Solids Handling

Maryland Center for Environmental Training
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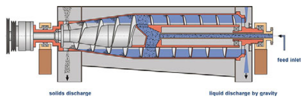
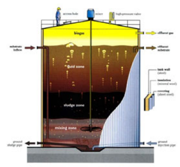
Sludge Handling



Presented by Ed Jones

MceT



Process Training Sessions

Before class starts, please:
- **Check in**

During class, please:
- **Asks questions**
- Feel free to get up at any time (i.e., rest rooms, phone calls, etc.)

After class, please:
- Complete class evaluation
- **Answer questions** on post quiz

Housekeeping

- Start class – 8:00 am
- Please mute/silence cell phones
- 10-minute Breaks – every hour
- Lunch ~ 11:30 am - 12:30 am
- End class ~ 3:30 – 4:00 pm

Solids Handling

MWO 8210

7 contact hours

9 CC10 hours

Wastewater operators need to have practical knowledge for dealing with sludge thickening and dewatering. In this course, students will analyze the characteristics of primary, secondary, and chemical sludge and the types of treatment processes used for each. Topics covered will include gravity thickening, dissolved air floatation, centrifuge operation, gravity belt, and belt filter presses, and vacuum filters. **Each participant should bring a calculator to this course.**

1. List five reasons for using sludge stabilization and conditioning procedures
2. Compare and contrast the different characteristics and treatment requirements for primary sludge, and chemical sludge
3. State the operational strategies, requirements, and performance standards for typical thickening processes, digestion processes, chemical and thermal stabilization processes, and dewatering processes.

Agenda

8:00 AM to 8:30 AM	Introduction to Solids Handling
8:30 AM to 9:30 AM	Sludge Characteristics and Thickening • Settled Solids • Biological Solids • Chemical Solids
9:30 AM to 11:30 AM	Sludge Handling • Operating Problems • Solutions
11:30 AM to 12:00 PM	Conveyance and Troubleshooting • Belt Thickeners • Rotary Drum
12:00 PM to 1:00 PM	LUNCH
1:00 PM to 2:00 PM	Floatation Thickening and Sludge Stabilization • Anaerobic Digestion • Aerobic Digestion
2:00 PM to 3:00 PM	Technologies used for Sludge Thickening and Dewatering • Belt Filter Press • Centrifuge

- Filter Press
- Lagoons and Drying beds

3:00 PM to 3:30 PM	Summary/Review – Questions and Answers
3:30 PM to 4:00 PM	Final Exam/Evaluations

Ice Breaker

- Before we start, let's…
  - Name one thing you know or want to know about:
    - Sludge thickening or dewatering
    - Anaerobic digestion
    - Class "A" or "B" sludge

Instructor Expectations

- Begin and end class on time
- Be interactive
- Share experiences and needs
- ***Make this an enjoyable and informative experience!***

Groundrules

- Participate at your own comfort level
- Use terms we all understand
- Everyone is different, so please show respect for others
- Listen with an open mind
- Express opinions
- Maintain confidences

Introduction

Purpose, Objectives, Overview

Purpose of Today's Class

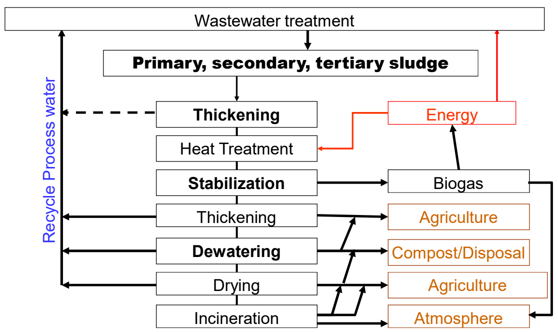
- To discuss sludge sources, dewatering characteristics, and the importance of removing sludge daily
- To focus on technologies for sludge handling – thickening, stabilization, dewatering, and post-dewatering

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

Overview



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

Agenda/Focus

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

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

Introduction

Definitions and Acronyms

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

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.

Sludge Stabilization and Dewatering

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

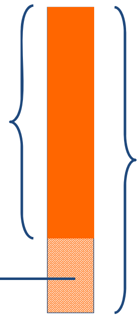
Dewatering
- Reduces Water Volume
- Returns Fines Back to Head of Plant
- Major Effect on Disposal Costs

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.

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

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)

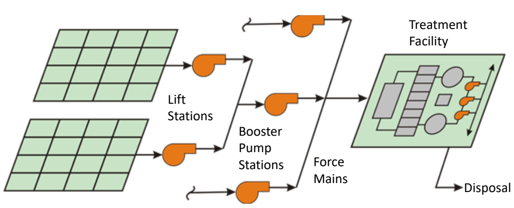
Sludge Characteristics

- 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

Introduction

WWTP Sludge

Wastewater Collection and Treatment

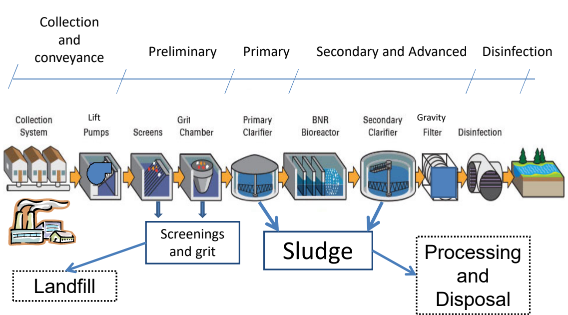


Gravity/Low Pressure Collection

Lift Station/ Booster Station

Wastewater Treatment

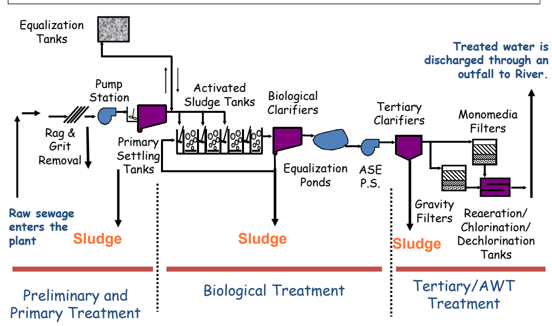
Wastewater Treatment - Sludge



Types of Sludge

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

Wastewater Treatment Process



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}

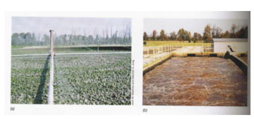
Primary Sludge

- 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

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

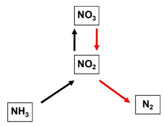


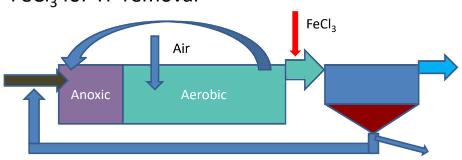
Biological Sludge

- 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

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





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

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

Sludge Handling Process

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

Thickening

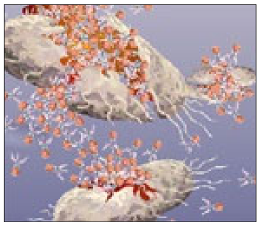
- Technologies
  - Gravity
  - DAF
  - Gravity Belt
  - Centrifuges
- Widely applied
- Multiple applications
- Ancillary systems
  - Thickened sludge pumping
  - Polymer conditioning

Sludge Stabilization

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

Cell Lysis - Enhancing Digestion

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

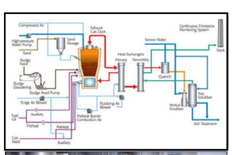


Sludge Dewatering

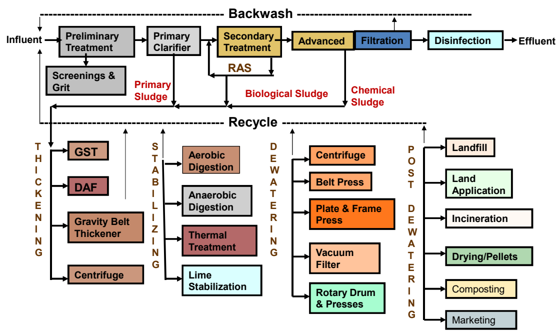
- Technologies
  - Belt Filter Presses
  - High Solids Centrifuges
  - Rotary Presses
  - Screw Presses
- Widely accepted
- Multiple applications
- Ancillary systems
  - Cake conveyance
  - Polymer conditioning

Post Dewatering Technologies

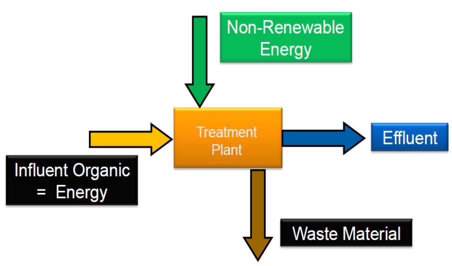
- Technologies
  - Incineration
  - Composting
  - Alkaline Stabilization
  - Thermal Drying
- Multiple applications
- Not as widely utilized
- Driver - Class A beneficial use



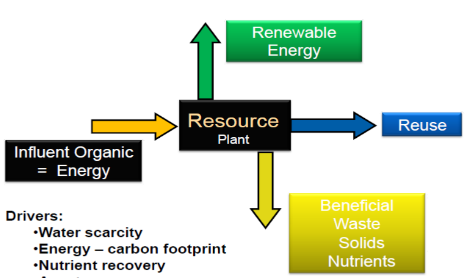
Wastewater Treatment: Liquids & Solids Trains



The old paradigm: “Wastewater is a waste…”



The new paradigm: Wastewater is a (valuable) resource



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

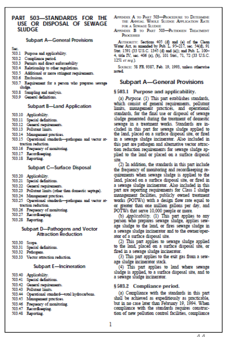
Regulations

40 CFR 503 and 261

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.

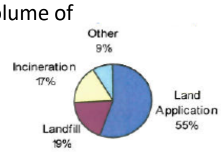
§ 503.2 Compliance period.

(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

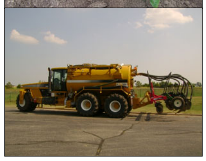
Key Sludge Issues

- To ensure that Part 503 standards are protective
- The US population is expected to double in 70 years
- What to do with increased volume of residuals
- 55% current production is land-applied



For land application sewage sludge must meet certain requirements

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

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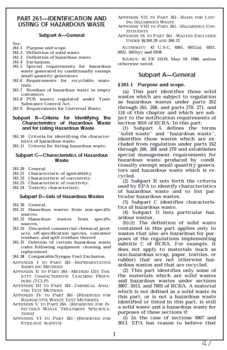
"Non-hazardous" sludge must meet the requirements of 40 CFR 261

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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If concentrations 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.

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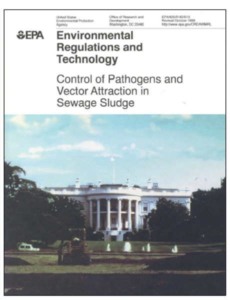
Regulations

Class “A” and Class “B” Sludge

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

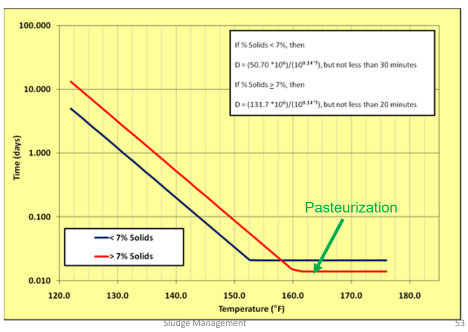
Regulations

- 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

"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)

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



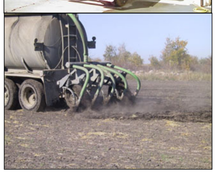
"Class A" pathogen reduction can be achieved using PFRP unit processes

- 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

"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

State and local regulatory 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

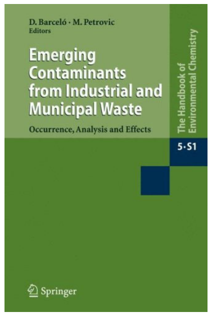
Legal Challenges
- Toxic Tort Claims
- Personal Property
- Public Nuisance Claims


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

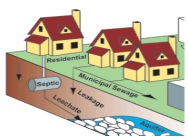


Where do Contaminants Originate?

We All Contribute

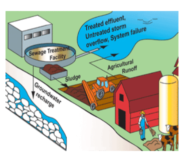
Behaviour:
- Ingest / use
- Excretion
- Bathing
- Disposal

voluntary

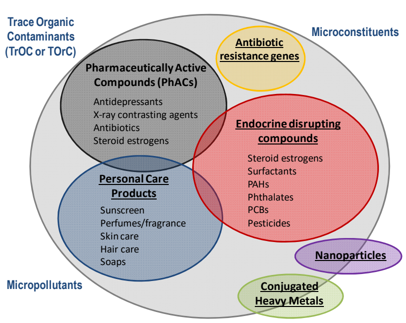


May make their way into soil and water:
- Wastewater
- Biosolids
- Irrigation
- Effluent

voluntary leading to involuntary



Contaminants of Emerging Concern (CECs)



So Why the Interest?

- CECs illustrate the connection of individuals' activities with their environment
- A large number of chemicals are getting into the environment with known and unknown concentrations and effects
- Detection of these chemicals is likely to increase
  - Analytical methods are developed
  - Look
- Numerous reports of intersex fish and other species have triggered Congressional and public interest
- No evidence of adverse human health effects, yet

Key Message

Focus on Source Control

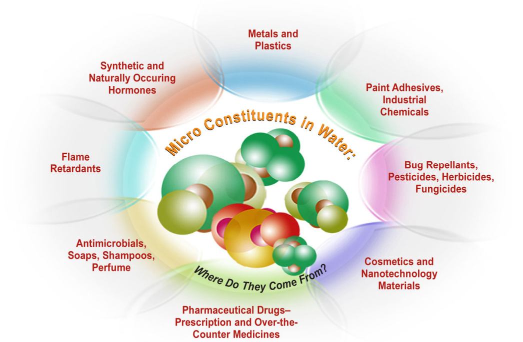
- Everyone contributes
- Clear linkages between individual behaviors and the presence of trace constituents
- We all should strive to minimize the amount of material we introduce into the water environment
- Think about product choices and source control

What's in a Name

What to call these 'compounds' without negatively branding them as "worry" or "concern"

- Contaminants of Emerging Concern
- Emerging Substances of Concern
- Compounds of Potential Concern
- Pollutants of Potential Concern
- Compounds of Emerging Concern
- Emerging Contaminants
- **Microconstituents**

Micro Constituents in Water: Where Do They Come From?



Solids Handling

Thickening Options

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

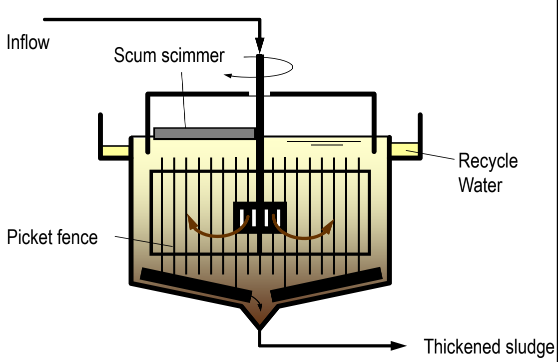
Thickening Options

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

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

Gravity Thickener



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

Gravity Thickening

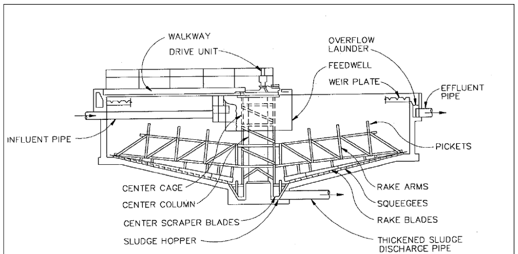


Figure 17.23 Typical gravity thickener.

Source: WEF, MOP-8.

Process Components

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

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

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

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%

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

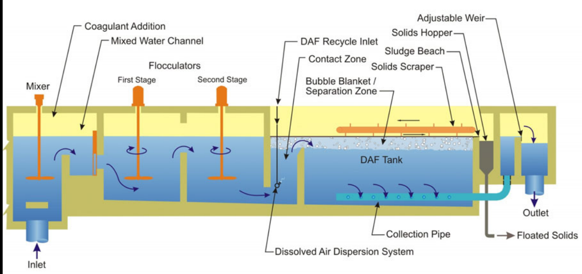
Dissolved Air Flotation Thickener-DAF

- 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.

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

Dissolved Air Flotation Schematic



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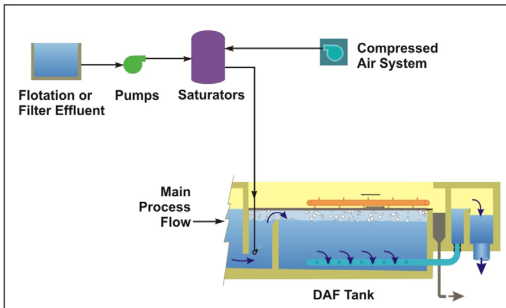
DAF Recycle System Schematic



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Dissolved Air Flotation Thickener

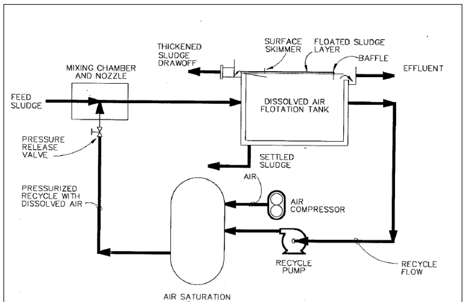

Figure 17.24 Schematic of dissolved air flotation thickener.

Source: WEF, MOP-

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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%

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

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

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

Gravity Belt Thickener

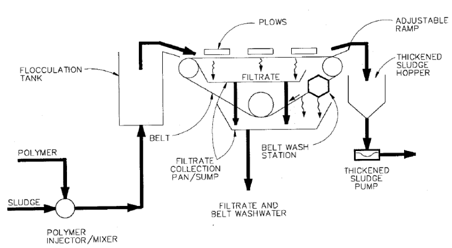

Figure 17.26 General schematic of a gravity belt thickener.

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

Solids Handling - Stabilization

Overview

Stabilization Options

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

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.

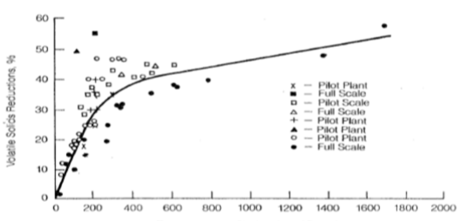

Figure 18.31 Typical volatile solids reductions as a function of digester liquid temperature and digester sludge age.[37] VS reduction depends on many variables, including prior processing, sludge characteristics, and digester operating conditions.[37]

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Conventional "pancake" style anaerobic digestion tank (low SWD/DIA ratio).

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

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

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

Anaerobic processes

→ Anaerobic fermentation

→ Anaerobic respiration

TWO-STEP REPRESENTATION

ORGANIC MATTER

↓ **Fermentation**

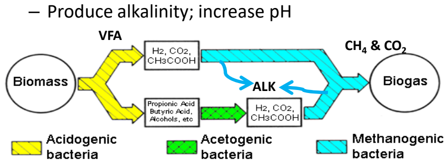
VOLATILE FATTY ACIDS

↓ **Methanization**

BIOGAS

Anaerobic Digestion

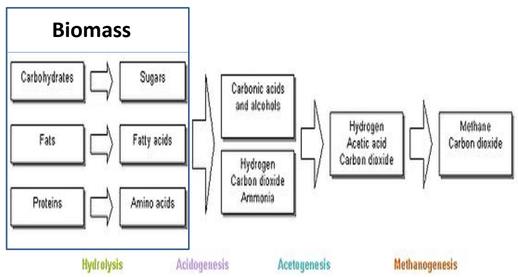
- Acid Forming Bacteria
  - Produce Organic or Volatile Acids
  - Can depress pH
- Methane Forming Bacteria
  - Produce CH_4 and CO_2
  - Produce alkalinity; increase pH



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

Anaerobic Digestion – Four Step Process



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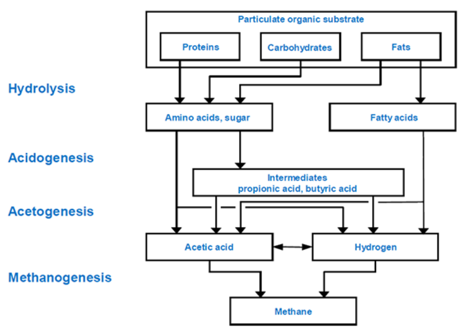
Anaerobic Digestion – Four Step Process



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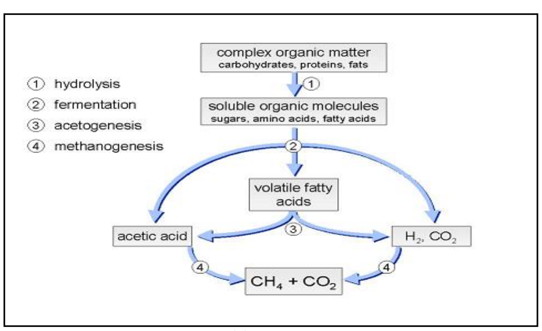
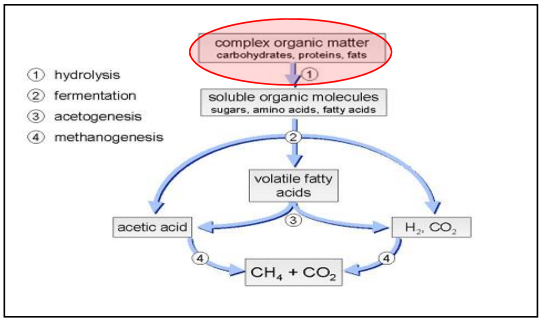
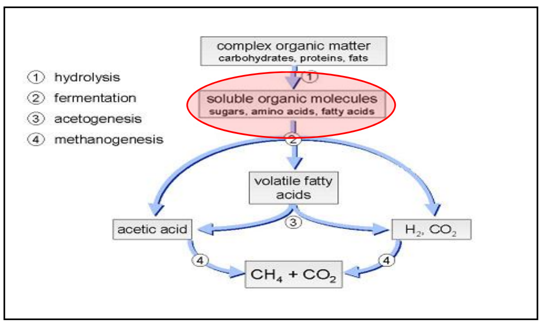
Anaerobic Digestion – Four Step Process



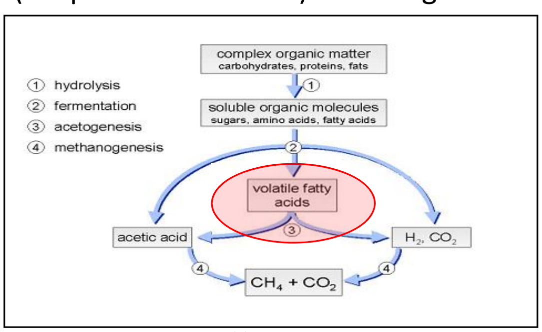
Complex solids are hydrolyzed into soluble organic molecules



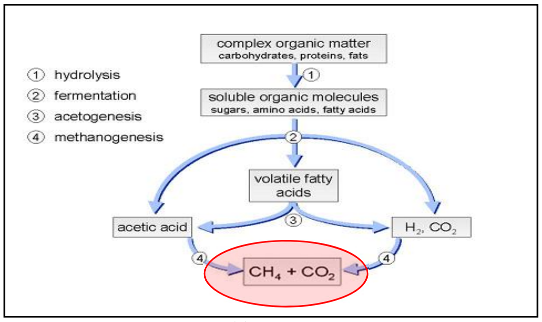
Soluble organics are fermented into volatile fatty acids (VFAs).



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



Acetic acid and hydrogen are converted to methane via methanogenesis.



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

Factors Affecting Anaerobic Digestion Performance

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

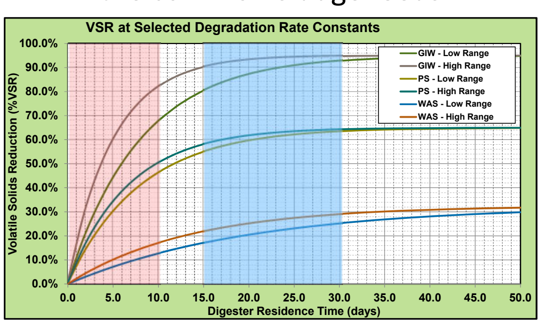
Implications of different sludge feeds to digestion

- 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

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

Relative degradation potential among the common sludge feeds



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

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%

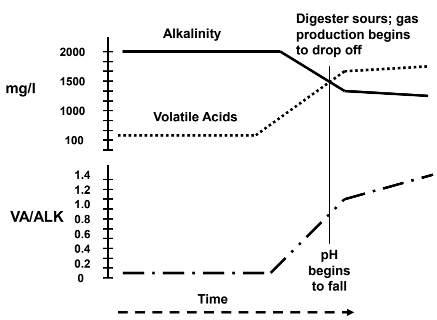
Digester Performance

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

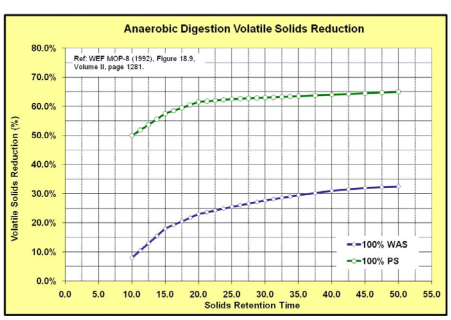
VFA/ALK Ratio

- 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

Alkalinity/Volatile Acid Ratio



Volatile solids reduction in digester



Some 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

Digester Performance

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

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

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

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

Typical and maximum VSLR for well heated and mixed digesters

	Metric Units (kg/m^3-day)	English Units (lb/1000ft^3-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.

Volatile solids reduction effectiveness can be using the Van Kleek Equation

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

Where:

%VSR = Volatile Solids Reduction Rate

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

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

Percent Volatile Solids Loss

- If the VS content of the sludge going into the digester is 72% and the VS content of the digested sludge is 48%, what is the percent destruction of volatile solids in the digester?

Answer: $\frac{(0.72 - 0.48) \times 100,\%}{\{0.72 - (0.72 \times 0.48)\}} = \frac{0.24 \times 100,\%}{0.72 - 0.35}$

$\frac{0.24 \times 100,\%}{0.37} = 0.64 \times 100,\% = 64\%$

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)

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)

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

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

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

Typical causes of process failure in anaerobic digestion systems

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

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

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

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

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

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.

Digester Supporting Systems

- Mixing
- Heating
- Covers
- Gas Handling & Treatment

Digester Mixing Systems

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

Effective Digester Mixing

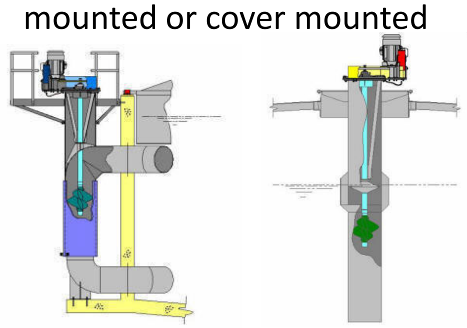
- Elimination of temperature stratification and maintenance of homogeneous mixture in the digester tank.
- Rapid dispersion of raw feed sludge with the active biomass within the digester tankage.
- Mitigation of formation of excessive floating scum layers or deposition of heavy silt, grit and inert solids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

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.

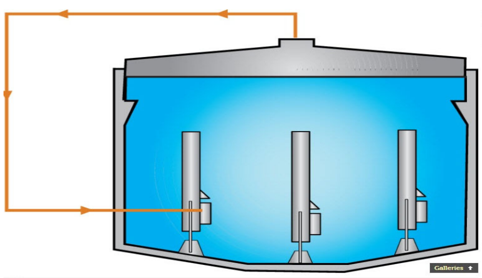
Draft tube mixers can be side mounted or cover mounted



Courtesy: Olympus Technologies, Inc.

Pumped mixing systems from using nozzles

"Cannons" are floor mounted inside the digester



Courtesy: Infilco Degremont Industries

Heating

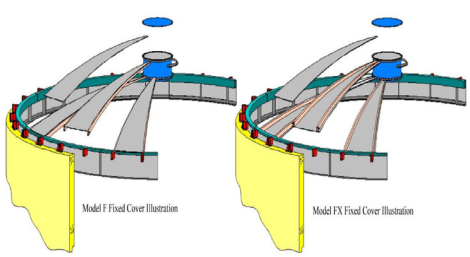
- Heat Exchangers
- Hot Water Boilers
- Combination Boiler / HEX Systems

Tube-in-Tube heat exchangers are most common

Covers

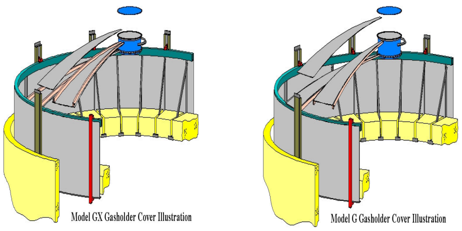
- Fixed Covers
- Gas Holder Covers
- Steel Truss Floating Covers
- Membrane

Fixed covers are the least costly



Courtesy: Olympus Technologies, inc.

Floating covers are ballasted and can provide some gas storage



Courtesy: Olympus Technologies, inc.

Membrane covers can provide high gas storage volume

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

Gas Handling and Treatment

- Condensate and Moisture Removal
- Sulfide Removal
- Siloxane Removal
- Gas Storage
- Waste Gas Flaring

Conventional digester gas utilization equipment as a bare minimum…



Gas storage can be provided in several different ways within the facility.

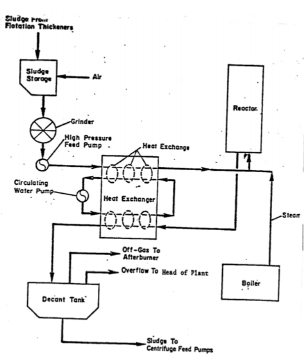



Waste gas flare for burning excess digester gas

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!!

Heat Treatment

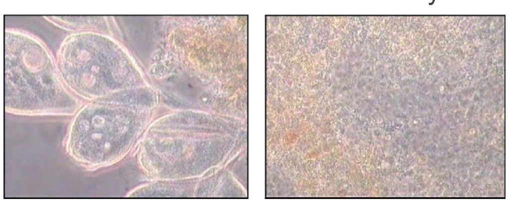


Cambi Thermal Hydrolysis Process (THP)

- Process for preconditioning biosolids prior to anaerobic digestion
- Stage 1: High temperature pressure cooker
  - Dissolves extra-cellular polymetric substances (EPS)
  - Time and temperature destroys pathogens – Class A biosolids

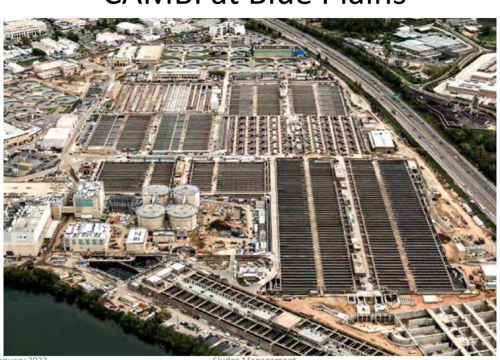
What is Cambi Thermal Hydrolysis?

- Stage 2: Rapid depressurization results in steam explosion, cellular disintegration and a dramatic decrease in viscosity

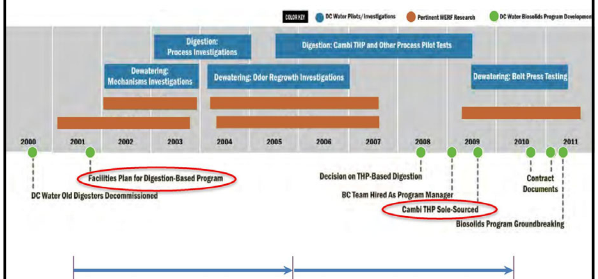


Cells Before Hydrolysis Cells After Hydrolysis

CAMBI at Blue Plains



DC Water Planning and Research



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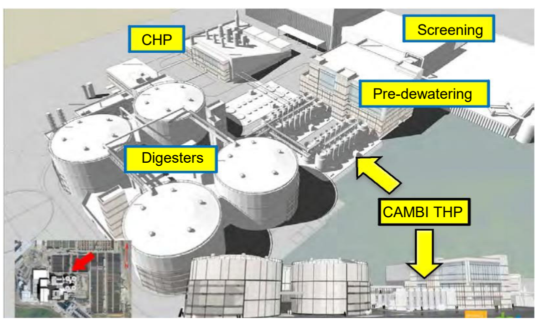

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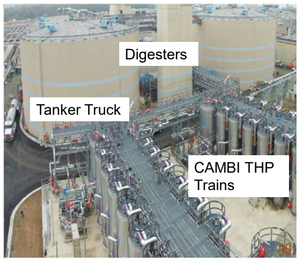
DC Water Blue Plains - THP

January 2023 Sludge Management 162

DC Water Blue Plains - THP

- Four independent Cambi THP trains each rated at 112.5dtpd. Whole system rated at 450dtpd.
- Design based on standard B12 linear train layout with six reactors per train.
- Manufactured in the US and UK.
- 20 month site installation started August 2012.
- 3 month seeding operation using trucked in, AlexRenew pasteurized sludge



DC Water Blue Plains - THP

Operational targets:
- Cambi feed sludge TS – 16.5%
- Digester feed TS – 10.5%
- Cambi reactor – 87 psi, 330°F

Digester conditions:
- Temperature = 100°F
- TS = 5.5 %
- Ammonia-N = 2800 mg/L
- pH = 7.6
- Bicarbonate alk = 8,000 mg/L +/-
- Approx. 65% VSR

Reached Class A February 2015

DC Water Blue Plains - THP

Blue Plains Belt Press Performance with CAMBI

- Loading rate:
  - 1000 lbs/m/hr avg
  - 1500 lbs/m/hr peak
- Diluting feed from 5% to 3.5%
- Cake TS = 30 - 32%
- Polymer dose = 18 lb/dt +/-
- Filtrate and wash water are collected separately
- High ammonia filtrate will be treated using DEMON (Future)

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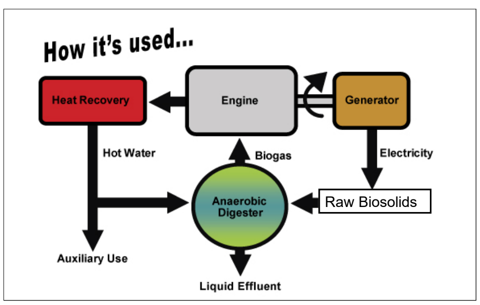
Gas beneficial use via Combined Heat & Power (CHP) systems



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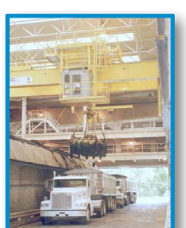
Blue Plains Lime Stabilization and Truck Loadout - before CAMBI THP

- Large-scale Class B lime stabilization program
- About 65 truck-loads per day (1200 wet tons/day)
  - Agriculture – 39 counties in MD and VA
  - Silviculture – 40,000 acres
  - Poplar plantation and reclamation projects



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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.

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

Solids Handling - Conditioning

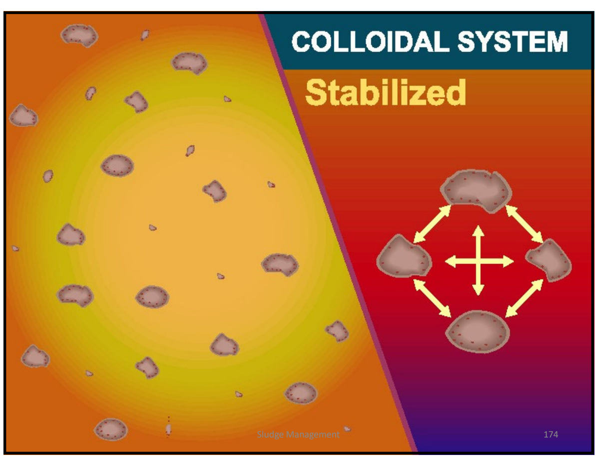
Coagulation and Flocculation

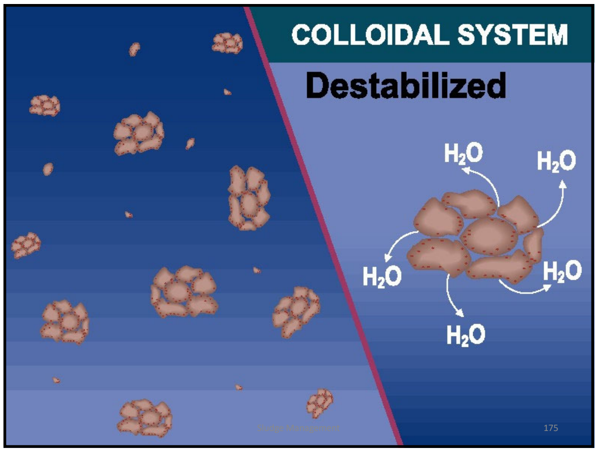
Sludge Conditioning

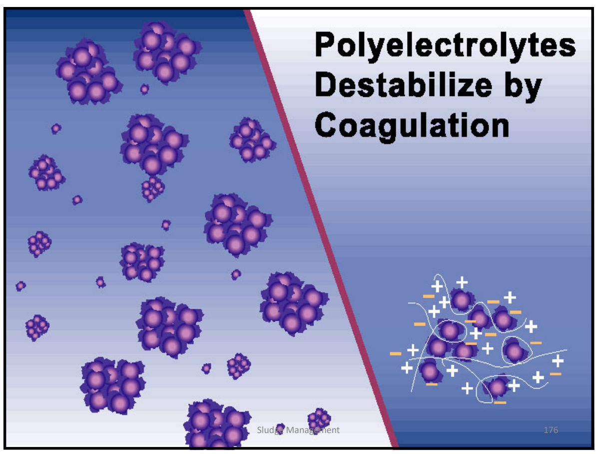
- Coagulation – the clumping together of very fine particles (floc) into larger particles using chemicals (coagulants).
- Flocculation – The gathering together of fine particles after coagulation to form larger particles by a process of gentle mixing.
- Polymers – Coagulant chemicals used in binding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

Conditioning Options

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







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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Solids Handling - Dewatering

Overview

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.

Dewatering Options

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

Solar sludge drying beds can be covered to reduce seasonal impacts

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

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

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

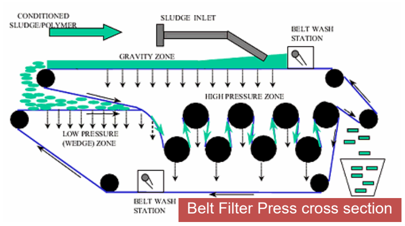
Factors Affecting Belt Press Performance

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

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 %

Belt Filter Press Overview

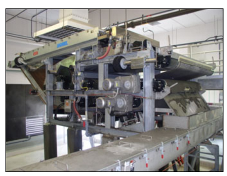


Belt Filter Press cross section

Major Manufacturers
Andritz
Ashbrook
BDP
Charter

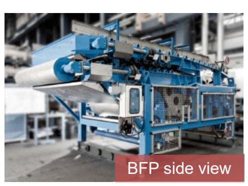
Belt Filter Press

- 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



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

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


Ashrook BFP

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

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

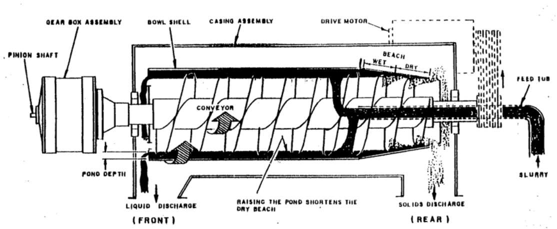
Trouble Shooting

- 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.

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

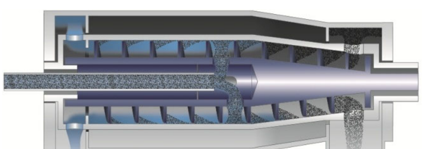
Centrifuge



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

Centrifuge Overview



Centrifuge cross section

Major Manufacturers

Alfa Laval

Andritz

Centrisys

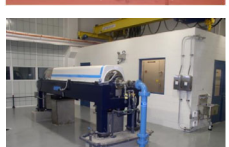
Flottweg

Westfalia

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

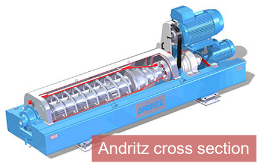
Flottweg Centrifuge



Andritz Centrifuge

Centrifuge
Key Sizing Criteria

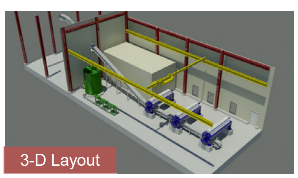
- Bowl Diameter
- G-Volume
- Operating Speed
- Hydraulic Loading (flow)
- Solids Loading
- Solids Capture
- Cake Solids
- Polymer Dosage



Andritz cross section

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

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

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)

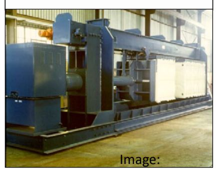
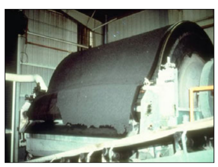


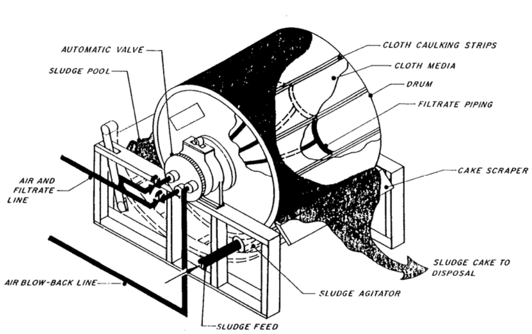
Image: WesTech Industries

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.



Vacuum Filter



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

Rotary drum thickener

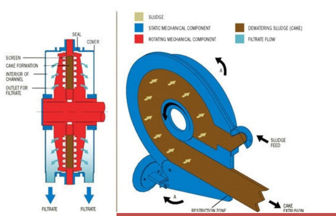
New Dewatering Processes

- Rotary Screw Presses
- Rotary Fan

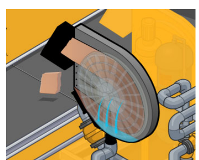
Rotary Fan Presses

- 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

Rotary Fan Press Overview



Fan Press cross section



Fan Press cross section

Major Manufacturers
Fournier
Prime Solutions

Rotary Fan Press Comparison

- Good
  - Low speed, low power
  - High solids capture rate
  - Low water requirements
  - Automated operations
  - Ease of maintenance
  - Fully enclosed
- Not so Good
  - Unit capacity
  - Generally lower solids content
  - Better with primary solids
  - Performance with WAS should be piloted

Fournier Fan Press

Fournier Fan Press

Rotary Fan Press
Key Sizing Criteria

- Fan / Disc Diameter
- Rotational Speed
- Backpressure
- # Rotary Fans / Shaft and Motor
- Hydraulic Loading (flow)
- Solids Loading
- Solids Capture
- Cake Solids
- Polymer Dosage

Prime Solutions Fan Press

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Rotary Fan Press
Key Layout Considerations

- Fan and pressure disc replacement
- Removal from shaft
- Solids conveyance
- Motor maintenance
- Air changes / odor

Fournier Fan Press

January 2023 Sludge Management 212

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

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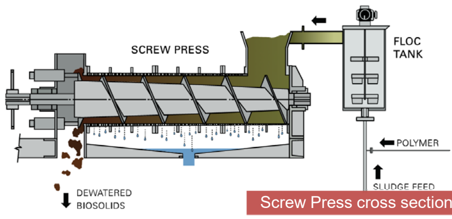
Rotary Screw Press Overview



Screw Press cross section

Major Manufacturers
Alfa Laval, Andritz,
Huber, Parkson,
Schwing, FKC

January 2023 Sludge Management 214

Rotary Screw Press Comparison

- Good
  - Low speed, low power
  - High solids capture rate
  - Low water requirements
  - Automated operations
  - Ease of maintenance
  - Fully enclosed
- Not so Good
  - Unit capacity
  - Generally lower solids content
  - Better with primary solids
  - Performance with WAS should be piloted

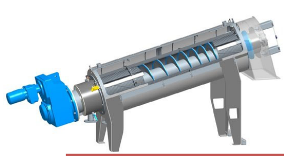
Alfa Laval Screw Press

Andritz Screw Press

January 2023 Sludge Management

Rotary Screw Press Key Sizing Criteria

- Scroll and Screen Diameter
- Rotational Speed
- Backpressure
- Screen Mesh Openings
- Shaft Size
- Hydraulic Loading
- Solids Loading
- Solids Capture
- Cake Solids
- Polymer Dosage



Screw Press cross section

January 2023 Sludge Management

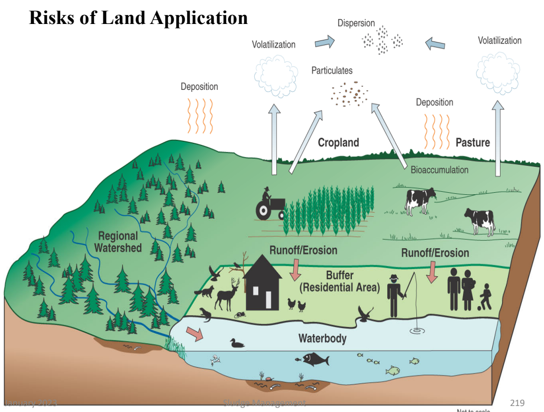
Rotary Screw Press
Key Layout Considerations

- Pressure disc replacement
- Screen and scroll removal
- Solids conveyance
- Motor and bearing maintenance
- Air changes / odor

Disposal Options

- Marketing of Compost and Dried Sludge Pellets - economical
- Landfill - reliable
  - Sludge
  - Ash
- Land Application
  - Seasonal
  - Agriculture
  - Land Reclamation

Risks of Land Application



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

January 2023 Sludge Management 221

Basic process configuration for biosolids composting unit treatment process.

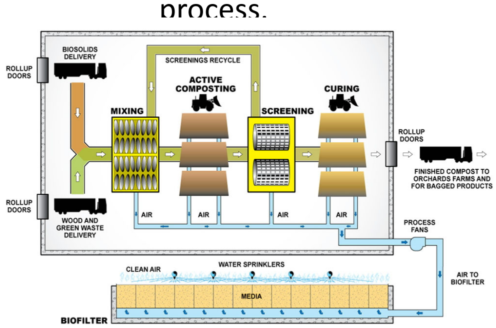

Image: Inland Empire Regional Composting Authority (http://www.ierca.org/process/compostprocess.html)

January 2023 Sludge Management 222

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

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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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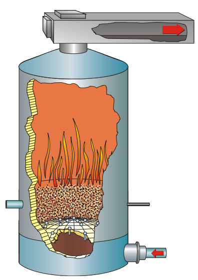
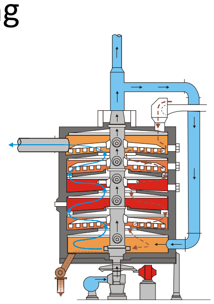
Incineration: Multiple Hearth & Fluidized Bed

- 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

Sewage Sludge Incineration (SSI) regulatory requirements are changing





Fluid bed thermal oxidation - standard in incineration technologies.

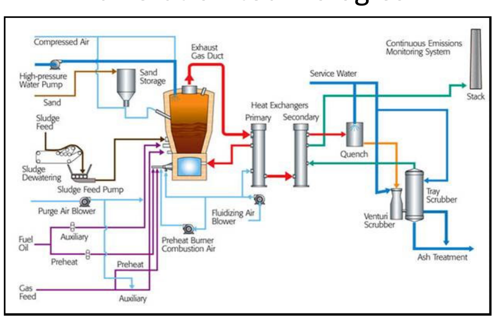
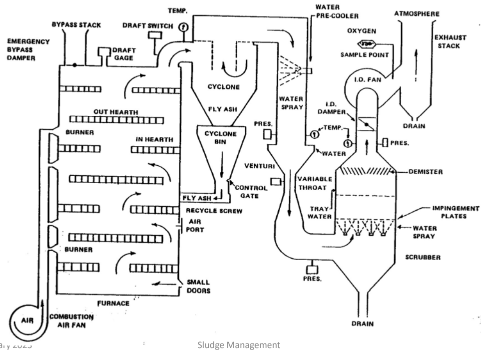


Image Courtesy IDI Technologies

Multiple-Hearth Incinerator



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 (NESHAPS)
  - Mercury (Hg)
  - Beryllium (Be)
- 40 CFR 503 Regulations
  - Incorporate 40 CFR 61 NESHAP Limitations for Be, Hg
  - Total Hydrocarbons & Carbon Monoxide
  - Lead, Arsenic, Cadmium, Chromium, Nickel (Measured in Biosolids)

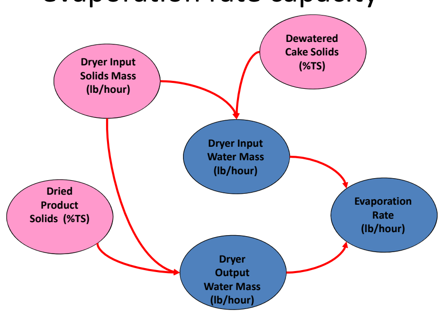
Regulations have been evolving based on an expanded waste definition

- 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 the other categories in 12/2005 and did not include SSIs as part of the group.

Regulations have been evolving based on an expanded waste definition

- Sierra Club Petitions EPA for SSI emission standards/litigates
- EPA classifies sewage sludge as a "solid waste" and therefore regulated by CAA
- Rule promulgated to establish regulatory requirements for SSI units both "new" and "existing"

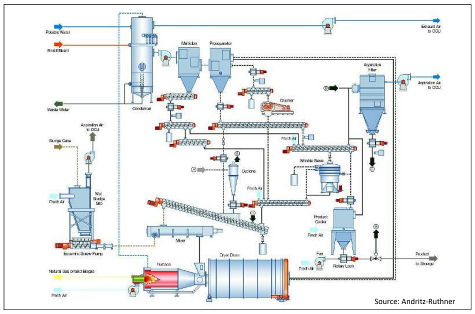
Thermal drying systems are "rated" by evaporation rate capacity



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

Rotary drum thermal drying is the most prominent technology for "large" systems.



Compact rotary drum drying systems are available for "smaller" size systems.

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.

Questions

Thank You

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