \times C \times 8.34}{S/100}$ (< 100% pure)
  - S = % of chemical, %

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Liquid Chemical Use Calculations

- $q = \frac{w}{8.34 \times sg \times S/100} = \frac{Q \times C \times 8.34}{8.34 \times sg \times S^{(1)}}$
  - q= Liquid chemical feed rate, gpd
  - w = Weight of pure chemical, Lb/day
  - sg = Specific gravity of chemical solution
  - S = % of chemical solution, %

1. 8.34 x sg x S = Bulk Density of chemical, lbs/gal

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Polymer Usage Calculations

- $p = \frac{2000 \times P, gpm \times P, \%}{Sludge, gpm \times C, \% solids}$
  - p= Polymer feed rate, lbs/dry ton
  - P, gpm= Polymer feed rate, gpm
  - P, % = Polymer, % solution
  - Sludge, gpm = Sludge feed, gpm
  - C, % = Concentration of solids, %

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Polymer Use Calculations

- A centrifuge is processing 150 gpm of 4.1% sludge using a 0.1% polymer dosage of 54 gpm. Calculate lbs/dry ton.

Answer: $$\text{p, lbs/dry ton} = \frac{2000 \times 54 \times 0.1}{150 \times 4.1} = 17.5 \text{ lbs/DT}$$

166

Heat Treatment

- Operating Principles: "Cook" Sludge
- Sludge Type (s): Primary, Secondary
- Operational Factors: Temperature, Decanting, Odor Control
- Advantages: Enhances Dewaterability
- Disadvantages: Odors, High O&M Costs, Re-Solubilizes Organics and Nutrients (P) by Bursting Cell Walls, ODORS!!

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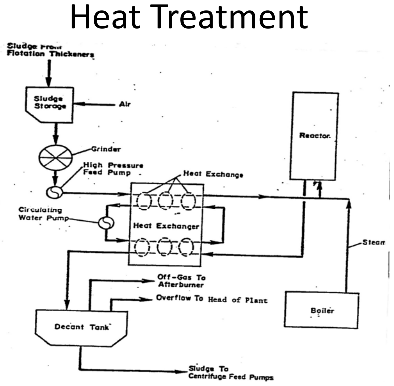
Heat Treatment



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Solids Handling - Dewatering

Overview

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Sludge Dewatering

- Primary sludge dewaters more readily and requires less chemical conditioners than biological and chemical sludge.
- Belt speed, pressure levels, and cleanliness of filter media affect performance of dewatering devices.

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Dewatering Options

- Drying Beds
- Belt Filter Presses
- Centrifuges
- Plate and Frame Filter Presses
- Vacuum Filters

171

Solar sludge drying beds can be covered to reduce seasonal impacts.

172

Automation can be applied to increase solids loading rates to reduce footprint.

173

Belt Filter Press

- Operating Principles: Gravity Belt and Pressure Belt
- Sludge Type (s): Secondary, BNR
- Operational Factors: Belt Speed and Pressure, Polymer, Belt Wash
- Advantages: Lower Power than Centrifuge, Relatively Simple Maintenance Procedures
- Disadvantages: Grease "Blinds", O&M Costs, Many Moving Parts

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Belt Filter Press Components

- Typical operations:
  - Gravity zone
  - Low-pressure zone
  - High-pressure zone
- Polymer addition to gravity zone
- Two porous belts
- A series of rollers
- Belt wash

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Factors Affecting Belt Press Performance

- Sludge Characteristics
  - Concentration of sludge feed
  - Solids loading rate
- Operational Controls
  - Polymer type and dosage
  - Belt size, type and speed
  - Belt washing efficiency

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Typical Belt Press Performance

- Solids loadings (lbs/hr/m):
  - Digested (anaerobic) – 300 to 450
  - Raw primary/blends – 500 to 1,000
- Dewatered cake solids, % TS
  - Digested (anaerobic) – 15 to 20%
  - Raw primary/blends – 20 to 25%
- Solids capture
  - 90 to 95 %

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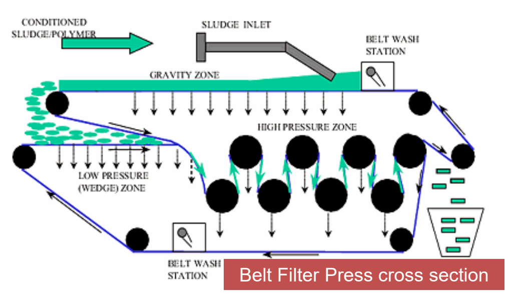
Belt Filter Press Overview



Belt Filter Press cross section

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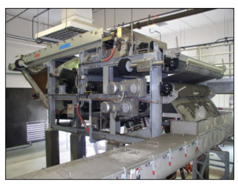
Belt Filter Press

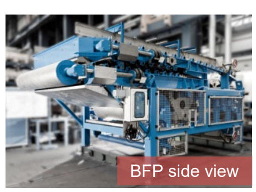
- Good
  - Simpler than centrifuge operation
  - Can be automated
  - High solids capture rate
  - Relatively low maintenance costs
- Not so Good
  - Odor control
  - High water requirements
  - Difficult for large roller and belt replacement
  - Large footprint requirements



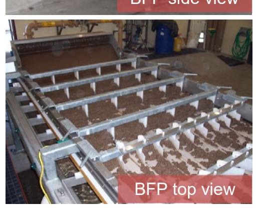
179

Belt Filter Press Comparison

- Good
  - Simpler operation
  - Able to view process
  - Can be automated
  - High solids capture rate
  - Low maintenance costs
- Not so Good
  - Odor control
  - Generally lower solids content
  - High water requirements
  - Difficult for large roller and belt replacement
  - Large footprint requirements



BFP side view



BFP top view

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Belt Filter Press Key Sizing Criteria

- Belt Width and Length
- # Rollers and Size
- Extended thickening
- Hydraulic Loading (flow)
- Solids Loading
- Solids Capture
- Cake Solids
- Polymer Dosage


Ashbrook BFP

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Belt Filter Press Key Layout Considerations

- Roller removal
- Belt removal
- Platform / viewing area
- Solids conveyance
- Motor and bearing maintenance
- Structural support
- Air changes / odor


Andritz BFP


Andritz BFP

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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

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Trouble Shooting

- Low cake solids:
  - Check belt speed, belt tension, and polymer dosage; decrease belt speed, increase belt tension, or increase polymer dosage.
- Low solids capture rates:
  - Check belt speed, belt tension, and polymer dosage; increase belt speed, decrease belt tension, or increase polymer dosage.

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Centrifuges

- Operating Principles: Centrifugal Force
- Sludge Type (s): Primary, Secondary
- Operational Factors: Polymer, Scroll Speed, Pond Depth
- Advantages: Minimal Operator Attention, Few Moving Parts, Good Dryness
- Disadvantages: High Energy Costs and Repair Costs When Needed

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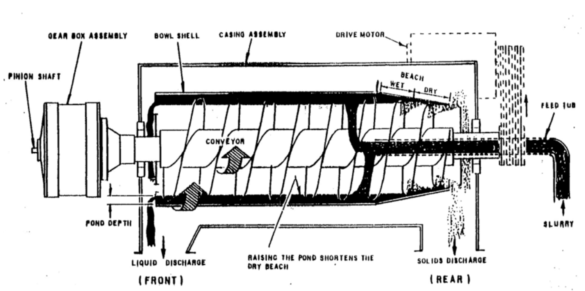
Centrifuge



186

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

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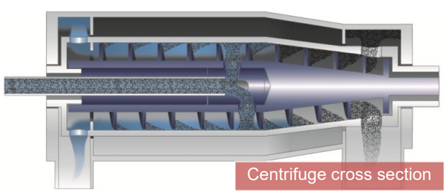
Centrifuge Overview



Centrifuge cross section

188

Centrifuge Comparison

- Good
  - Generally higher solids content
  - Compact footprint
  - Can generally be automated
  - High solids capture rate
  - Fully enclosed
  - Washwater only at start/stop
- Not so Good
  - Specialized O&M
  - High rotational speeds
  - Higher power consumption
  - Higher noise
  - Wear and tear

Flottweg Centrifuge

Andritz Centrifuge

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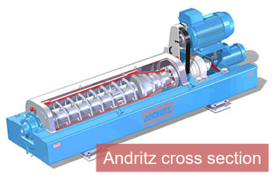
Centrifuge Key Sizing Criteria

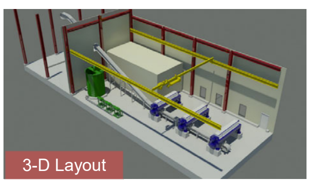
- Bowl Diameter
- G-Volume
- Operating Speed
- Hydraulic Loading (flow)
- Solids Loading
- Solids Capture
- Cake Solids
- Polymer Dosage


Andritz cross section

190

Centrifuge Key Layout Considerations

- Bowl/Scroll removal
- Feed tube removal
- Solids conveyance
- Motor and bearing maintenance
- Structural support / vibration isolation
- Air changes / odor


3-D Layout

191

Plate & Frame Press

- Operating Principles: Squeeze Water Through Filter Cloths
- Sludge Type (s): Primary, Secondary
- Operational Factors: Feed Pump Pressure, Polymer, Run Time
- Advantages: Driest Cake
- Disadvantages: Batch Process, High Operator Attention at Cake Dumping

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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)

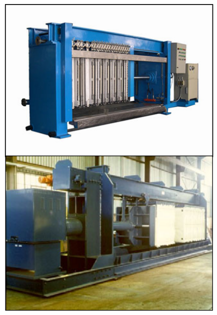
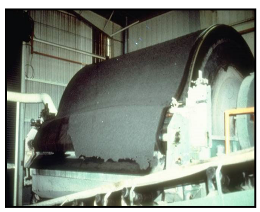


Image: WesTech Industries

193

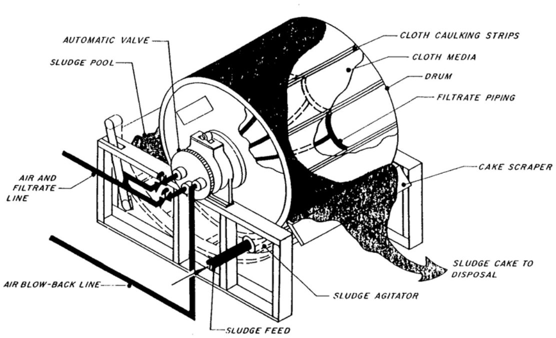
Vacuum Filter

- Operating Principles: Vacuum
- Sludge Type (s): Primary
- Operational Factors: Drum Speed, Chemical Conditioning, Zones (Cake Formation, Drying, Discharge),
- Advantages: Few!
- Disadvantages: Odors, Rag Clumps Break Vacuum, Vacuum Pumps High Maintenance, Old Technology.



194

Vacuum Filter



195

Rotary Drum

- Operating Principles: Gravity Dewatering Through cloth in rotating drum
- Sludge Type (s): Secondary, BNR
- Operational Factors: Polymer, Drum Speed & Loading Rate, Belt Wash
- Advantages: High Loading Rates
- Disadvantages: High O&M Costs, Grease Clogging

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Rotary Drum Thickener

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Composting

- Operating Principles: Aerobic Processes
- Sludge Type (s): Blends
- Operational Factors: Temperature, DO, pH, DT, moisture content
- Advantages: Meets 503 Regulation for Class A Sludge, Commercial Value
- Disadvantages: Potential for odors IF Inadequately Dried

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Composting can be utilized to achieve 40 CFR 503 “Class A” standards.

- Space intensive
- High odor potential
- Labor and equipment intensive for material handling
- Seasonal product demand
- Unique marketing and distribution challenges

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Basic process configuration for biosolids composting unit treatment process.

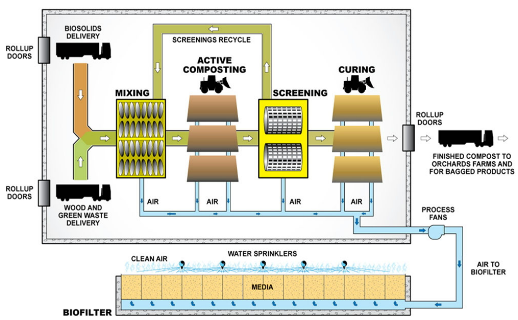

Image: Inland Empire Regional Composting Authority (http://www.ierca.org/process/compostprocess.html)

200

Process Components

- Types of composting operations:
  - Static pile
  - Windrow
  - In vessel
- Importance of temperature:
  - Mesophilic (<38 degrees C)
  - Thermophilic (>38 degrees C) – Class A
- Aeration equipment
- Bulking agent, wood chips
- Sludge and bulging agent mixing devices
- Screening to recover bulking agent
- Curing and storage area

201

Process Operating Criteria

- Compost Moisture Content
  - Initial - 45% to 65%
  - Final - 25% to 30%
- Composting retention time:
  - 14 days first phase
  - 3 to 5 days @ 55 to 60 degrees C
  - 14 days second phase
  - Total 28 to 35 days
- Aeration:
  - During first two week phase – 1,000 to 6,000 ft^3/hr/dry ton
  - Second two week phase - 700 to 1,800 ft^3/hr/dry ton of sludge
  - Oxygen levels – 5 to 15%
- Curing and storage – 30 to 50 days

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Trouble Shooting

- Anaerobic conditions
  - Check moisture content; remix; increase aeration rate; decrease moisture content
- Low compost temperatures
  - Check aeration rate and moisture content; remix; decrease aeration rate; decrease moisture content
- Odors
  - Check moisture content; consider exhausting air through finished product

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Incineration: Multiple Hearth & Fluidized Bed

- Operating Principles: Drys Then Ignites Sludge Organics
- Sludge Type (s): Primary, Secondary
- Operational Factors: Drying, Combustion and Cooling Zones
- Advantages: Ash is Inert, Sterile and 100% Dry Solids.
- Disadvantages: Very High O&M Costs, Ash Handling, stack emission controls

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Fluid Bed Thermal Oxidation Standard in Incineration Technologies

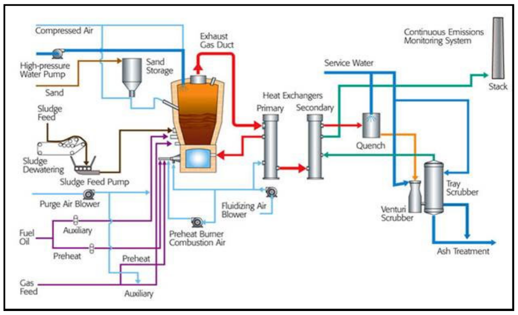
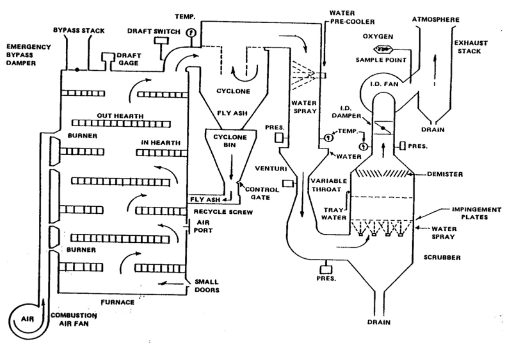


Image Courtesy IDI Technologies

205

Multiple-Hearth Incinerator



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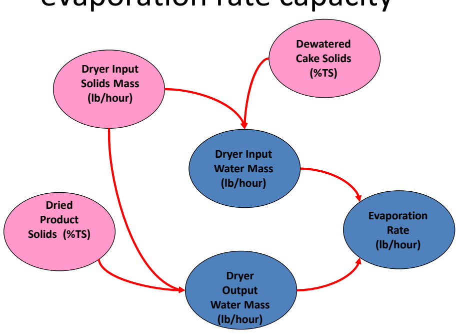
Thermal drying systems are “rated” by evaporation rate capacity



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Pelletization

- Improves marketing value of sludge
- Operating Principles: Drying
- Sludge Type (s): Primary, Secondary
- Operational Factors: Temperature, Achieve > 80% Dryness,
- Advantages: Commercial Value
- Disadvantages: Explosion Potential IF Inadequately Dried, High O&M Costs

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Solids Handling - Summary

- On-site sludge stabilization and handling requirements are largely governed by the “downstream” sludge management processes
- Federal regulations under 40 CFR 503 establish minimum requirements for management of sludge
- Thickening, stabilization, dewatering, and post-dewatering treatment must work together to achieve sludge processing objectives.

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Let’s Call it a Day

See you next time

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