TRAINING OF TRAINERS PROGRAMME ON CAPACITY DEVELOPMENT OF ETP OPERATORS

Promotion of Sustainability in the Textile and Garment Industry in Asia - FABRIC

giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

FABRIC Asia

Day 4: Presentation 1

Sludge Treatment

Contents

- Objective of sludge dewatering
- Sludge pre-conditioning
- Mechanical sludge dewatering
- Sludge drying beds

What is sludge?

- ETP sludge is the solid, semisolid, or slurry residual material from ETP
- Three types of sludge: primary, secondary and tertiary treatment sludge.
- Primary sludge, two categories: generated with chemicals & without chemicals.
- Secondary sludge is excess activated biomass, purposely wasted.
- It is from (a) inorganic portion of inlet suspended solids + (b) residuals of COD removed in the biological treatment
- Tertiary sludge: tertiary chemical precipitation from softening, colour removal etc.
- In most of ETPs sludges are combined together for treatment and disposal.

Source of sludge in ETP

- **Solid wastes from primary treatment**: screenings, grit and sludge.
- **Also irregular sources** : residual sediments from emptying-cleaning of tanks/chambers
- **Contribution of chemical sludge**: (a) suspended solids in effluent (b) precipitated mass from chemicals used.
- Precipitated mass include insolubles from reaction of chemicals or precipitated metal hydroxides.
- **Screenings & grit**: mostly dry, needs only draining to get moisture content of **30-40%.**

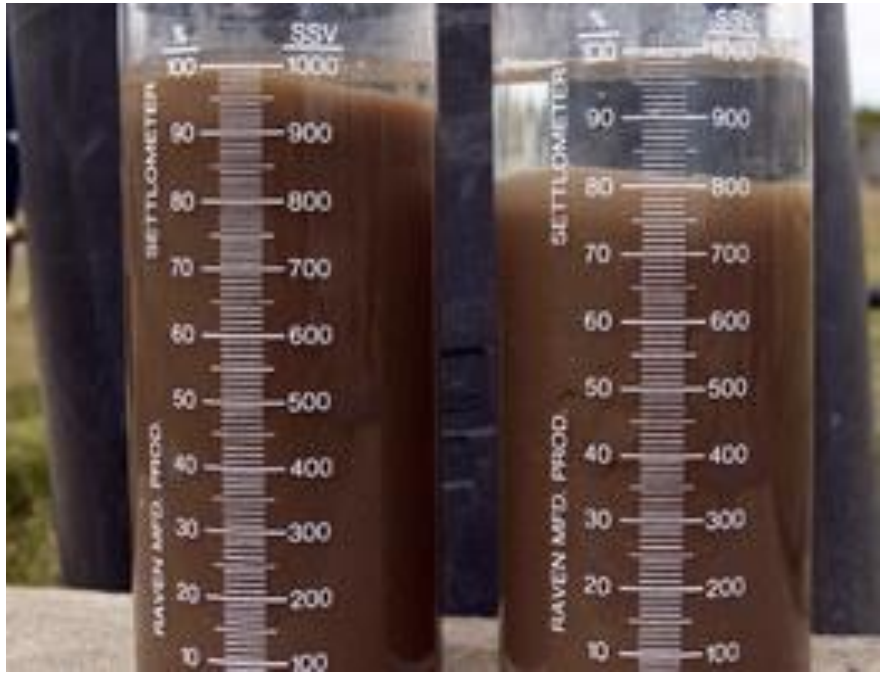
Source of sludge in ETP

- **Pre-settler sludge**: medium thick, solids content **2-3%**
- **Chemical sludge from primary sedimentation tank**: **3-4%,** depending on chemicals used.
- **Sludge from lamella clarifier/ tube settlers**: lighter (say, **2-3%**).
- **Sludge from dissolved air floatation**: **1.5-2.5%**, depending on polyelectrolyte dosages.
- Small quantity of sludge from operations such as cleaning of chemical preparation tanks: mostly thick lime sludge, very dry and solidified.
- **The sediments cleaned from tanks** : very thick – may need scooping using mechanical means

What is bio-sludge in ETP?

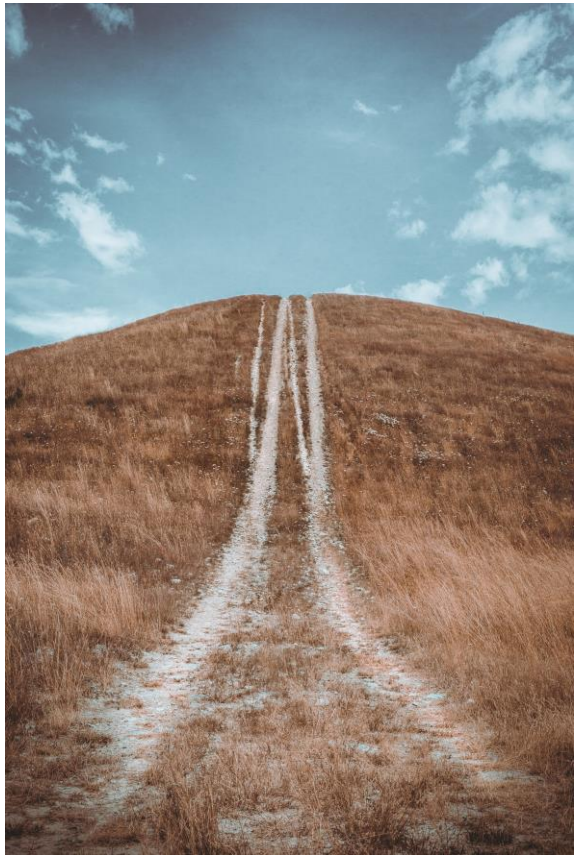
- Biological treatment utilises micro-organisms for degradation of organic materials in the effluent.
- This process involve an intermittent stage where suspended bio-solids are created.
- On this bio-solids, micro-organisms accumulate and this suspension is called MLSS.
- To keep prime microbial activity & keep generating fresh MLSS, it is necessary to waste part of the ‘old’ MLSS in the tank.
- Excess bio-sludge is from (a) mineralised organics and (b) non-degraded suspended solids entering the aeration tank.

Nature of bio-sludge in ETP



- Waste sludge is withdrawn from sludge recirculation line.
- Concentration of MLSS in aeration tank **3000-5000 mg/l (0.3-0.5%)**.
- So, Concentration of sludge returned double: i.e., **0.6%-1%**.
- In most cases, the wasted bio-sludge would be dark-brown in colour.
- Once dissolved oxygen in wasted MLSS is gone, it can putrefy anaerobically & floatation of sludge.

Purpose and basic approaches to reduce sludge



Common methods

- Replacement or reduction of chemicals in ETP
- Anaerobic sludge digestion
- Aerobic sludge digestion
- Incineration
- Thermal drying of sludge
- Sludge maturation through storage

Replacement or reduction of treatment chemicals

Replacement or reduction of chemicals

Jar test apparatus

Optimization of chemical use

Basic approaches

- **Select** good **treatment chemicals**
- Determine **correct dosing** using jar test
- In combined ETP use chemical **treatment** to **maintain steady level of organics** in aeration tank inlet

Replacement or reduction of chemicals

Jar test apparatus

Optimization of chemical use

Basic approaches - chemical use

- Ferrous sulphate only when reactive dyes present in effluent
- Pre-hydrolyzed inorganic coagulants based on aluminum and iron:
  - ✓ aluminum chloro-hydrate
  - ✓ poly-aluminum chloride
  - ✓ poly-aluminum sulfate chloride and mixes with polymers

Replacement or reduction of chemicals

Ferrous sulphate

Ferric chloride

Optimization of chemical use

Basic approaches – chemical use

- Different coagulants and flocculants resulting in different quantities of sludge
  - ✓ Sulphate-based chemicals (alum, ferrous sulphate etc.) with lime produces calcium sulphate and adding to sludge
  - ✓ Chloride-based chemicals (poly aluminum chloride or ferric chloride)
    - Only fully soluble calcium chloride is generated: not adding to sludge
    - However slight increase of TDS in supernatant

Conversion of chemical treatment into biological treatment

Replacement or reduction of chemicals

- **Less sludge generation in all-biological treatment** compared to primary chemical treatment
- Conversion of primary ETP into all-biological treatment already done in Bangladesh

  - ✓ Be aware of costs
  - ✓ All-biological treatment requiring more space
  - ✓ Parts of primary treatment (e.g. screening, equalisation, sludge dewatering) usable in new ETP

Replacement or reduction of chemicals

No use for	Additional units needed
× flash mixer/flocculator × chemical preparation/dosing	+ Cooling tower & pH correction before aeration tank + Additional electricity power requirements

Conversion of primary to biological treatment

- All physical treatment upto equalization remains same.
- Primary clarifier can be used as secondary unit if:
  - ✓ unit is of sufficient volume
  - ✓ Hydraulic levels not at limit

Replacement or reduction of chemicals

Advantages

Conversion of primary to biological treatment

Advantages

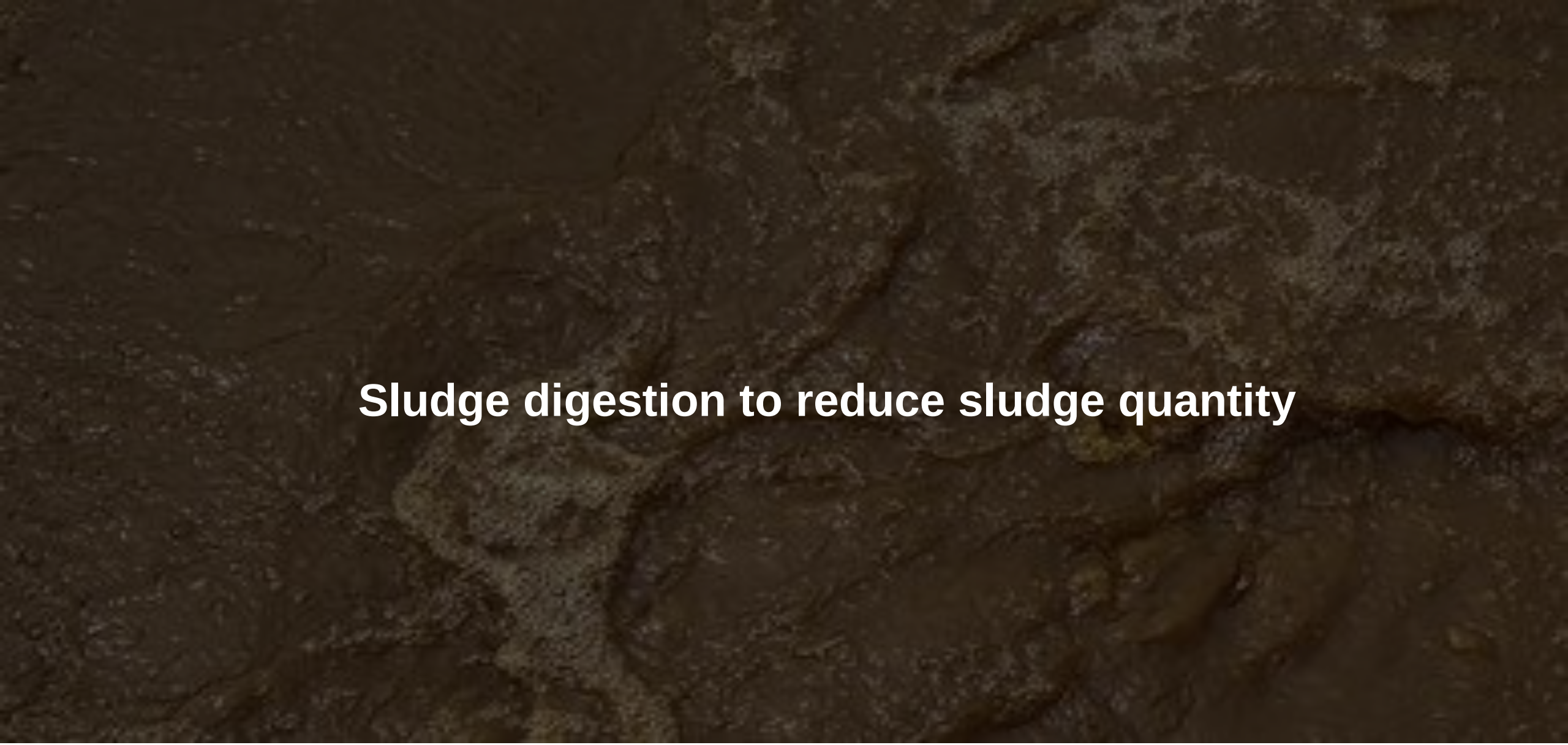
- Higher efficiency of **75 - 85%**
- Simpler and easier to operate
- Cleaner since no risk of chemical spillage
- **50%** less sludge quantity compared to primary ETP
- Cheaper in operation and maintenance
- Less cluttered since no need for chemical storage and mixing area

Replacement or reduction of chemicals

Conversion of primary to biological treatment

Disadvantages

- Need for professional engineering guidance in planning
- Higher power consumption (**about 50 - 60 HP**) though overall cost lower
- Additional capital cost for implementation of aeration system (e.g. blowers, diffusers, piping)
- Shutdown of existing ETP or interim arrangement required during implementation (**2 - 3 months**)
- More space required (**abut 1.5 – 2 times more**)



Sludge digestion to reduce sludge quantity

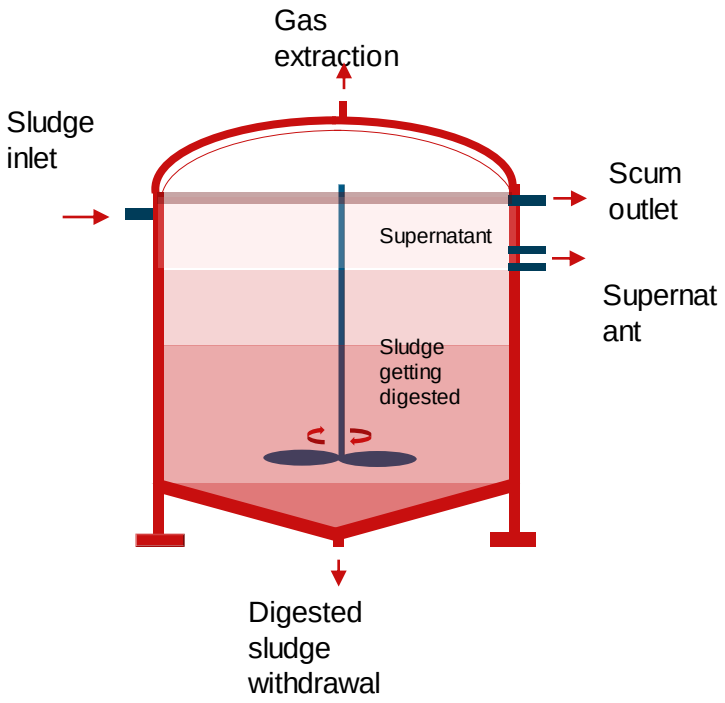
Sludge digestion

Anaerobic sludge digestors

- Most common unit in ETPs, mainly for handling primary sludge
- Good option to reduce quantity of organics and overall quantity of sludge
- Mostly provided with heater:

  ✓ higher bacteria efficiency
  ✓ not needed in tropical climates (e.g. Bangladesh)
  ✓ biogas partly usable for heating

Anaerobic sludge digestors

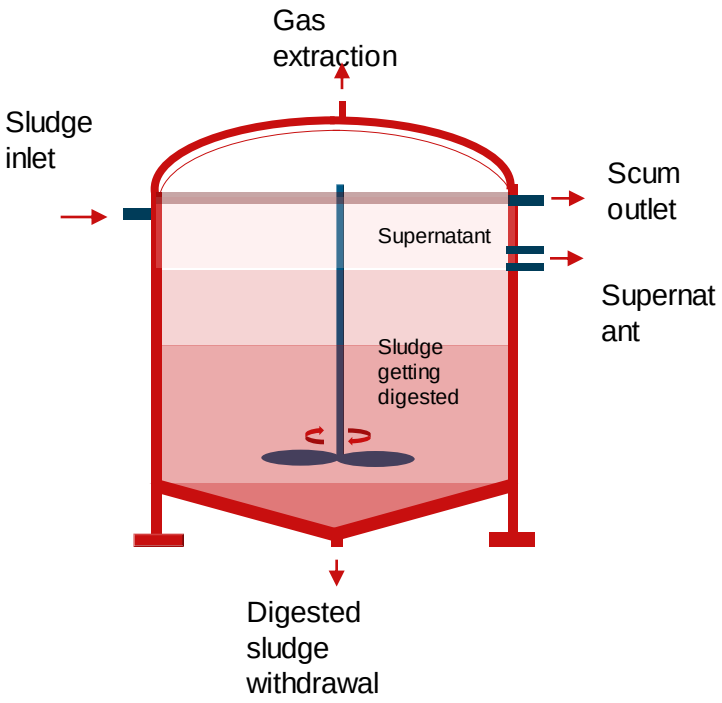


Anaerobic sludge digestors

Operational concept

- Organic material degraded into carbon dioxide and methane
- Supernatant returned to equalisation tank
- Produced biogas collected and re-used (e.g. as fuel in boilers and electricity)

Anaerobic sludge digestors



Anaerobic sludge digestors

Operational concept

- **50 - 75% reduction in organics/ and sludge volume**
  - ✓ depending on organics concentration and nature in sludge
- **Size of digestor for efficient use**
  - ✓ Most digestors for textile ETP sludge too small
  - ✓ Inadequate biogas quantity for proper use, instead escape or burned off in flare
  - ✓ Mixer not must but helpful

Anaerobic sludge digestors

Operational steps with unheated batch reactor

- Stop mixer for 15 minutes, drain out scum and supernatants
- Drain digested sludge by opening bottom valve
- Switch on digestor mixer and collect sample
- Check gas pressure and operation of emergency release valve
- Ensure continuous running of agitator/mixer in sludge holding tank
- Pump liquid sludge upto designed stop level
- Add nutrients as needed @BOD: N: P at 100:2.5:0.5
- Leave digestor to operate

Anaerobic sludge digestors

- Process used to reduce both organic content and volume of sludge
- Organic matter in sludge oxidized biologically by microorganisms to carbon dioxide and water
  - **50-70%** reduction in solids content
- Flow operations:
  - Continuous
  - In batch with sludge added to reaction tank while contents continuously aerated

Anaerobic sludge digestors

Aerobic sludge digestors

Operational aspects

- Continuous **aeration for long period** (≈ 2 weeks), depending on frequency of sludge wasting in ETP
- **Feeding** aerobic digestor:
  - in **batch units** at least **every week**
  - In continuously operated digestors small portion of sludge wasted every day
- After aeration separation of solids and liquids
  - In batch reactor clarified liquid supernatant decanted and recycled to ETP

Anaerobic sludge digestors

Aerobic sludge digestors

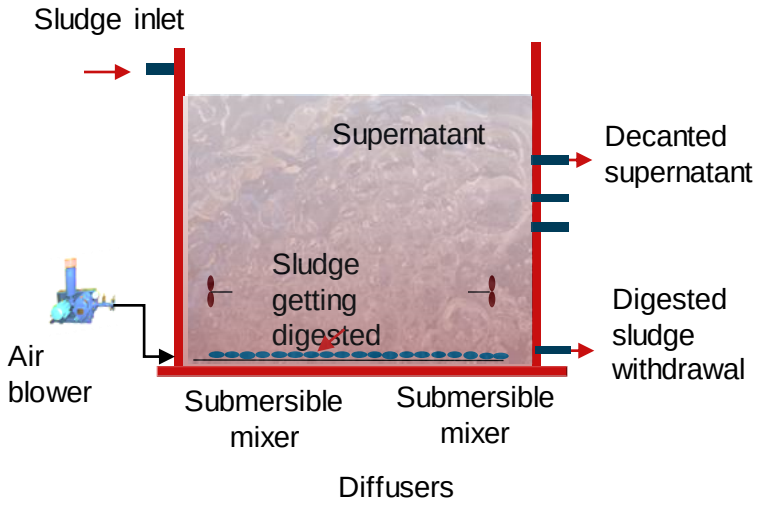
Operational aspects

- In continuous flow system normal aeration tank used with sometimes with higher density of diffuses followed by settling tank

  ✓ Some units equipped with extra submersible mixers

- Aerobic sludge digestion **usually for biological sludges** from secondary treatment units
- In endogenous respiration microorganisms utilizing own cell contents for metabolic purposes with remaining sludge mineralized

Anaerobic sludge digestors

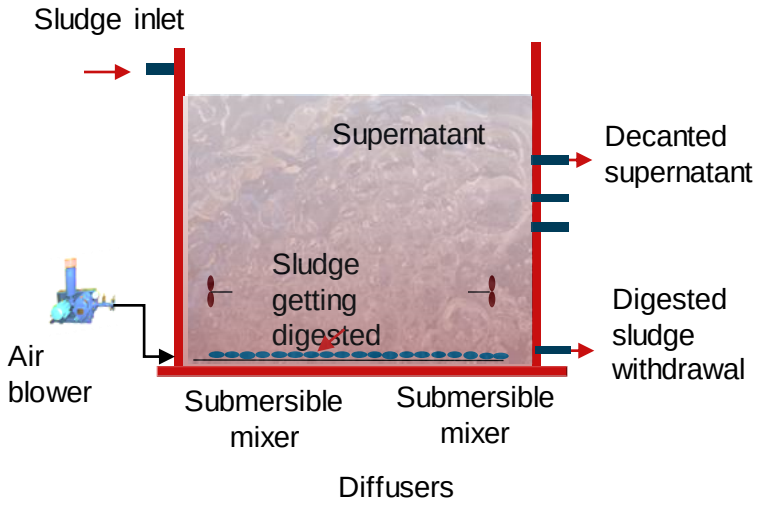


Aerobic sludge digestors

Operational aspects

- Switch off blower for 2 hours and observe settling in level tubes
- Once sludge settling below bottom of drain channel, open top drain valve
- Once draining slowing open lower drain until all supernatant drained
- Start air blower and aeration

Anaerobic sludge digestors



Aerobic sludge digestors

Operational aspects

- Open bottom drain valve and withdraw digested sludge
- leave about one-fourth of tank volume to preserve needed biomass for digestor.
- Once draining complete pump fresh sludge into digestor.
- Sludge not to be held in collection tank for long time and turn anaerobic in nature.

Anaerobic sludge digestors

Advantages

Aerobic sludge digestors

Advantages

- Simplicity of operation and maintenance
- Lower capital costs
- Lower levels of biochemical oxygen demand (BOD) and phosphorus in supernatant
- Fewer effects from upsets (e.g. presence of toxic interferences or changes in loading and pH)
- Less odor and nonexplosive
- Shorter retention periods
- Suitable for small wastewater treatment plants

Anaerobic sludge digestors

Aerobic sludge digestors

Disadvantages

- Higher operating costs, especially energy costs
- No useful by-products such as methane gas
- Less reduction in volatile solids
- Too costly option for larger wastewater treatment plants

Objective of sludge dewatering

Sludge generated like watery slurry

- Make fit for handling before discharge or disposal.
- Still polluted & hence cannot be discharged anywhere.

Reduce sludge moisture content by

- Sludge **thickening**
- Sludge **dewatering** to turn into **dry cake**

Sludge treatment and handling

Gravity thickener

Proprietary mechanical thickener

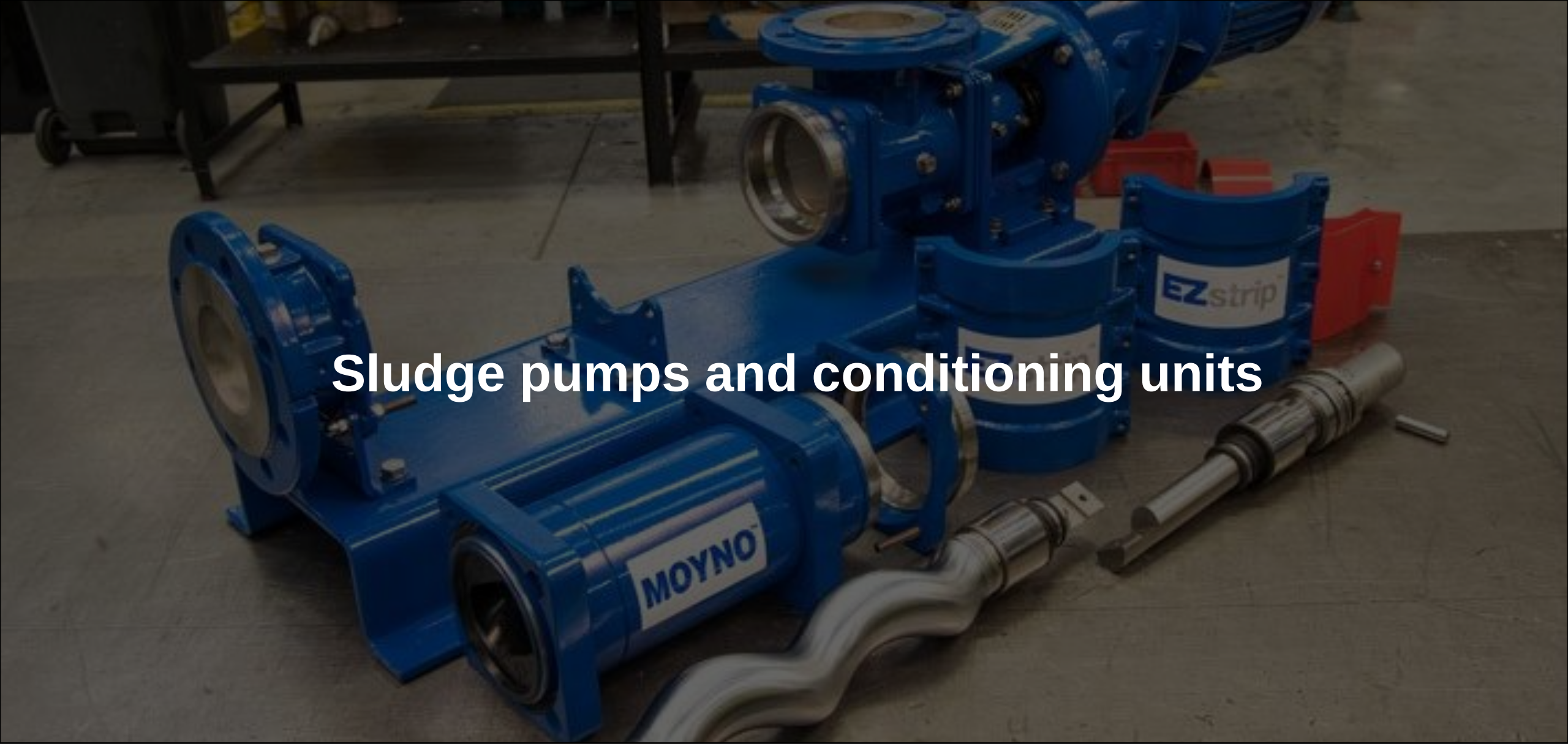
Sludge thickening

- **Gravity thickening**
  - ✓ Most common
  - ✓ Simple operation
  - ✓ Low operating cost
- **Mechanical thickening**
  - ✓ Costlier
  - ✓ It is ‘Preliminary’ mechanical dewatering

Overview of units and equipment

Common units in sludge management

- Sludge pumps and conditioning units
- Sludge thickeners
- Sludge volume reducing systems including digestors
- Sludge dewatering
- Sludge driers (thermal/natural)
- Sludge disposal/utilisation systems



Sludge pumps and conditioning units

Sludge pumps and conditioning units

Designed to handle high solids content (1-7%)

Types of pumps

- **Centrifugal** pumps with open/semi open impellers
- **Submersible** pumps
  - ✓ For low solids content (e.g. thickener feed pump) and low pressure requirements
- Archimedean **screw type** pumps:
  - ✓ Designed to handle huge quantities
  - ✓ Not popular in small-medium ETPs
  - ✓ Not suitable for thick sludge

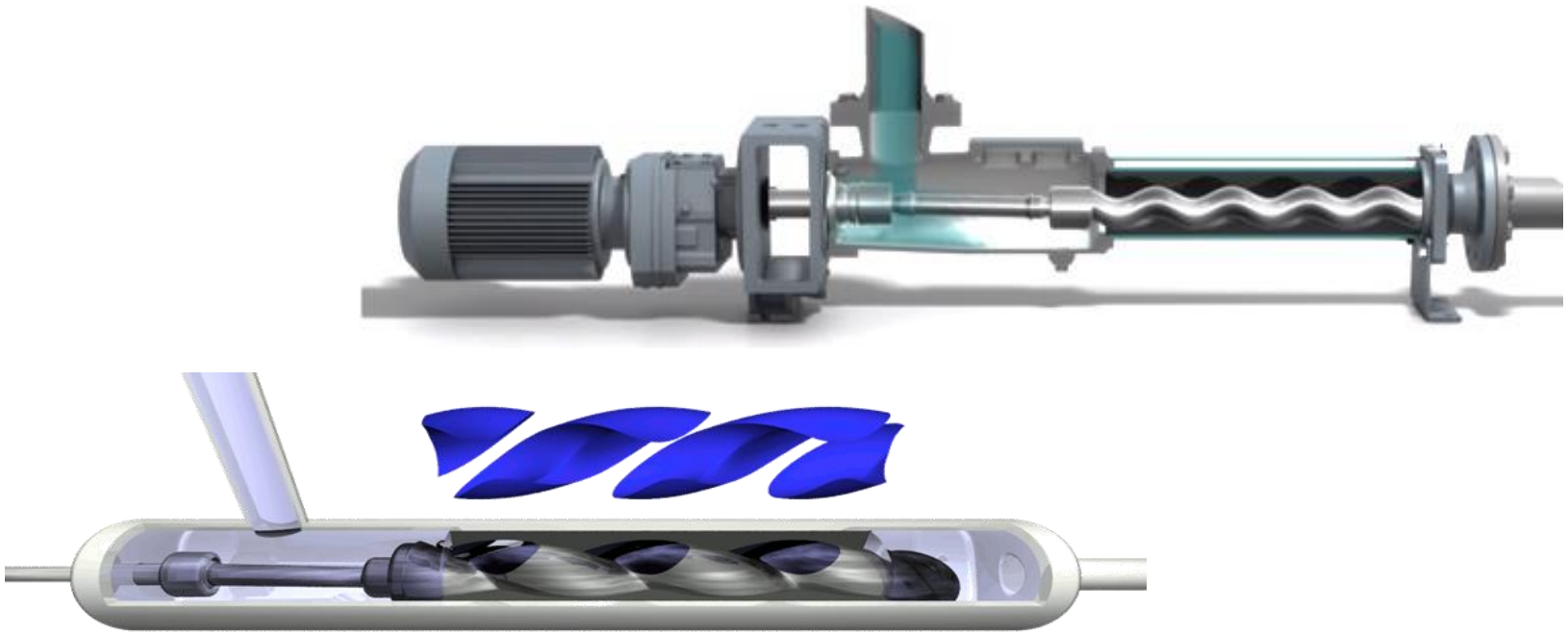
Sludge pumps and conditioning units

Types of pumps

- Progressive **cavity pumps** or ‘screw pumps’
  - Most common unit
- Air-operated **diaphragm pumps**:
  - Simple and comparatively cheaper
  - Need compressed air
  - Suitable for ETP with large pneumatic systems
- **Rotary lobe** pumps
  - Similar to air blowers used to pump thick sludge

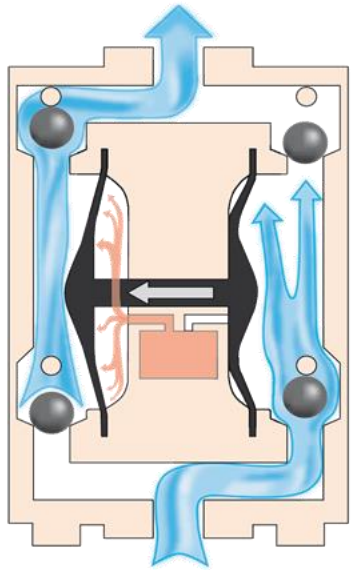
Sludge pumps and conditioning units

Pumps for liquid sludge: Progressive cavity pumps



Sludge pumps and conditioning units

Pumps for liquid sludge: Air operated diaphragm pumps



QUIZ

What is the objective of sludge thickening?

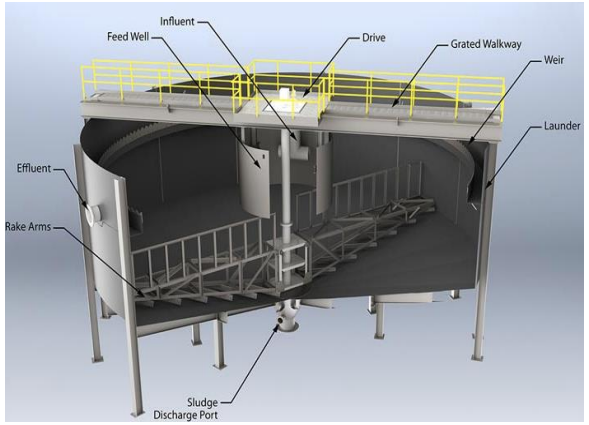
Sludge thickening systems

Sludge thickening

Gravity thickener

- To **concentrate solids** (2 - 5 times more) and **reduce sludge volume**
- Depending on required capacity
  - hopper bottom
  - rectangular
  - circular in shape
  - Common and similar to clarifiers with picket fences added to scrappers
- Seldomly used in Bangladesh except few units with hopper bottom thickeners or rectangular tanks

Sludge thickening



Gravity thickener

- **Loading rate** (solids load per m2 of the tank):
  - Primary 100 kg/m2/day
  - Secondary 25 kg/m2/day
  - Combined ETP: 35 kg/m2/day
- **Retention time**: ≈ 1 day
- Clear **overflow** returned **to equalization** tank
  - Faulty operations resulting in thick sludge overflow (!)
- Effective with combined sludge, not effective with all-biological sludge

Sludge thickening

Dissolved air floatation (DAF) thickener

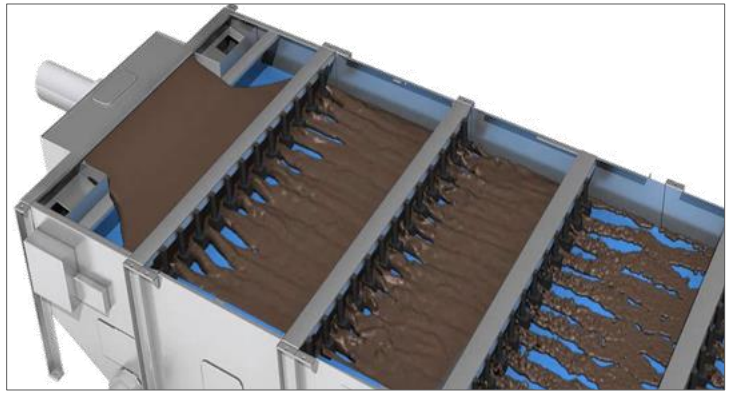
- Effective for **wasted activated sludge**
- Similar operation like dissolved air floatation in primary treatment:
  - ✓ Sludge mixed with compressed air
  - ✓ Thickened sludge rising to top
  - ✓ Sludge scooped using scum scrapper
- Used for **thickening secondary sludge** (from **1% to 3%**)
  - ✓ not for heavy primary sludges (!)

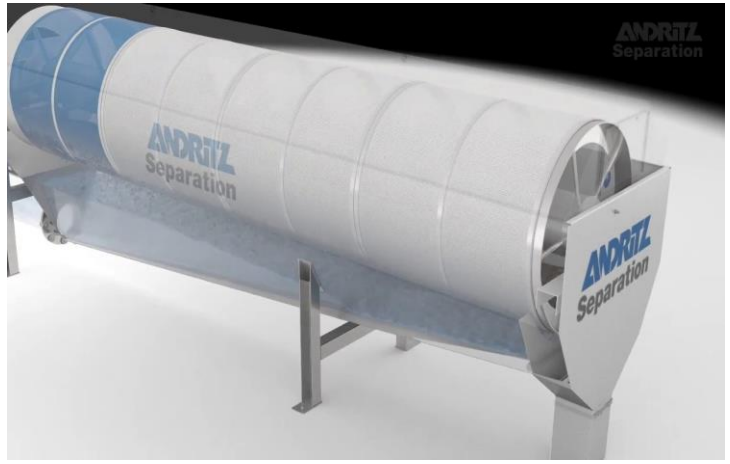
Sludge thickening

Dissolved air floatation (DAF) thickener

- **Conditioning chemicals** for enhancing thickening
  - Flocculants or polyelectrolytes (quite often)
- **Loading rate** for secondary sludge:
  - 50-120 kg/m2/day of surface without conditioning
  - 200-250 kg/m2/day of surface with conditioning
- **Advantage**
  - Low retention time
  - Sludge staying aerobic
  - Preventing putrefaction avoiding odor

Sludge thickening



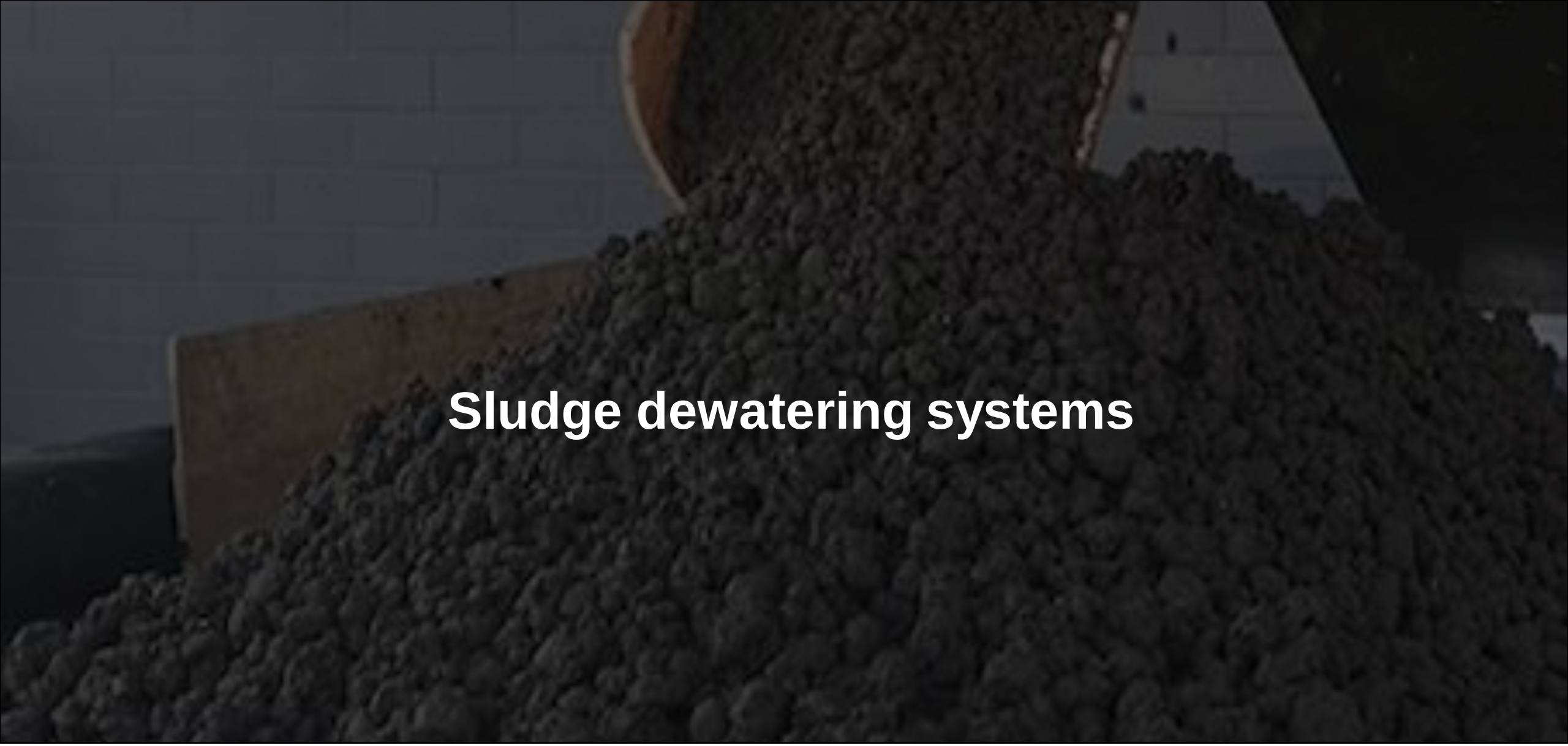


Mechanical thickening

- Uncommon Bangladesh
- Common systems
  - **Gravity belt thickener** with sludge passing perforated belt
  - **Rotary drum thickener** with sludge fed into to slowly-rotating vessel with porous walls
  - **Screw thickener** with central screw pressing sludge through rotating multi-disk filters
- Spray system required to clean perforated platforms and prevent pores blockage

QUIZ

What are the options for sludge dewatering?



Sludge dewatering systems

Sludge dewatering

Chamber filter press

- Most **popular** mechanical sludge dewatering unit for **small and medium ETPs**
- Simple, sturdy and reliable
- Filter plates used as cavities (recessed chambers)

Sludge dewatering

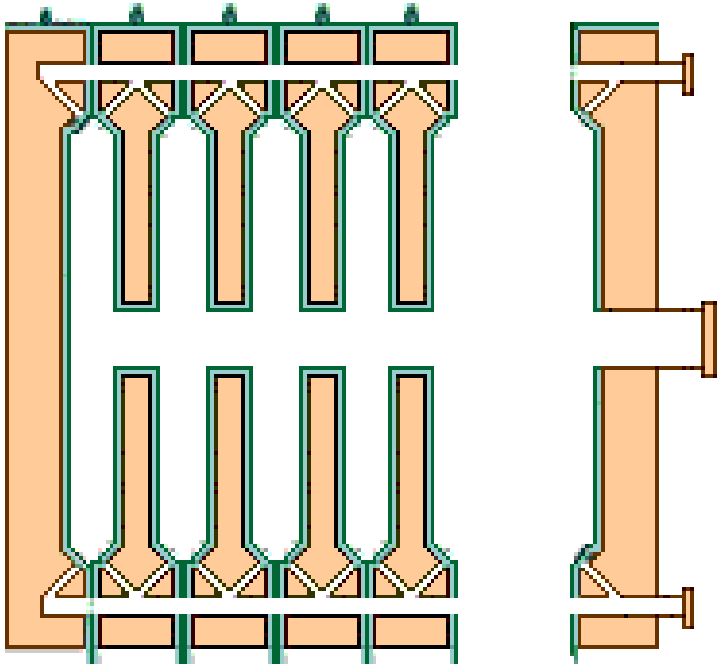
Chamber filter press

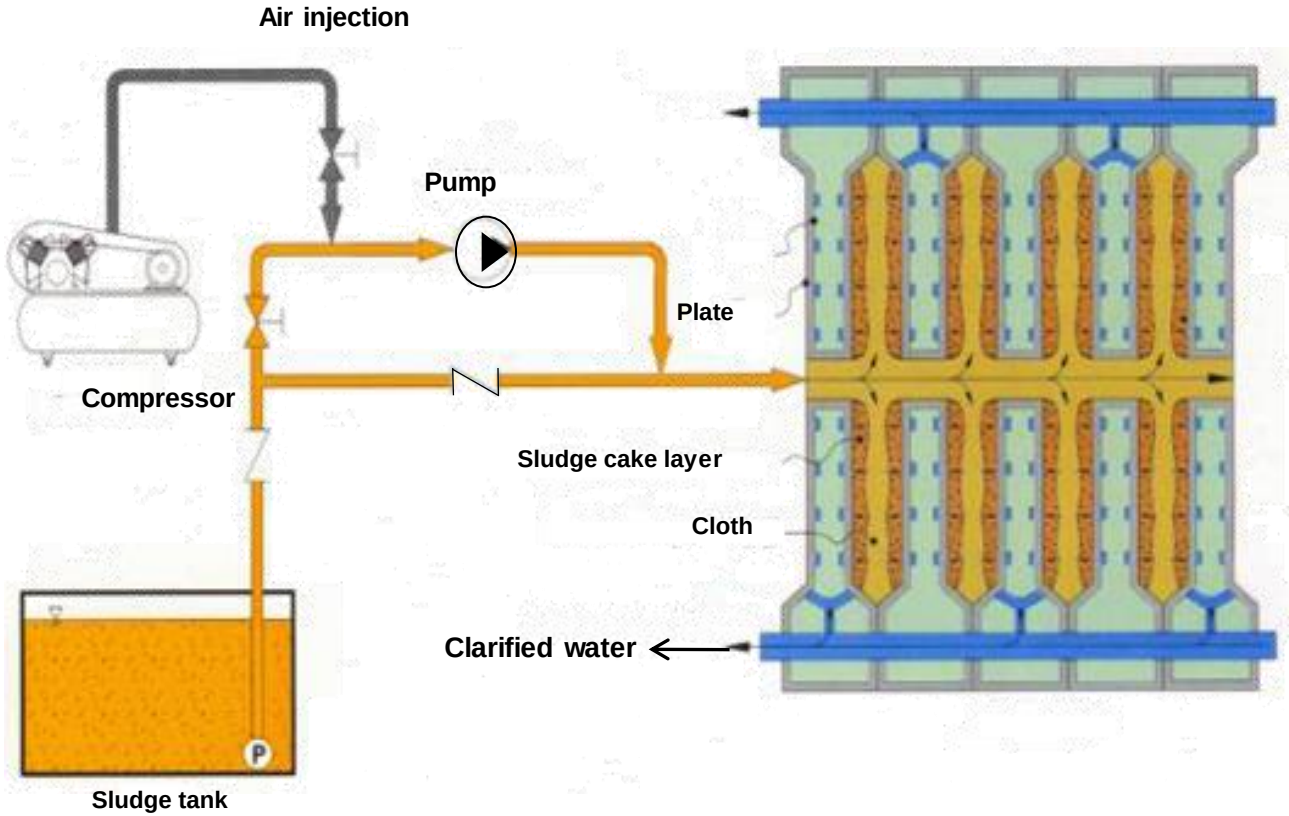
Operation – filtration cycle

- Press with filter plates closed by hydraulic locking cylinder
- Chamber formed between individual filter plates with sludge pumped in under high pressure
- Cake forming by increasing thickness of sludge
- Plates opening and caking fall out
- Filtrate flowing through cloth and discharged through filtrate channel

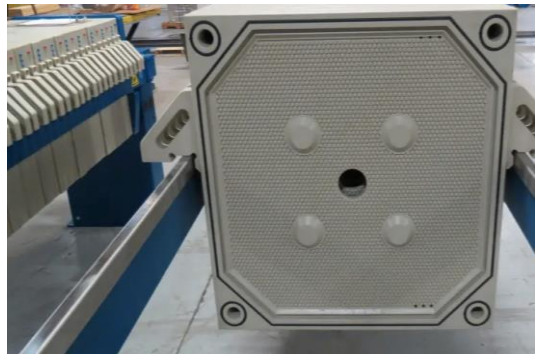
Sludge dewatering

Chamber filter press





Sludge dewatering



Chamber filter press

- **Optional features**
  - Provision for air/steam passing through centre for drier sludge
  - Cake collector in trailer or container
- **Advantage**
  - **High level of dryness** (moisture reduction by 60-65%)
- **Disadvantage**
  - **Higher capital cost**
  - Higher **area requirement**
- Conditioning using Ferric chloride/lime

Sludge dewatering

Sludge centrifuge

- **Decanter centrifuges most popular in large ETPs**
  - Models with vertical and specially horizontal mount
  - Cylindrical bowl rotating at 4000 - 6000 rpm
- **Concept:**
  - Heavier particles separated faster when rotating at high speeds
  - Slow moving screw conveyor within bowl to transport separated solids to collection bin

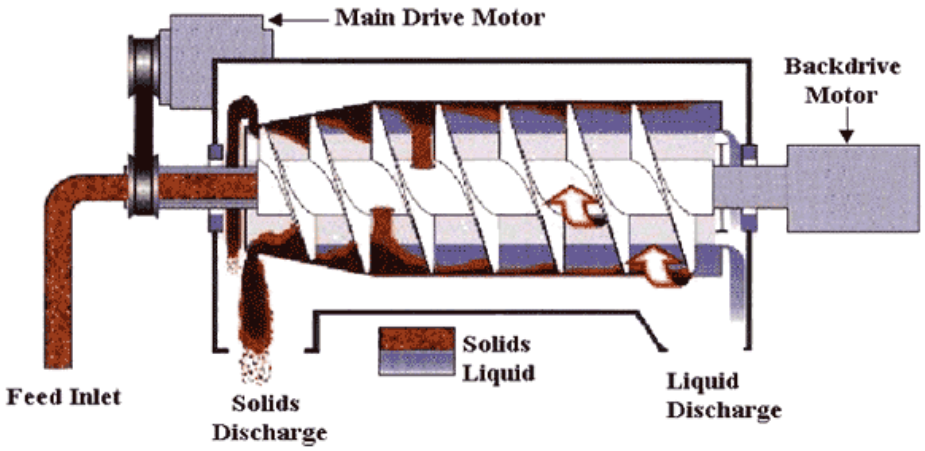
Sludge dewatering

Sludge centrifuge

- **Advantages:**
  - no odor problem
  - very small area requirement
  - minimum labor requirement
- **Disadvantages:**
  - high noise level during operation
  - high power consumption
  - need for conditioning with polyelectrolyte
  - high moisture content in dewatered sludge (75%)

Sludge dewatering

Sludge centrifuge

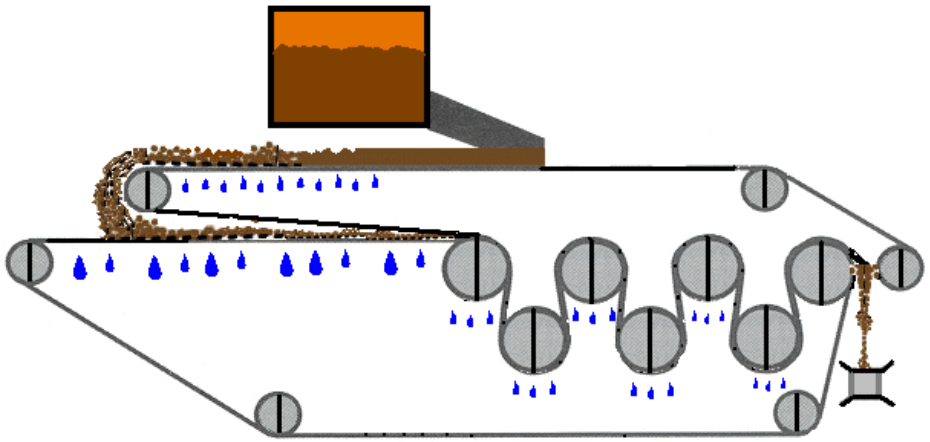


Sludge dewatering

Belt filter press

- Popular for medium and large ETPs
- Concept:
  - Two moving belts with sludge admitted between theses
  - Sludge moving between series of rollers and squeeze
  - Water released and drained by gravity
  - Squeezed and dewatered sludge getting scraped by stationary blade

Sludge dewatering



Belt filter press

Important features

- **Jet spray** to wash cloth
- Arrangement to keep **alignment of belts**
- **Differential speed motors** to adjust the speed

Sludge dewatering

Belt filter press

Advantages:

- less pressure pumps required
- very little noise emission
- easy to monitor since open

Disadvantages:

- odor problems
- issues with belt alignment
- lower dryness of sludge (25 - 30%)
- need for polyelectrolyte conditioning (operating cost!)

QUIZ

What is the simplest sludge dewatering system?

Sludge dewatering

Sludge drying beds

- Masonry units with no mechanical arrangements
- Suitable for small ETPs if space available
- Set-up:
  - Series of shallow tanks with sloped floor towards center
  - Perforated pipe to collect and drained water
  - Topped with gravel/sand media of different sizes (with finer sand on top)

Sludge dewatering

Sludge drying beds

- Process
  - Liquid sludge pumped in and spread on open bed of sand
  - Allowed to remain until dry
  - Drying through evaporation and gravity drainage
  - 1 week of drying => solids content **35-40%**
  - Drained water pumped back to ETP

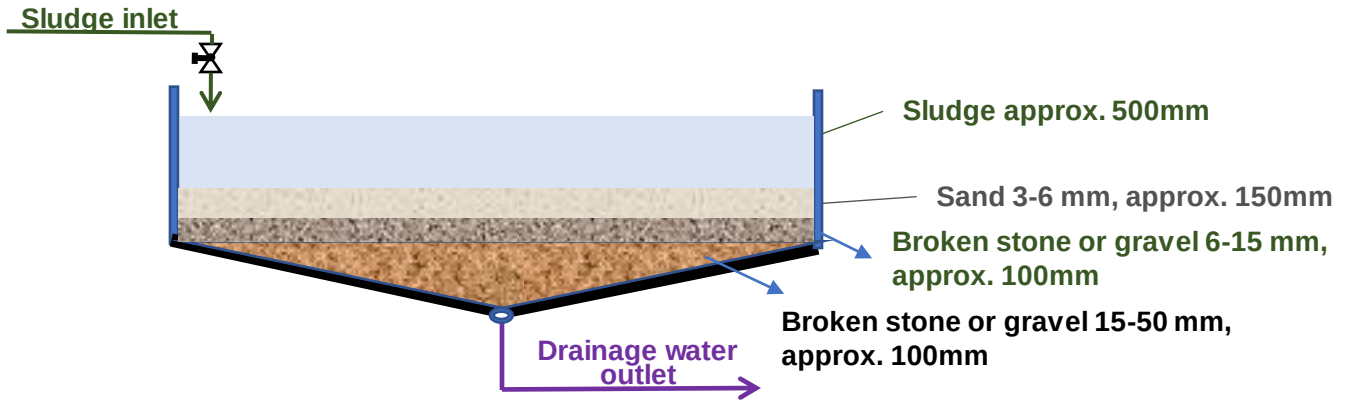
Sludge dewatering

Sludge drying beds

- **Advantages**
  - **Simple** construction
  - **low maintenance**
  - comparatively **lowest drying costs**
  - **emergency standby** unit during any breakdown of mechanical dewatering equipment
- **Disadvantages:**
  - high **land requirement**
  - potential for **odor**
  - high **manual labor** requirement

Sludge dewatering

Sludge drying beds



Sludge dewatering

	Decanter	Belt press	Chamber filter press	Sludge drying beds
Way of operation	Continuous	Continuous	Batch	Batch
Sludge dryness	Low	Medium	High	High
Sludge conditioning	required	required	not required	Not required
Washing water	not required	required	not required	Not required
Labor	only supervision	only supervision	required during cake discharge	Required
Sensitive to sludge variability	very sensitive	very sensitive	less sensitive	Less sensitive
Energy required (electricity)	high	medium	low	NA
Maintenance	sophisticated	medium	low	low

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