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SOLIDS DIGESTION & HANDLING for WASTEWATER

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Solids Digestion & Handling

Topics

Solids Handling

- Solids, known as **sludge**, must be stabilized and reduced in volume before they can be reused or disposed of <u>economically</u> and <u>safely</u>
- The processes used to stabilize sludge and reduce its volume are known as ***solids handling***.
- Includes
  - Thickening
  - Digestion
  - Dewatering
  - Disposal
- Types of Sludge
  - Primary sludge
  - Trickling filter humus sludge
  - Activated sludge
  - Digested sludge
- Solids must be thoroughly stabilized in order to avoid problems:

- odors
- human exposure to pathogenic organisms
- attraction of vectors (mice, dogs, birds).

- Biological digestion is the process most often used to stabilize sludge
- Chemical Stabilization
  - addition of large doses of lime
  - temporary - mainly for upsets
  - costly
- Aerial View
  - Solids Building and Drying Beds SEWRP
  - Digesters SEWRP

 

- Dry solids content about 2%
- All solids handling processes create side stream flows that are returned to the head of the plant
- High in BOD and suspended solids and usually have no DO
- Tests for BOD and SS should be run on:
  - thickener overflow
  - supernatant
  - other solids handling side streams
  - every shift
- Suspended solids are again settled in the primary clarifiers, but the organics that are present are mostly dissolved.
- The secondary processes must deal with the majority of the BOD that is being returned and must be taken into calculation considerations
- Solids handling incorporates four functions:
  - Thickening
    - decrease the amount of water that is handled by increasing the solids concentration
    - double the solids concentration, the amount of water needed to move a pound of solids is cut in half

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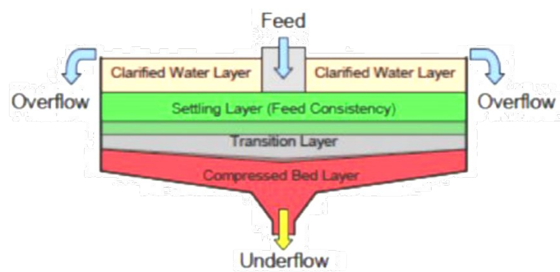
- Digestion
  - "breaking down" sludge into simpler components through the action of microorganisms
  - Aerobic
  - Anaerobic
- Dewatering
  - dewatering processes are located after digestion
  - Chemicals (***polymers)*** used to enhance many of the sludge dewatering and drying processes
  - filter presses, vacuum filtration, belt presses, centrifuges and sludge drying beds
- Sludge disposal and/or reuse
  - Sanitary landfill
  - Land application
  - Composted

Thickening



- Agglomeration (floc and cake)
- Flotation (DAF)
- A "thick" sludge, (5 – 6% total solids), still contains over 90% water
- Processes thicken sludge but remains a liquid or slurry
- gravity thickeners
- diffused air floatation (DAF) units
- gravity belt thickeners
- rotary drum thickeners
- Most commonly used before digestion
- Polymers can aid in process and is referred to as ***conditioning***
- It is always best to *NOT* send thin sludge (or lots of water) to the anaerobic digester
- Thickening normally increases the dry solids content to 4 – 6%.

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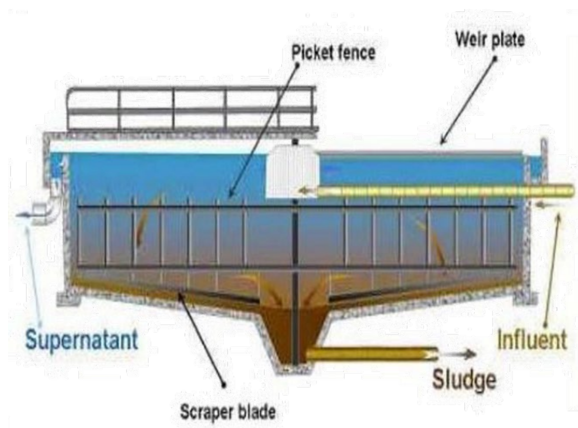
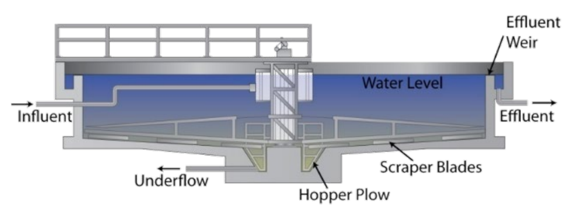
Gravity Thickeners

- Uses gravitational forces to separate water from sludge and is mainly used on ***primary sludge***
- Scaled down clarifier
- Process is identical but the unit is designed for heavier sludges and lower flows
- Surface loading rates are about 400-800 gpd/ft^2.
- Detention times vary from 1-2 days.
- Solids loading on the unit is calculated in lbs/day/ft^2.
- Can be thickened to 8-10% total solids but typically 2-6%
- Poor thickener performance can cause organic overloading in the secondary process





- Efficiency depends on:
  - Type of sludge being thickened
    - Primary sludge thickens best, but must not be allowed to become septic
    - Secondary & activated sludge is difficult due to their lower solids content and denitrification.
  - Age of the feed sludge
    - Older sludges prone to gasification from denitrification and septic conditions; floats
  - Sludge temperature
    - Warmer sludge settles better
    - Shorter DT times in warmer weather because of gasification due to the increase in biological activity
  - Sludge blanket depth
    - compaction that occurs from the overlying sludge
    - between 5-8 feet deep
  - balance must be struck between maintaining blanket thickness and removing the solids before gasification
  - Hydraulic and solids loading.
- Different zones of concentration:
  - Clarified Effluent Water Zone
    - topmost zone

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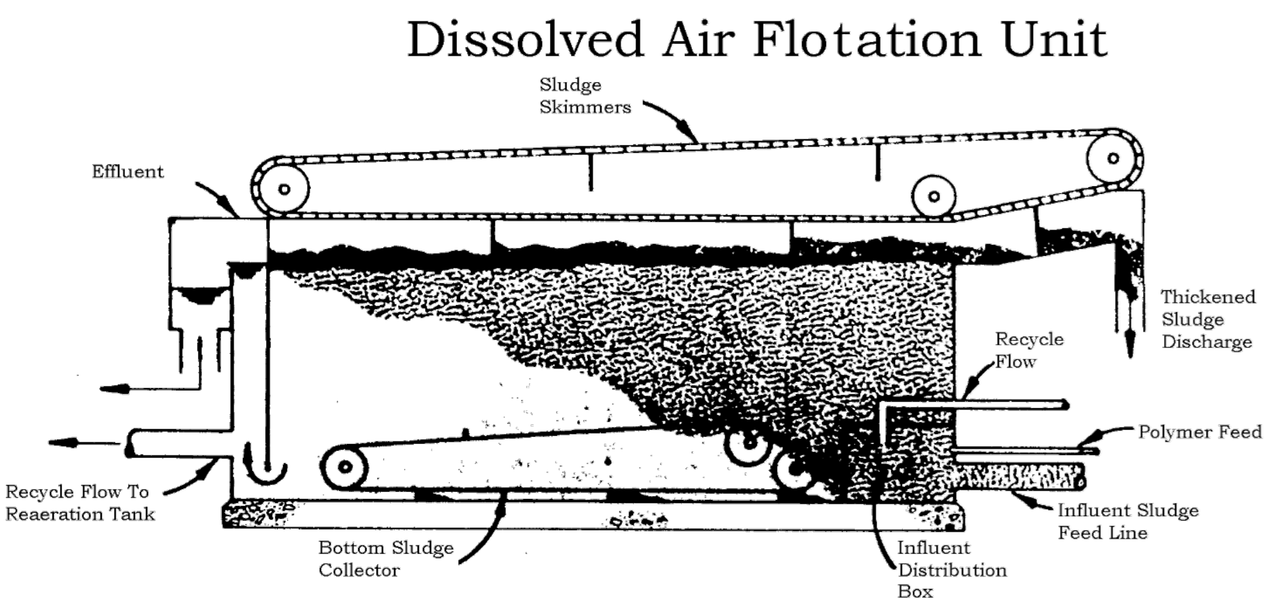
- free of solids
- Feed Zone
  - does not necessarily have the same concentration of feed solids
  - uniform solids concentration
- Compaction Zone
  - increasing solids concentration
  - from feed zone concentration to underflow concentration

Diffused Air Floatation (DAF) Units

- Uses air bubbles to float solids to the surface for removal.



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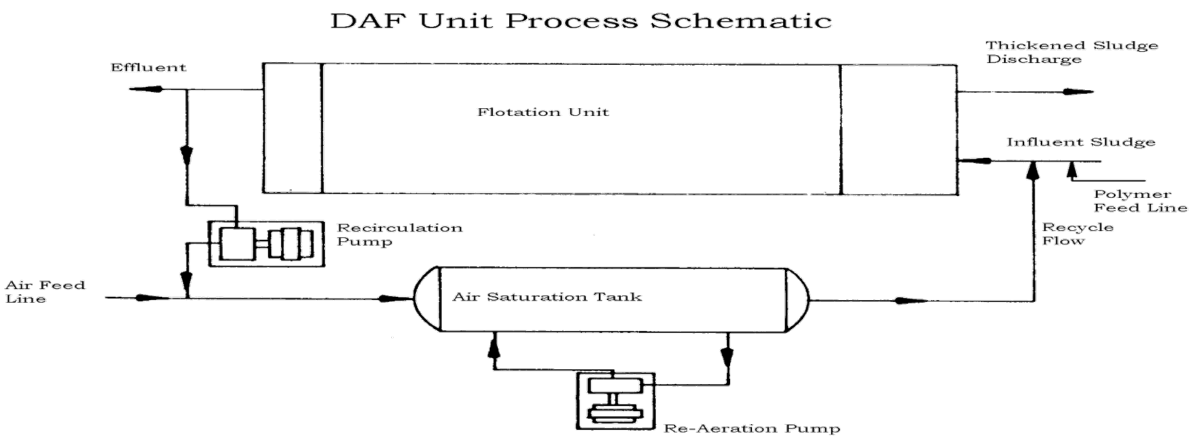
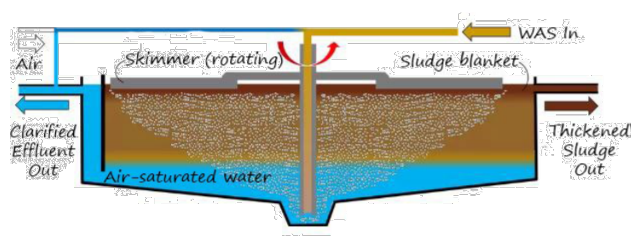
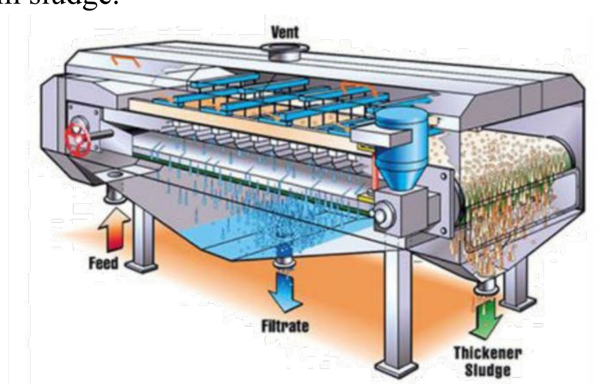
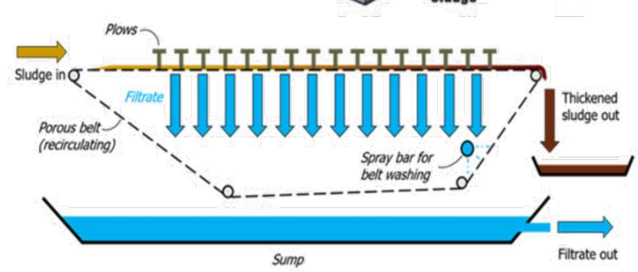




Gravity Belt Thickeners (GBT)

- Uses a moving porous belt to drain water from sludge.





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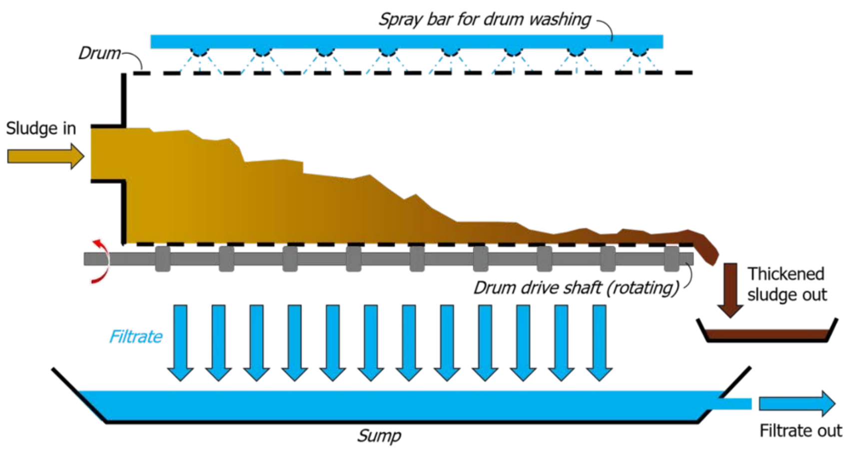
Rotary Drum Thickeners (RDT)

- Uses a rotating drum to separate water from sludge.



Digestion

- Sludge digestion is the *primary means* of stabilizing the volatile organic material in the sludge
  - Sludge from the secondary clarifiers is already partially stabilized
  - Sludge produced by primary clarifiers is unstable, odorous and full of pathogenic bacteria (raw).
- Biologically degradable organics (volatile solids) account for ***60-65%*** of the total solids.
- Releases most of the bound water in the sludge.
- Sludge decomposes the organic material into gases:
  - water vapor
  - carbon dioxide (CO_2)
  - methane (CH_4)
  - hydrogen sulfide (H_2S)
- Reduces the volume of sludge that will ultimately have to be landfilled, land applied, or composted.
- Accomplished by either **Anaerobic** or **Aerobic** digestion
- Only reduces the volume of organic material, not inorganic waste, such as grit or plastics.

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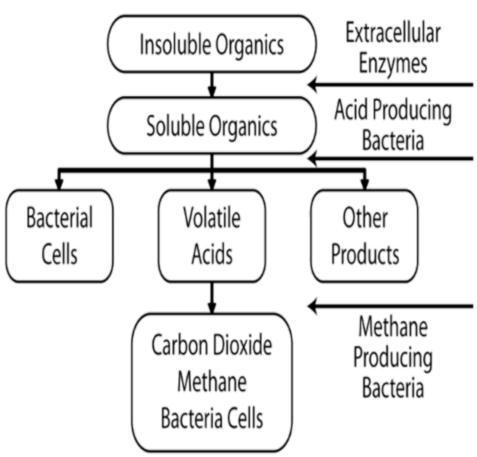
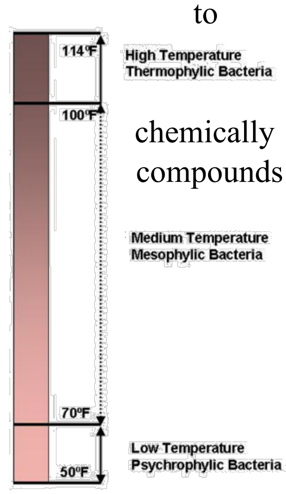
- Digested sludge is inoffensive, having the appearance and characteristics of a rich potting soil.

Anaerobic Digestion

- Must occur in the ***absence*** of dissolved oxygen



- In sealed tanks and systems to prevent atmospheric from interfering
- Use oxygen that is chemically bound in organic compounds like sugars and starches
- Stages of digestion
  - Acid fermentation
  - Methane fermentation
- Types of digestion
  - Low-temperature
  - Medium-temperature
  - High-temperature



- Mixing and heating required
- No more than 1°C/F per day change
- Excess water causes upsets

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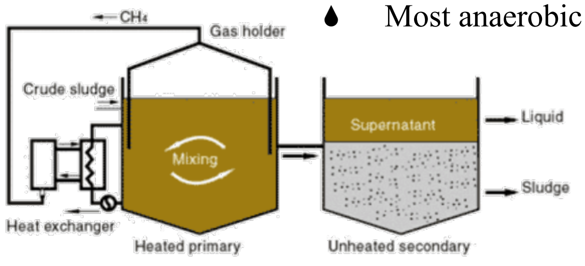

- Most anaerobic digesters are operated as a 2-stage process
  - Primary - receives raw
    - Mixed and heated
    - Where most of the stabilization takes place
    - Fixed cover
  - Secondary
    - Sludge solids are allowed to settle and drawn off for disposal
  - 'Dish water grey' supernatant draw off and sent back to primary
  - Supernatant concentrated in ammonia and BOD with no DO
  - Usually floating cover to allow for gas and sludge storage
  - Serves as a source of *seed* organisms for the primary digester in case it becomes upset
- Solids are reduced 50-60%

Tanks

- Sized based on a solids loading rate of 0.15-0.35 lbs/day/ft^3
  - Cylindrical in shape
  - Around 20 ft deep
  - Sloped floors for sludge withdrawal
  - May be double stacked (clarifier inside digester)
  - Contains tubes or manifolds for supernatant removal

Covers

- Pressure Relief Valve – Top
- Vacuum Relief Valve – Middle
- Flame Arrester - Bottom

  Fixed
  - Keep ambient O_2 out
  - Handles gas processing equipment
  - Limits capacity

  Floating
  - Slide guides allow the cover to travel above the tank wall
  - Uses 8-12 inches of water to maintain seal of gases
  - Rapid rise or fall breaks seal
  - Flexible capacity for gas and sludge
  - Gas pressure in the system must be kept at less than 8 inches of water column to prevent the water seal from blowing out.

  Gas Holder
  - PVC-coated polyester fabric membranes, stainless steel anchors

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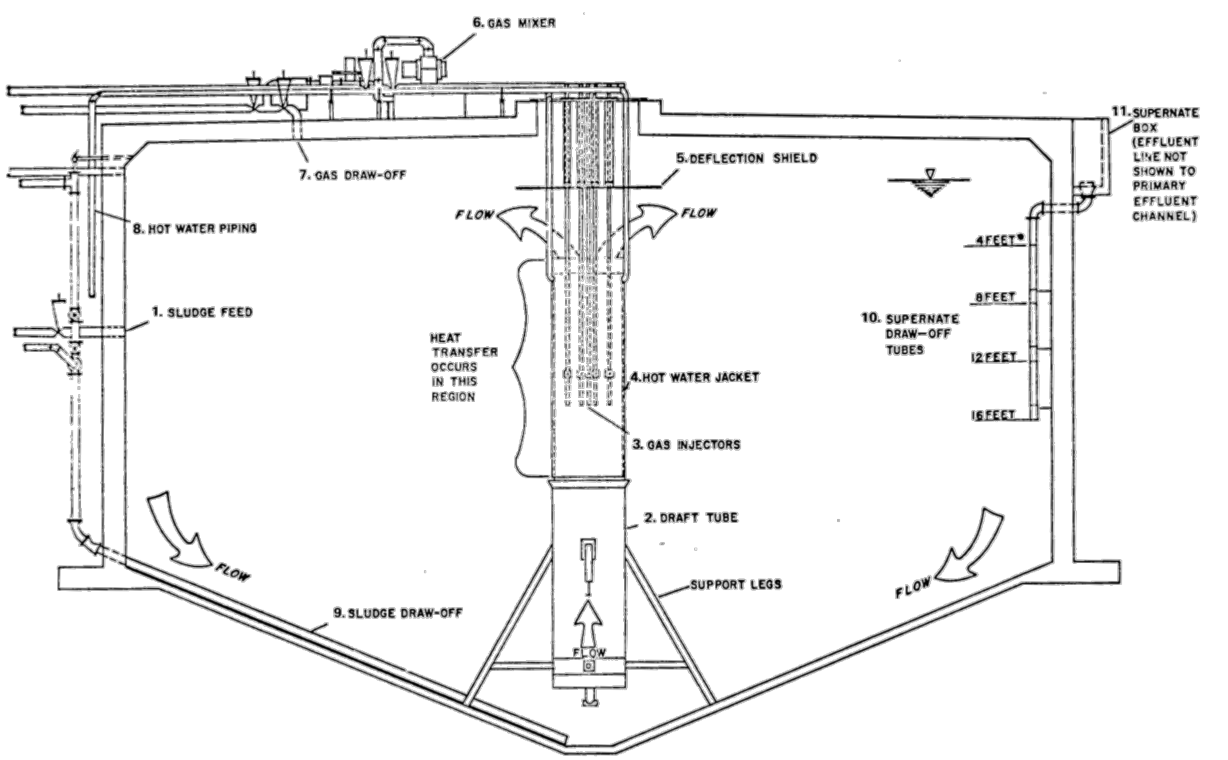
Anaerobic Digestion Schematic



Primary Digester

Gas Handling Systems

- Contains a heat value of 500 – 600 BTU/ft^3 (Natural gas contains 900 – 1200 BTU/ft^3)
- The volatile solids concentration is reduced 50-60%, producing 8-12 ft^3 of gas for every pound of volatile matter added.
- For every pound of volatile matter destroyed, 12-18 ft^3 of gas is produced.
- The gas produced is composed of 65-70% methane and 30-35% carbon dioxide.
- Approximately 1-2% of the emitted gas contains nitrogen (N_2), hydrogen (H_2) and hydrogen sulfide (H_2S).
- Since anaerobic digestion is an anaerobic process, if air enters the digester, an explosive mixture of gases can result.
- Often reused for mixing and heating

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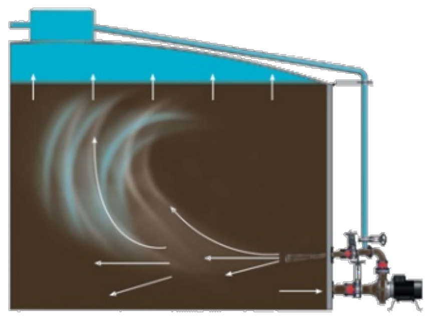
Mixing and Heating

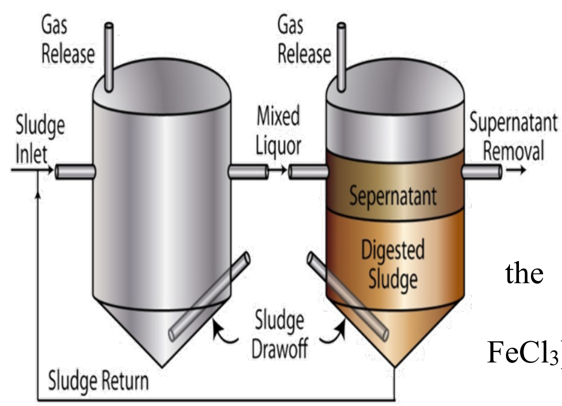
- Mechanical mixers that utilize propellers and draft tubes are common.



- Mixers that work by compressing and bubbling methane gas into the sludge are also used.
- A boiler fired off of digester gas, natural gas or propane typically provides the heat for the digester.
- Boiler water is best maintained at between 60 and 82°C.
- 2 common methods of heat exchange:
  - sludge recirculation through an external heat exchanger
  - heat exchangers located inside the digester

Piping

- Sludge Feed (inlet) Line
- Supernatant Tubes
- Sludge Draw-Off Lines
- Must be able to withstand pumping pressures and severe corrosion
- Cast iron or steel is typically used
- ***Struvite*** is magnesium ammonium phosphate ($NH_4MgPO_4 \cdot 6H_2O$) which causes hard scale on the inside of the piping system and clogs piping
- Controlled by adding iron salts (ferric chloride, $FeCl_3$) to react with the phosphorus, preventing the formation of struvite.



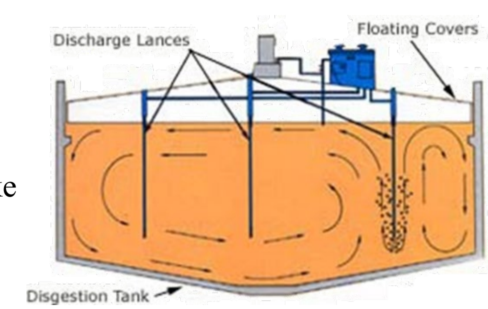
- Higher the wastewater pH, the more likely struvite crystals form.

Characteristics and Chemistry

- Enzymes break down the solid organic compounds into:
  - organic fatty acids
  - alcohol
  - carbon dioxide (CO_2)
  - ammonia (NH_3)

Acid Stage

- Facultative acid-producing bacteria (***saprophytic***) take complex raw organic compounds, like sugars and starches, and break them down into organic acids



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- H_2S and CO_2 are produced
- Lowers pH
  - Important to maintain enough alkalinity to buffer the effect of the acids.
  - Necessary to keep the pH above 7.0 and maintain maximum methane production
- Nitrogen content is about 1% - 5%
- Reduces volatile solids content of the sludge by 30 – 60%
- pH not good process control
- Volatile Acid/Alkalinity Ratio is key parameter when monitoring the health of the anaerobic digester
  - Running volatile acids and alkalinity tests is an important part of efficient digester operations.
  - The VA/ALK ratio will change before the pH begins to drop.
  - Upsets and foaming occur when acid production is not buffered (heartburn)
  - VA/ALK ≤ 0.1 optimal

Methane Fermentation Stage

- Not as abundant as acid producers in raw wastewater due to narrow pH range => Easy to kill, hard to grow
- Takes the organic acids from the acid formers and converts them into methane (CH_4)
- Ammonia (NH_3) production neutralizes the acid production and the pH begins to rise.
- Stabilization will occur with the production of Methane
- Methane gas = 65% - 75%
- Methane fermenters (***methanogens***) will not work or reproduce if the pH is < 6.6 or > 7.6. (picky eaters)
- They work best when the pH is 7.0-7.2.
- CH_4 (blue flame) and H_2S & CO_2 (yellow/orange flame) gas must be either scrubbed and reused as fuel or flared off

Low-temperature

- ***Psychrophilic*** bacteria
- Rare design--unheated Imhoff tank digesters and septic tanks
- Slow process, 50-120 days to stabilize sludge
- Large amounts of CO_2 & H_2S
- No methane gas production
- Plenty of odor due to no gas collection/flare
- Operating temperature 50 - 70°F (10 - 20°C)
- Poor separation of solids and liquids
- Supernatant high in BOD and TSS
- pH 5.1 - 6.8

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Medium-temperature

- ***Mesophilic*** bacteria
- 70 - 100°F (20 - 45°C)
- 85-100°F Optimal
- 95 - 98°F Operating
- Detention Time 25-30 days
- CO_2, CH_4 and NH_3 production
- 65-70% CH_4 & 30% CO_2
- 8-12 ft^3 of digester gas for every pound of organics
- 500-800 BTU/ft^3
- pH close to neutral (7)
- Mixed
- Good solids separation from liquid
- Favors bacterial growth
- Most common design

High-temperature

- ***Thermophilic*** bacteria
- Highest temperature range 120 - 135°F (49 - 57°C)
- Operating range 124 - 126°F (51 - 52°C)
- Rapid digestion
- Increased gas
- Poor separation of liquids from solids
- Detention time of 5-12 days required
- More energy to heat the system and negates any advantage from the increase
- Heat exchangers or heating coil temperature approach 130°F, sludge begins to cake on the piping
- Few plants operate in this range
- Anaerobic Digestion

Basic Troubleshooting Concepts

- Operators should be aware of signs that a digester is not functioning properly:
  - Strong odors
  - Foaming
  - Poor gas production
  - Unstable pH
  - High volatile acids
  - Low alkalinity
  - Poor sludge quality

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- If these conditions occur, operators notify supervisors or higher-level operators who perform testing and adjustments

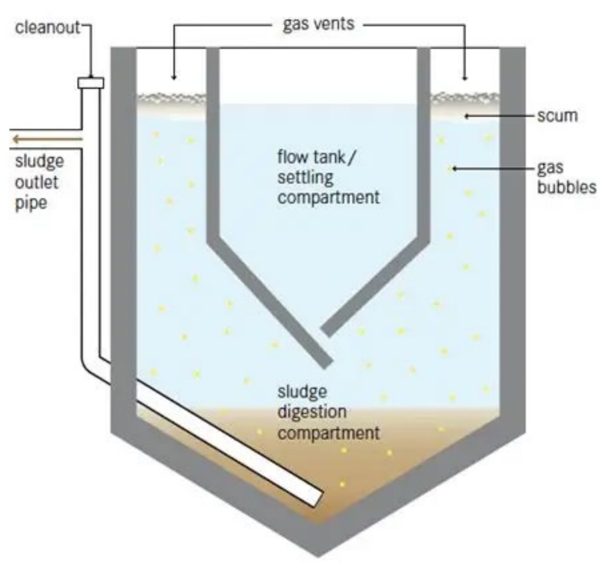
Older Anaerobic Digesters

- Imhoff Digester
- Anaerobic Clarigester
- Upflow Anaerobic Sludge Blanket (UASB)

Imhoff Tank

- The **Imhoff tank** is the **ancestor** of both the **clarigester** and the **modern anaerobic digester**. It was the **first practical design** to combine **settling and digestion** in one structure: a true "two-story" tank.

- **How it works (Basic-safe explanation):**
  - **Upper chamber:** acts as a **primary clarifier** where solids settle out.
  - **Lower chamber:** acts as an **anaerobic digester**, where settled sludge slowly decomposes.
  - **Gas vents** allow CO_2 and H_2S to escape.
  - **No heating or mixing** — it's a **psychrophilic** (low-temperature) process.
  - **Supernatant** returns to the plant for further treatment.
  - **Sludge** is partially stabilized before withdrawal.
  - Psychrophilic (cold-loving) anaerobic bacteria operate in a range from 50-68˚F



Anaerobic Clarigester

- A **clarigester** is a combined **primary clarifier and anaerobic digester** used in older municipal plants and still found today in **feedlots, wineries, and small biogas facilities**.
- **How it works:**
  - **Wastewater enters the upper clarifier zone**, where solids settle out.
  - **Settled sludge drops into the lower digestion zone**, where anaerobic bacteria slowly stabilize it.
  - **Gas vents through the top**, releasing CO_2 and small amounts of methane.
  - **Supernatant returns** to the plant or process for further treatment.
  - **Sludge is partially stabilized** before withdrawal and may be reused or further digested.
  - **No heating or mechanical mixing** — relies on natural psychrophilic digestion.
  - **Retention time** is long (weeks to months), allowing gradual breakdown of organics.

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- **Modern applications:**
  - Still used in **agricultural and industrial wastewater** where flow and solids are high but energy input must stay low.
  - Common in **feedlots, wineries, distilleries, and small biogas plants** for primary treatment and gas recovery.
  - Favored for **simplicity, low maintenance, and low energy demand**.
  - Often paired with **secondary anaerobic digesters or lagoons** for complete stabilization.

Upflow Anaerobic Sludge Blanket (UASB)

- A **UASB reactor** is a modern evolution of the old clarigester idea. It's still an **anaerobic digester**, but instead of settling sludge downward, it pushes wastewater **upward** through a dense "sludge blanket" of active bacteria.
- **How it works:**
  - **Influent enters at the bottom** and flows upward through the sludge blanket.
  - **Bacteria digest organics** as the water rises, producing methane and carbon dioxide.
  - **Gas bubbles** help keep the sludge blanket mixed.
  - **Effluent exits at the top**, where solids settle back down to maintain the blanket.
  - **Gas is collected** for reuse or flaring.

Anaerobic Contact Process (ACP)

- The **ACP** is the modern, controlled version of anaerobic digestion. It keeps the same biological principles as the old clarigester and UASB but adds **separate zones** and **recirculation** to make the process faster, cleaner, and more stable.
- **How it works (Basic-safe explanation):**
  - **Influent enters the digestion tank**, where anaerobic bacteria break down organics.
  - **Gas is collected** for reuse or flaring.
  - **Effluent flows to a separate settling tank**, where solids settle out.
  - **Settled sludge is recycled** back to the digester to maintain the active bacterial population.
  - **Clear supernatant** leaves the system for further treatment.

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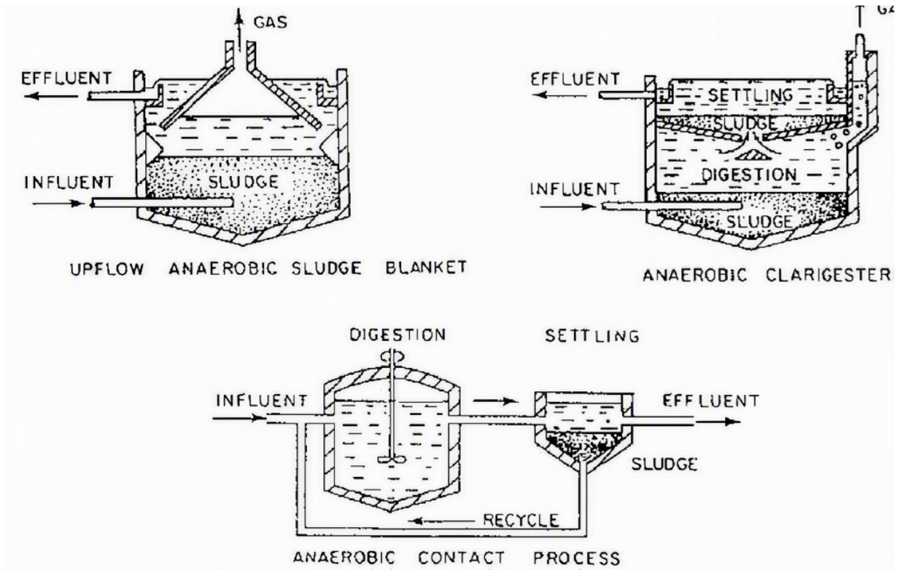
Comparison of Anaerobic Digestion Systems



Comparison of Anaerobic Digestion Systems

System	Era	Flow Direction	Heating	Mixing	Gas Handling	Efficiency	Notes
Imhoff Tank	Early 1900s	Downward	None	None	Minimal	Low	First combined clarifier-digester; simple gravity flow
Clarigester	Mid 1900s	Downward	None	None	Minimal	Moderate	Improved sludge flow and gas venting; unheated
UASB (Upflow Anaerobic Sludge Blanket)	Late 1900s	Upward	Often mesophilic (85–100 °F)	Gas-induced	Moderate	High	Compact, efficient, modern industrial design
ACP (Anaerobic Contact Process)	Current	Controlled flow with recycle	Heated and controlled	Mechanical or pumped	Fully collected and reused	Highest	Modern municipal standard; best solids separation and gas recovery

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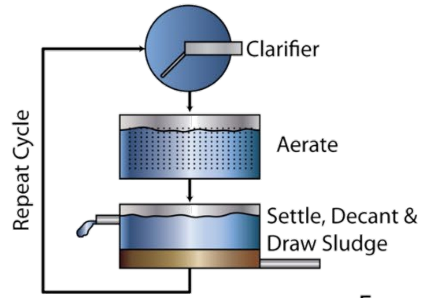
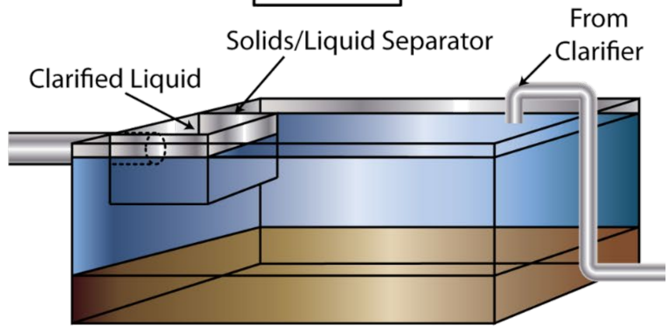
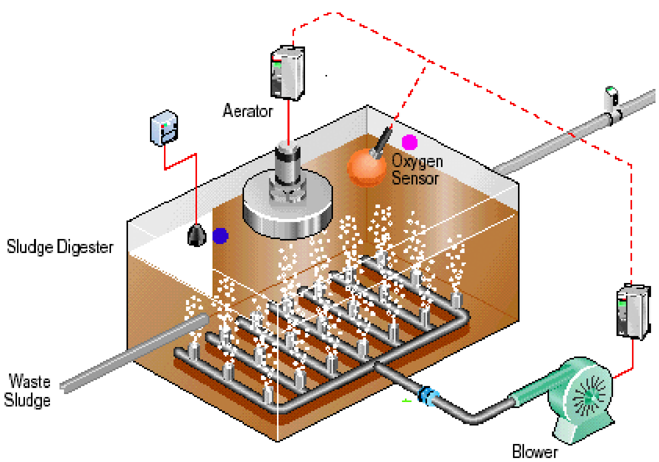
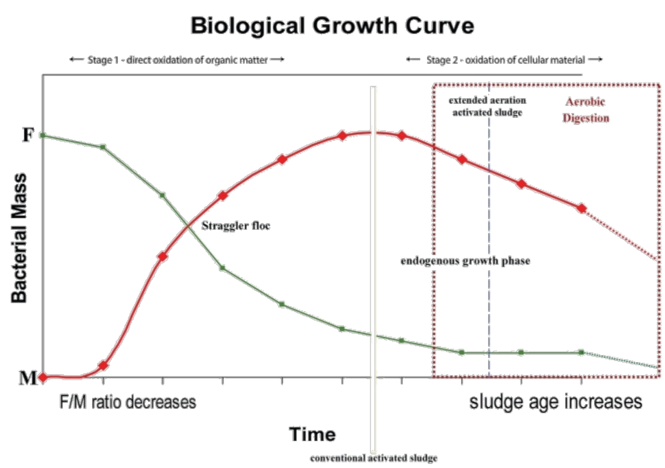
Aerobic Digestion









- Aerobic digesters resemble an extended aeration activated sludge process in that it retains the solids until nearly all of the volatile solids have been stabilized.
- Not as efficient as anaerobic digestion
- WAS & trickling filter humus can be mixed with primary sludge and sent to the digester for further decomposition
- Suitable for small to medium sized treatment plants
- Built with multiple tanks or stages
- 18-20 feet deep
- Aerated by diffuser headers

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- DO level of 1 - 2 mg/L must be maintained
- pH 6.8 - 7.4
- Brownish color
- Very little odor
- Produce a "rotten melon" odor that becomes progressively more offensive
- DT = 25 - 45 days
- TS in aerobic digesters typically range from 1.5 –4%
- Volatile solids reduction 20–40%
- If sludge is to be applied to land it must be kept under aeration for at least 45 days
- Sludge lines should be a minimum of 3 inches in diameter to prevent plugging from grease, rags, etc.
- If falls to unacceptable levels, empty and clean for sediment

Characteristics and Chemistry

- Achieve proper digestion w/o offensive odors:
  - Organisms must be kept at their highest level of metabolism
  - ***Endogenous respiration*** is cycle of organism eating organism because no food source is provided to the organisms in the tank other than more organisms (sludge) which breaks down the sludge
- Level of pathogens is significantly lowered
- Overflow is returned to the head of the plant
- May still have a high organic strength
- If operated at thermophilic temperatures:
  - Loss of nitrifiers creates high nitrate concentrations
  - More oxygen is needed and either has to come from purer source and volume ↑
- Should be taken off-line and completely cleaned at least once every three years
- Aerators should be shut down for 30-60 minutes prior to wasting
  - Allows for settling to occur
  - Results in lower solids in the supernate
  - Supernatant draw off is not always a good practice.
  - Aerobic sludge does not usually settle well and leave a clear supernatant (without the use of settling aids)
  - If the digester aeration system cannot maintain at least 1.0 mg/L, the supernatant itself can be a source of filamentous organisms
- Difficult to dewater w/o polymers
- Occasionally last stage of SBR process

Daily Monitoring & Factors affecting Aerobic Digestion

- Operators must monitor aerobic digesters daily to maintain stable digestion.
- Temperature

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- Affects activity and oxygen requirements
- NM desert heat can push digesters toward thermophilic range
- High temperatures cause:
- Loss of nitrifiers
- Increased nitrate concentrations
- Higher oxygen demand
- O_2 Requirements
  - Maintain 1 – 2 mg/L DO in digester
  - <1 mg/L → filamentous growth risk
- Mixing & Odor
  - Combines bacteria with organics
  - Avoid supernatant draw-off unless necessary
    - aerobic sludge settles poorly.
  - Brownish sludge, mild odor
  - "Rotten melon" smell indicates instability
- pH
  - Near neutral pH desired
  - Keep between 6.8–7.4
  - Lime may be used to raise pH
- Solids Reduction & Thickness
  - Supernatant is lower in BOD/solids
  - Bacteria feeds upon itself (endogenous)
  - Do NOT over-thicken
    - Over-thickened sludge becomes difficult to pump
    - May require adding water to keep lines flowing
  - Use polymers for dewatering; aerobic sludge resists drainage

Sludge Draw-Off

- Sludge Draw-Off
- Sludge draw-off is the removal of sludge from the bottom of clarigesters, Imhoff tanks, or digesters so it can be thickened, dewatered, or disposed.
- **Purpose**
  - Prevents excessive solids buildup
  - Maintains digester volume
  - Clears scum blankets
  - Moves sludge to secondary digesters, dewatering equipment, or directly to disposal
- **How It's Done**
  - Sludge is withdrawn through draw-off lines near the digester bottom
  - Flow is controlled by valves
  - Removed sludge is sent to the next solids-handling step

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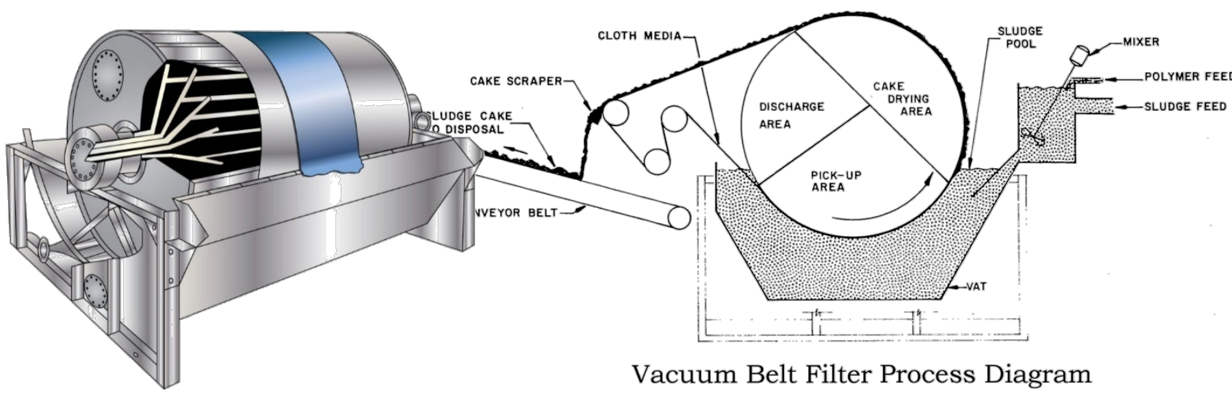
- **Operator Role**
  - Recognize draw-off piping and valves
  - Know where sludge is removed from
  - Know where sludge goes next

De-watering

- Dewatering
- Last stage before disposal or incineration
- Similar processes as thickening, semi-dry to dry solid
- Dewatering reduces water content to lower hauling and disposal costs
- Operators must be able to identify equipment and basic components
- Follows digestion, mostly mechanical
- Types
  - Vacuum Filter Presses
  - Belt Filter Presses
  - Sludge Drying Beds
  - Centrifuges
  - Membrane/Filter Plate Presses
- Use polymers to condition stabilized sludges

Vacuum Filter Presses



Vacuum Belt Filter Process Diagram

- Dewaters the sludge by
  drawing a cake of sludge onto a belt drum and then sucking the water out of it.
- The filter belt rotates through a vat of conditioned sludge and the vacuum draws the sludge onto the belt.
- The sludge cake that is picked up on the belt moves out of the sludge vat and into the drying zone.
- The vacuum continues to draw air through the sludge cake to dewater it until the belt leaves the drum.
- Scraped off of the filter belt and carried by a conveyor to a disposal vehicle.
- A set of spray nozzles wash the belt as it returns to the drum.

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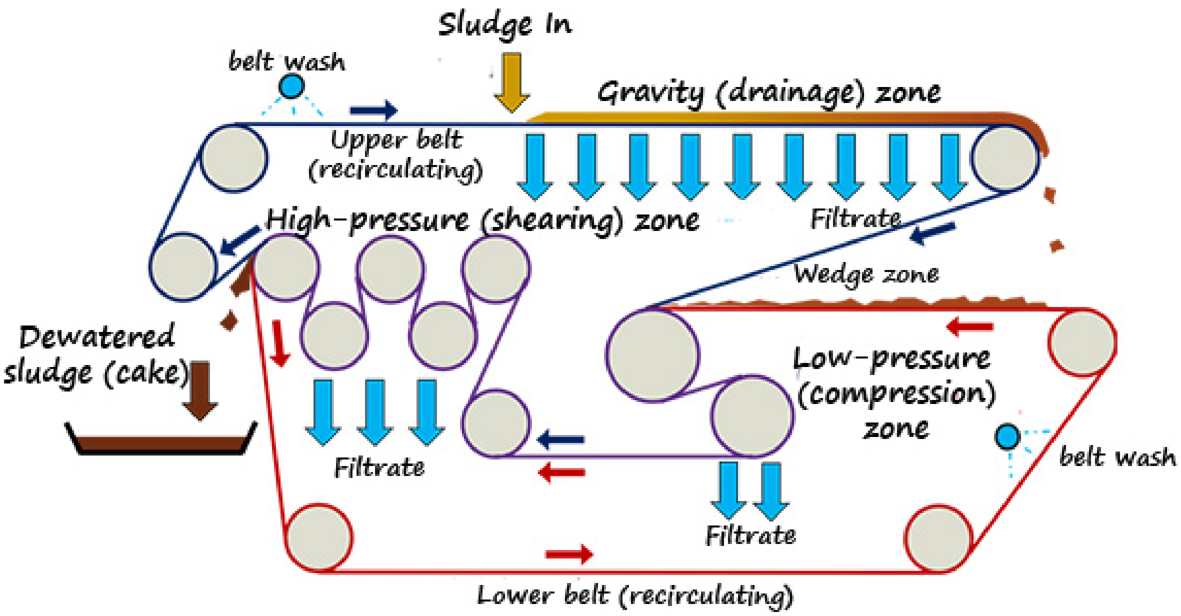
- Produce solids in the 15-24% range
- Uses a lot of energy.



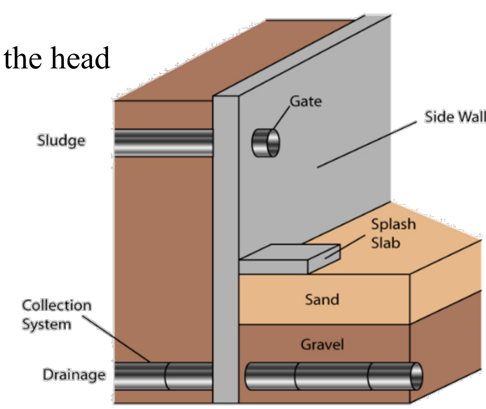


Belt Filter Presses

- Most simple and least expensive means of mechanically dewatering sludge
- Same process as gravity belt thickener, but sludge is pressed between 2 porous belts controlled by a series of rollers
- Sludge cake is then scraped from the belts and sent by conveyer to disposal truck
- Set of spray nozzles are used to clean he belt.
- Creates another side stream that returns water & filtrate to the head of the plant

Sludge Drying Beds

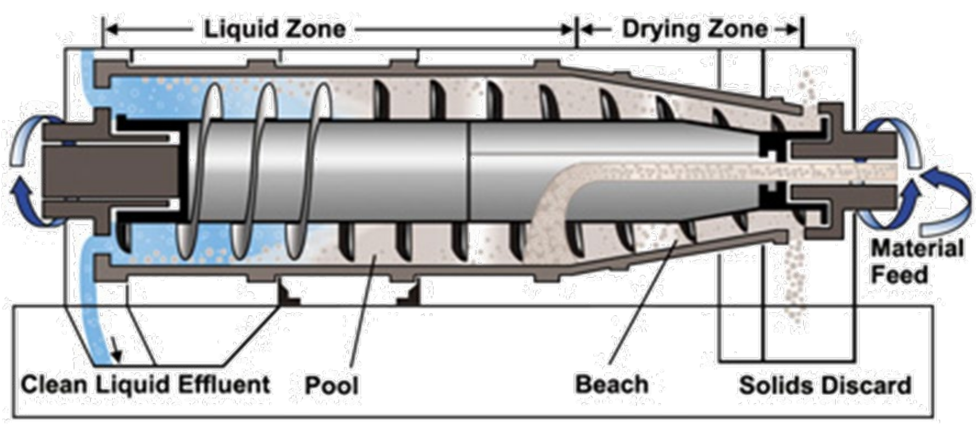
- Beds are shallow rectangular basins with a sand, asphalt, vacuum tray, or concrete bed and underdrain system
- Dries by evaporation and gravity separation of the water



- Placed on the bed in 10-12 inch pours
- Underdrain valve is opened to allow the water that drains out of the bed to return to the head of the plant
- Length of time it takes to dry the sludge will depend on the condition of the sludge and degree of digestion.

- Seasonal temperature differences and compaction of the sand bed can also affect drying times.
- Never put digester sludge in a drying bed that already has dry sludge in it.
- Capable of drying to > 95% Solids
- 70-80% typical TS%

Centrifuges



- Centrifuges spin the conditioned sludge and separate the solids from the water by centrifugal force.

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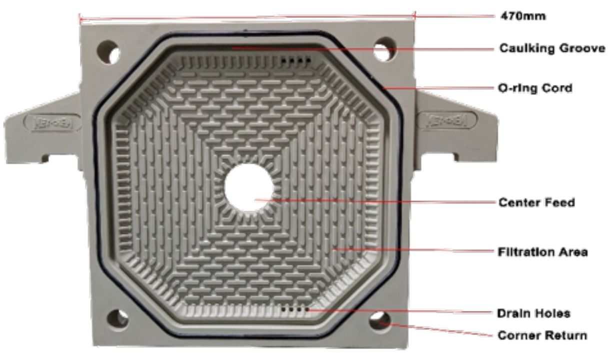
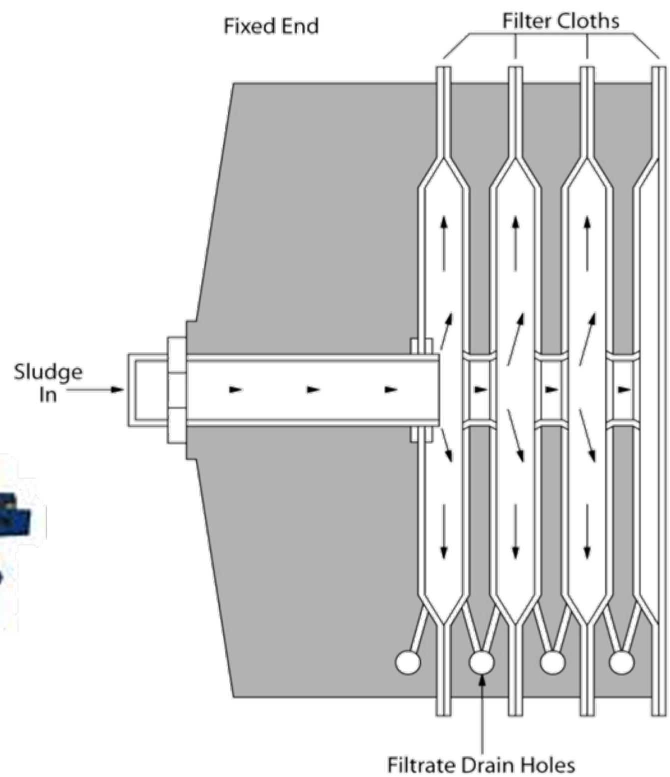
- Spin cycle of a washing machine or certain carnival rides
- 2 types of centrifuges:
- Batching centrifuge can only process a single load of sludge at a time
- Scrolling centrifuge is designed to run with a continuous sludge flow.
- Conditioned sludge is fed into one end of the centrifuge drum.
- Solids are forced to the outside and a scrolling conveyor pushes them out one end of the unit
- Water that is left behind, known as ***centrate***, collects in the center and overflows to drain as a side stream
- High energy use and hearing hazard
- 20-40% TS





Membrane/Filter Plate Presses

- Recessed-plate filter presses are among the oldest types of dewatering devices
- Produce the highest cake solids concentration of any mechanical dewatering equipment (35-50% TS)
- Two plates are joined to create a chamber to pressurize solids and squeeze out liquid through a filter cloth lining the chamber.
- Several plates (ranging from 12 to 80, depending on the capacity required) are suspended from a frame face to face. to form a series of chambers.
- Conditioned solids are pumped into the center hole to fill each chamber.
- Pressure increased by:

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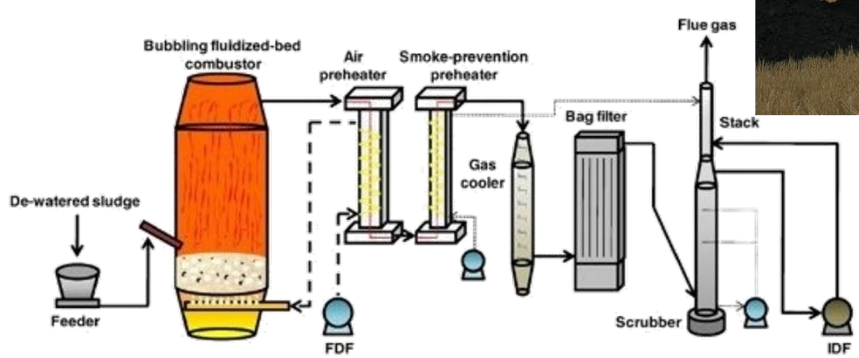
- Adding more conditioned solids (fixed volume press)
- Expanding a membrane (variable volume press)
- Solids are retained on the filter cloth while liquid passes through and is drained away from the machine.
- Free water is released and passes through the filter cloth during the filling phase.
- Pressure builds as the chamber fills with solids beginning the consolidation process
- Required filtration pressure (100 psi to 225 psi).
- Cake is formed until a set-point of low filtrate flow is reached to indicate the end of the cycle.

Disposal & Reuse



Schematic diagram of a conventional incineration plant, which is equipped with an atmospheric bubbling fluidized bed combustor

- Once sufficiently dewatered, sludge is disposed of or reused by:
  - Incineration - rare due to Clean Air Act rules
  - Sanitary landfill
  - Land application
  - Composting
- Federal regulations for the use or disposal of sewage sludge were promulgated in 1993 under 40 CFR Part 503.
- The 503 sludge regulations commonly referred to as '503s'
- 503 applies to virtually any primary and secondary sludge and scum produced as a result of wastewater treatment and even covers some disposal practices for domestic septage.
- 503 specifies two types of activity;
  - Beneficial use (Reuse)
  - Disposal

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- Permits or approval from:
  - EPA
  - New Mexico Environment Department's Ground Water Quality Bureau (NMEDGWQB)
  - Surface Water Quality Bureau (NMED-SWQB)
  - Solid Waste Bureau (NMED-SWB)
  - DOT

Beneficial use (Reuse)

  - Surface Disposal or Land Application, either in bulk or in bags to public contact sites. (includes Composting)
  - Land Application, in bulk to non-public contact sites. (includes Composting)

Disposal

- Incineration
- Municipal landfill is an acceptable
  - Covered under NM Solid Water Bureau regulations, ***not*** 40 CFR 503.

503 sets requirements for:

- Reduction of pathogens
- Reduction of the vector attraction of the sludge
- Pollutant limits for heavy metals and PCBs
- Restrictions for land application and surface disposal sites
- Management practices for land application and surface disposal activities
- 503 sets a limit on how long sludge can be stored at a wastewater treatment plant before it must be beneficially re-used or disposed.
- If sludge remains in storage for more than two (2) years, the site is considered a surface disposal site and all applicable aspects of the 503 regulations must be met, unless the owner/operator can demonstrate the storage constitutes treatment based on operational practices
- FAILURE TO ABIDE BY THESE LAWS CAN LEAD TO CIVIL AND EVEN CRIMINAL PROSECUTION.

Sampling & Testing

- Operators perform basic sampling and testing of sludge to monitor solids handling and digestion.
- **Sampling Practices**
  - Collect representative sludge samples
  - Use proper containers and labeling
  - Avoid contamination

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- Deliver samples promptly for analysis
- **Tests Performed**
  - **Percent Solids (TS%)** – determines dryness and readiness for dewatering or disposal
  - **pH** – ensures sludge is not excessively acidic or alkaline
  - **Temperature** – confirms digestion activity (especially aerobic digestion)
  - **Dissolved Oxygen (DO)** – verifies aerobic digestion conditions
  - **Odor and appearance** – identifies septic sludge, scum, grit, or grease
  - **Sludge depth/blanket measurements** – monitors accumulation in digesters or clarigesters

Sampling

Collect representative sludge samples

- Collected by:
  - Sludge Judge used to measure sludge blanket depth and collect vertical profile samples
  - Bottle on the end of a pole used to grab samples from tanks or digesters
  - Sample port controlled by a valve used to collect sludge directly from piping or draw-off lines
- Middle zone is the "sweet spot"
  - Best mixture of solids and liquid
  - Most representative of digested sludge
- Avoid the top layer
  - Contains scum, grease, floating solids, gas pockets
- Avoid the bottom layer
  - Contains grit, sand, heavy inorganics, and overly settled material
- Avoid sampling next to or near
  - Injectors (air or chemical)
  - Influent/effluent piping unless required

Use proper containers and labeling

- Container Selection
  - Choose containers based on the test: TS%, pH, temperature, DO, odor/appearance
  - Container type depends on the test:
  - Glass for chemical stability

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- Plastic (PPE) for general sludge samples
- Clear for visual/odor checks
- Darkened/amber for light-sensitive tests
- Sample Volume
  - Collect enough sample to perform all required tests
  - Avoid overfilling — leave headspace if temperature or DO will be measured
- Labeling & Chain of Custody (CoC)
  - Every sample bottle must be labeled and logged with:
  - Date
  - Time
  - Location / Sample point
  - Test(s) to be performed
  - Sampler initials
  - Permit ID (if required)
- Avoid contamination

Delivering to Lab for Testing

- Proper delivery ensures sludge samples remain valid for testing.
- **Delivery Requirements**
  - **Know the test timing**
    - Some tests must be run **within 15 minutes** of collection (temperature, DO, odor/appearance).
  - **Cooling / Ice**
    - If required, place samples on **ice immediately** to slow biological activity and preserve accuracy.
  - **Avoid shaking**
    - Shaking can introduce oxygen, disturb solids, or alter DO and temperature readings.
  - **Avoid sunlight**
    - Heat and UV exposure can change sample chemistry and invalidate results.
  - **Transport quickly**
    - Deliver samples to the lab **as soon as possible** unless the test is performed **on-site**.
- **On-Site Testing**
  - Some parameters (temperature, DO, odor/appearance) are best done **immediately at the sampling point**.

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Testing

Direct Read

- An instrument that gives you the value and no calculations are necessary
- Examples:
  - pH meter (no units)
  - Dissolved Oxygen Probe (DO), mg/L
  - Temperature, ˚F or ˚C
  - Chlorometer (Chlorine) mg/L
- Must perform calibration check prior to sampling every day before 1st use
- Be aware that not all procedures are approved by the EPA or TCEQ
- EPA compliant DOES NOT mean approved
- When in doubt, check the record. 40 CFR §136.3

https://www.ecfr.gov/current/title-40/chapter-I/subchapter-D/part-136/section-136.3

Solids Analyses

- Solids are important in several aspects of wastewater treatment
- Organic Solids:
  - Another name is Volatile Solids
  - Are either living matter or the byproducts of previously living organisms
  - Will burn up in the muffle furnace, resulting in a decrease in weight, proportional to the amount of organics present
- Inorganic Solids:
  - Mostly consist of minerals found in the drinking water, as well as grit, sand, salts & other inorganic matter that entered the collection system
  - Inorganic solids will NOT burn in the muffle furnace.
- Total Solids (TS) includes both categories of solids:
  - Organics and Inorganics in all solids
  - Suspended Solids (TSS)
    - Include those solids that can be filtered out of the aqueous fraction and weighed
    - Suspended solids are considered Settleable Solids because they will settle out in the Imhoff Cone test, expected to also settle out in a Primary Clarifier.
  - Dissolved solids (TDS)
    - Can NOT be filtered out of a sample
    - Makes up about 40% of total solids
    - Responsible for conductivity, salinity, and other factors that affect water quality

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<u>TS/VS, TSS/VSS:</u>

- All solids analyses use the same formula
- Each procedure is a little different, but the calculations are the same. All involving measuring, drying, & weighing

    - TS/VS
    - Well mixed sample measured in graduated cylinder
    - Placed in evaporating dish

- TSS/VSS
    - Well mixed sample vacuum filtered
    - Weigh filter paper and solids

Special Thanks to Timothy Crosswhite for photographs.

Presentations based off:
Chapter 4: Solids Handling; pg. 4-1
Chapter 5: Digesters; pg. 5-1:
<u>Wastewater System Operator's Manual</u>
Ragsdale and Associates Training Specialists, LLC
https://www.nmwwa.org/_files/ugd/a8472e_ef77517d1bab42b08f7ae0f99d98005d.pdf

Older Digester information courtesy of:
FAO
https://www.fao.org/4/t0541e/T0541E05.htm#Chapter four: Microbiology biochemistry and physiology
Grokipedia

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Practice Exam

Choose the best answer.

1. Solids must be stabilized before disposal to prevent:
   a. Excessive foaming
   b. Odors, pathogens, & vector attraction
   c. High DO levels
   d. Increased alkalinity

2. Primary sludge is best described as:
   a. Already stabilized
   b. Odorous and full of pathogens
   c. Mostly dissolved organics
   d. High in DO

3. Thickening increases solids concentration typically to:
   a. 1–2%
   b. 4–6%
   c. 10–15%
   d. 20–40%

4. A "thick" sludge at 5–6% solids still contains:
   a. 50% water
   b. 75% water
   c. Over 90% water
   d. No water

5. Gravity thickeners are mainly used on:
   a. Activated sludge
   b. Primary sludge
   c. Trickling filter humus
   d. Digested sludge

6. Poor thickener performance can cause:
   a. High DO in effluent
   b. Organic overloading in secondary treatment
   c. Excessive nitrification
   d. Loss of alkalinity

7. In gravity thickening, sludge blanket depth is typically:
   a. 1–2 ft
   b. 3–4 ft
   c. 5–8 ft
   d. 10–12 ft

8. DAF units thicken sludge by:
   a. Gravity settling
   b. Air bubbles floating solids
   c. Centrifugal force
   d. Chemical oxidation

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9. Gravity Belt Thickeners remove water using:
   a. Heat
   b. Porous moving belts
   c. Vacuum pressure
   d. Chemical precipitation

10. Rotary Drum Thickeners separate water using:
    a. Rotating porous drums
    b. Air flotation
    c. Settling cones
    d. Membrane pressure

11. Volatile solids represent:
    a. Inorganic grit
    b. Organic matter that can be digested
    c. Dissolved minerals
    d. Heavy metals

12. Anaerobic digestion must occur:
    a. With high DO
    b. In the presence of oxygen
    c. Without dissolved oxygen
    d. At pH below 6

13. Most anaerobic digesters operate as:
    a. Single-stage systems
    b. Two-stage systems
    c. Aerobic reactors
    d. Trickling filters

14. The primary digester is:
    a. Unheated
    b. Where most stabilization occurs
    c. Used only for storage
    d. Aerated

15. Secondary digesters typically have:
    a. Fixed covers
    b. Floating covers
    c. No supernatant
    d. High DO

16. Digested sludge solids are reduced by:
    a. 10–20%
    b. 20–40%
    c. 50–60%
    d. 70–90%

17. Methane gas produced in digestion is typically:
    a. 10–20%
    b. 30–40%
    c. 50–60%
    d. 65–75%

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18. Psychrophilic digestion occurs at:
    a. 120–135°F
    b. 95–98°F
    c. 50–70°F
    d. 10–20°F

19. Mesophilic digestion operates best at:
    a. 50–70°F
    b. 70–100°F
    c. 120–135°F
    d. 32°F

20. Thermophilic digestion operates at:
    a. 50–70°F
    b. 70–100°F
    c. 120–135°F
    d. 150–180°F

21. A sign of digester upset is:
    a. High DO
    b. Strong odors
    c. Clear supernatant
    d. Low volatile acids

22. Imhoff tanks combine:
    a. Aeration and filtration
    b. Settling and anaerobic digestion
    c. Thickening and dewatering
    d. Oxidation and nitrification

23. Clarigesters are commonly used in:
    a. Large municipal plants
    b. Feedlots and wineries
    c. Industrial aeration basins
    d. Chlorination systems

24. UASB reactors flow:
    a. Downward
    b. Upward
    c. Horizontally
    d. In circles

25. ACP systems improve digestion by:
    a. Removing mixing
    b. Adding recirculation
    c. Eliminating settling
    d. Increasing DO

26. Aerobic digesters must maintain DO of:
    a. 0 mg/L
    b. 0.5 mg/L
    c. 1–2 mg/L
    d. 5–10 mg/L

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27. Aerobic digestion typically reduces volatile solids by:
    a. 5–10%
    b. 10–20%
    c. 20–40%
    d. 50–60%

28. Sludge draw-off removes sludge from:
    a. The top of the digester
    b. The middle zone
    c. The bottom
    d. The supernatant layer

29. Belt filter presses dewater sludge by:
    a. Air flotation
    b. Pressing sludge between two belts
    c. Heating sludge
    d. Chemical oxidation

30. Drying beds typically produce solids of:
    a. 5–10%
    b. 15–20%
    c. 70–80%
    d. 95%+

31. Centrifuges separate solids using:
    a. Gravity
    b. Air bubbles
    c. Centrifugal force
    d. Membrane pressure

32. Membrane/plate presses can achieve solids of:
    a. 5–10%
    b. 20–30%
    c. 35–50%
    d. 60–80%

33. 40 CFR Part 503 regulates:
    a. Chlorine residual
    b. Sludge disposal and reuse
    c. DO levels
    d. Nitrification rates

34. Sludge stored longer than 2 years is considered:
    a. Digested
    b. Stabilized
    c. A surface disposal site
    d. Compost

35. Representative sludge samples should be taken from:
    a. The scum layer
    b. The bottom grit layer
    c. The middle zone
    d. Near injectors

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36. Clear containers are used for:
    a. DO testing
    b. pH testing
    c. Visual/odor checks
    d. Temperature testing

37. Amber containers are used for:
    a. Light-sensitive tests
    b. DO tests
    c. Temperature tests
    d. Chlorine tests

38. Some tests must be run within:
    a. 1 minute
    b. 5 minutes
    c. 15 minutes
    d. 1 hour

39. DO, temperature, and odor are best measured:
    a. After shaking
    b. After sunlight exposure
    c. Immediately on-site
    d. After refrigeration

40. Direct-read instruments require:
    a. No calibration
    b. Calibration before first daily use
    c. Weekly calibration
    d. No maintenance

41. Thickening reduces the amount of water that must be handled.
    a. True
    b. False

42. Secondary sludge thickens more easily than primary sludge.
    a. True
    b. False

43. Anaerobic digestion reduces only organic solids, not inorganic solids.
    a. True
    b. False

44. Floating covers allow for gas and sludge storage.
    a. True
    b. False

45. Air entering an anaerobic digester can create an explosive mixture.
    a. True
    b. False

46. Methanogens operate best at pH 7.0–7.2.
    a. True
    b. False

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47. Aerobic digesters typically have DO levels below 0.5 mg/L.
    a. True b. False

48. Aerobic sludge settles well and produces clear supernatant.
    a. True b. False

49. Sludge draw-off prevents excessive solids buildup.
    a. True b. False

50. Belt filter presses create a side stream that returns filtrate to the plant.
    a. True b. False

51. Drying beds should never receive digester sludge on top of already dried sludge.
    a. True b. False

52. Centrifuges can be a hearing hazard due to noise.
    a. True b. False

53. Membrane presses produce the highest solids concentration of any mechanical dewatering equipment.
    a. True b. False

54. 503 regulations cover pathogen reduction and vector attraction reduction.
    a. True b. False

55. Sludge stored longer than two years must meet surface disposal requirements unless proven otherwise.
    a. True b. False

56. Representative samples should be taken from the top scum layer.
    a. True b. False

57. DO and temperature samples should not be shaken.
    a. True b. False

58. Sunlight exposure can change sample chemistry.
    a. True b. False

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59. pH meters are considered direct-read instruments.
    a. True b. False

60. Operators must calibrate direct-read instruments before first use each day.
    a. True b. False

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Answers

1. b. Odors, pathogens, and vector attraction
2. b. Odorous and full of pathogens
3. b. 4–6%
4. c. Over 90% water
5. b. Primary sludge
6. b. Organic overloading in secondary treatment
7. c. 5–8 ft
8. b. Air bubbles floating solids
9. b. Porous moving belts
10. a. Rotating porous drums
11. b. Organic matter that can be digested
12. c. Without dissolved oxygen
13. b. Two-stage systems
14. b. Where most stabilization occurs
15. b. Floating covers
16. c. 50–60%
17. d. 65–75%
18. c. 50–70°F
19. b. 70–100°F
20. c. 120–135°F
21. b. Strong odors
22. b. Settling and anaerobic digestion
23. b. Feedlots and wineries
24. b. Upward
25. b. Adding recirculation
26. c. 1–2 mg/L
27. c. 20–40%
28. c. The bottom
29. b. Pressing sludge between two belts
30. c. 70–80%
31. c. Centrifugal force
32. c. 35–50%
33. b. Sludge disposal and reuse
34. c. A surface disposal site
35. c. The middle zone
36. c. Visual/odor checks
37. a. Light-sensitive tests
38. c. 15 minutes
39. c. Immediately on-site
40. b. Calibration before first daily use
41. a. True
42. b. False
43. a. True
44. a. True
45. a. True
46. a. True
47. b. False
48. b. False
49. a. True
50. a. True
51. a. True
52. a. True
53. a. True
54. a. True
55. a. True
56. b. False
57. a. True
58. a. True
59. a. True
60. a. True