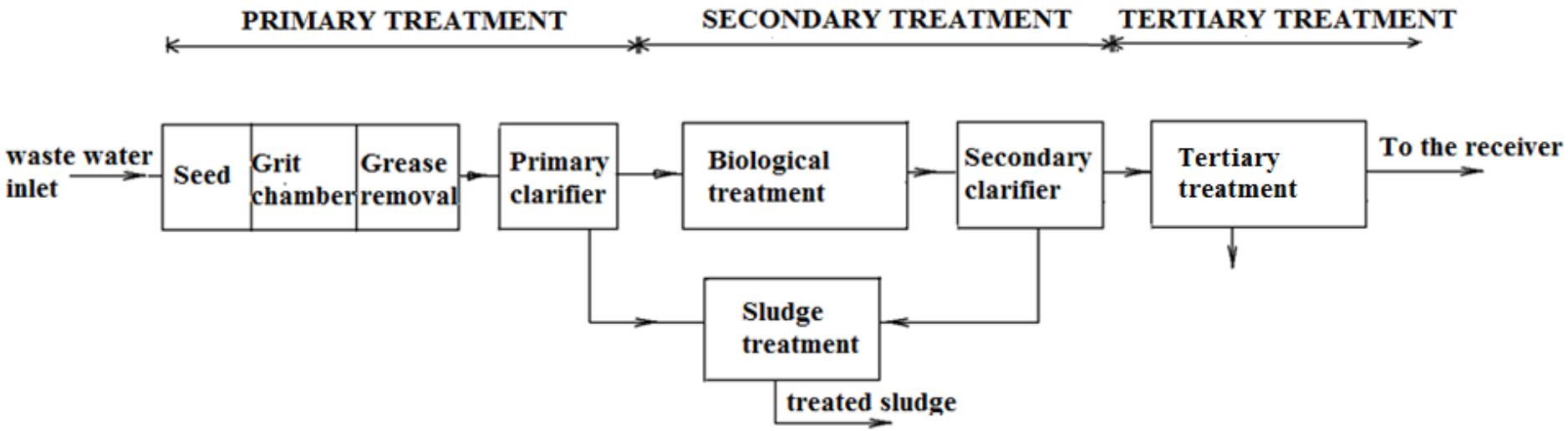
DEPARTMENT OF BUILDING SERVICES AND PROCESS ENGINEERING

Wastewater Sludge Treatment

General layout of a wastewater treatment plant



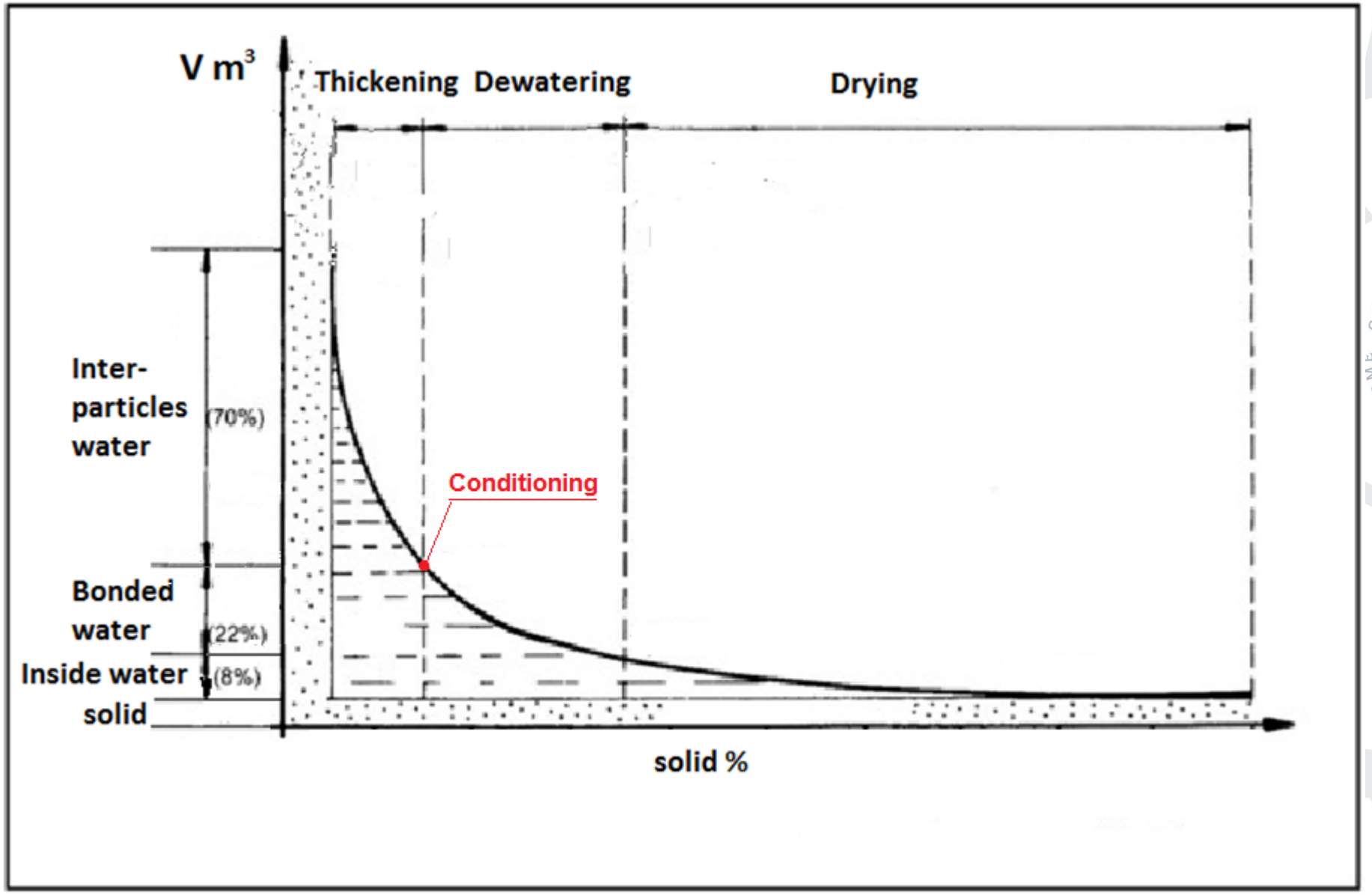
Content of wastewater sludge

1. Useful materials
   - Sludge water
   - Minerals
   - Organic compounds
   - Nutrients
   - Trace elements
2. Dangerous compounds
   - Toxic materials
   - Pathogens

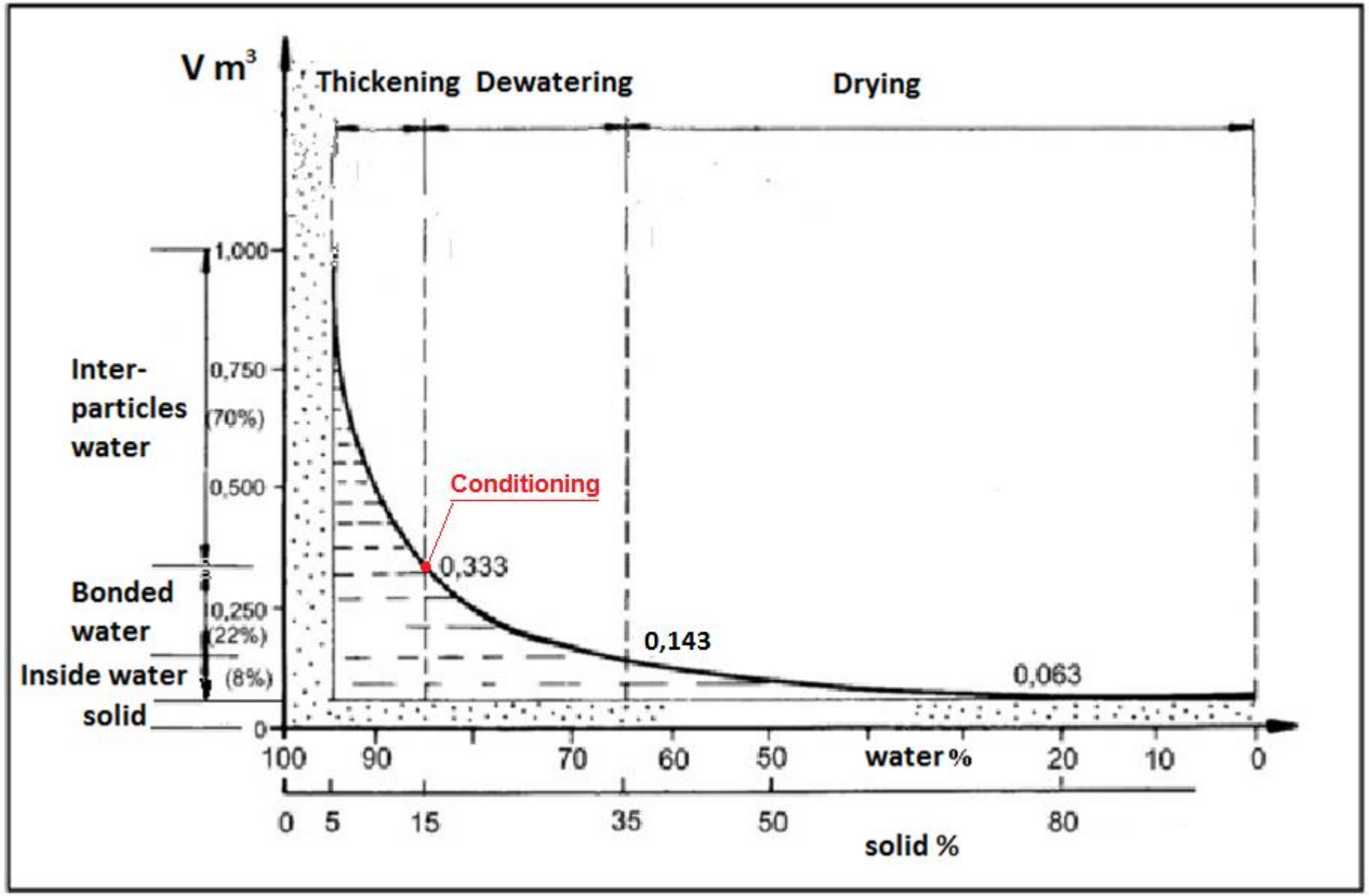
How to remove water from sludge?

Type of water	**Process**
Inter-particles water (~70%)	Thickening
Bonded water “colloidal water “ or “capillary water” (~22%)	After conditioning and stabilization: Dewatering
Inside water (~8%)	Drying

Sludge volume vs. solid content (concentration)



Sludge volume vs. solid content (concentration)



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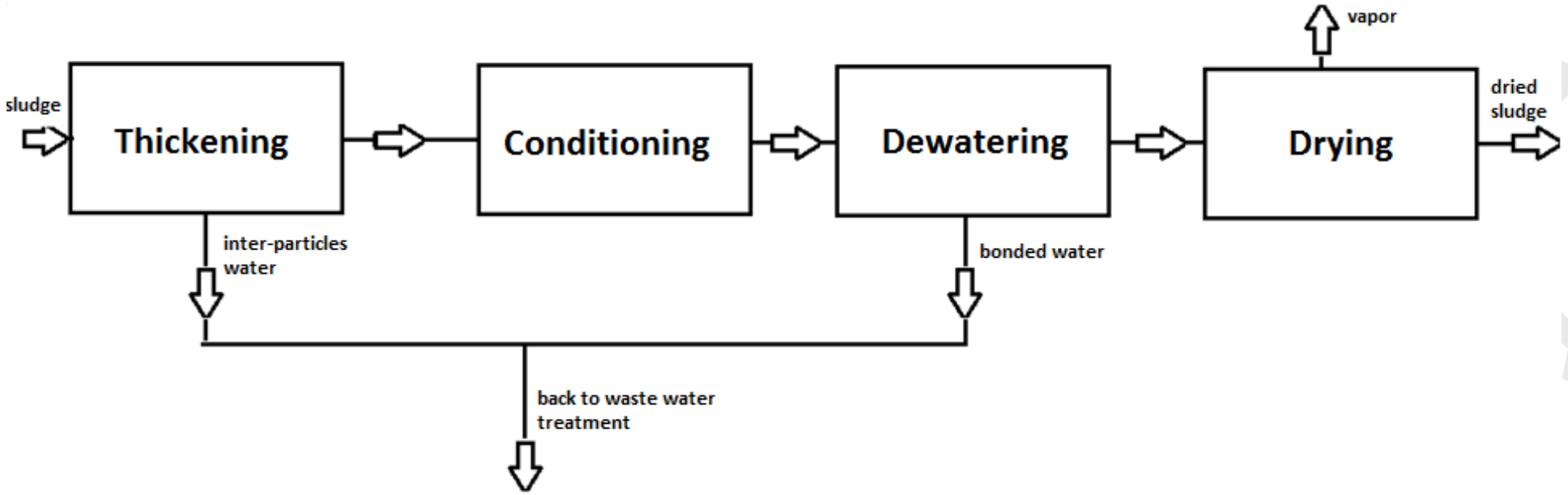
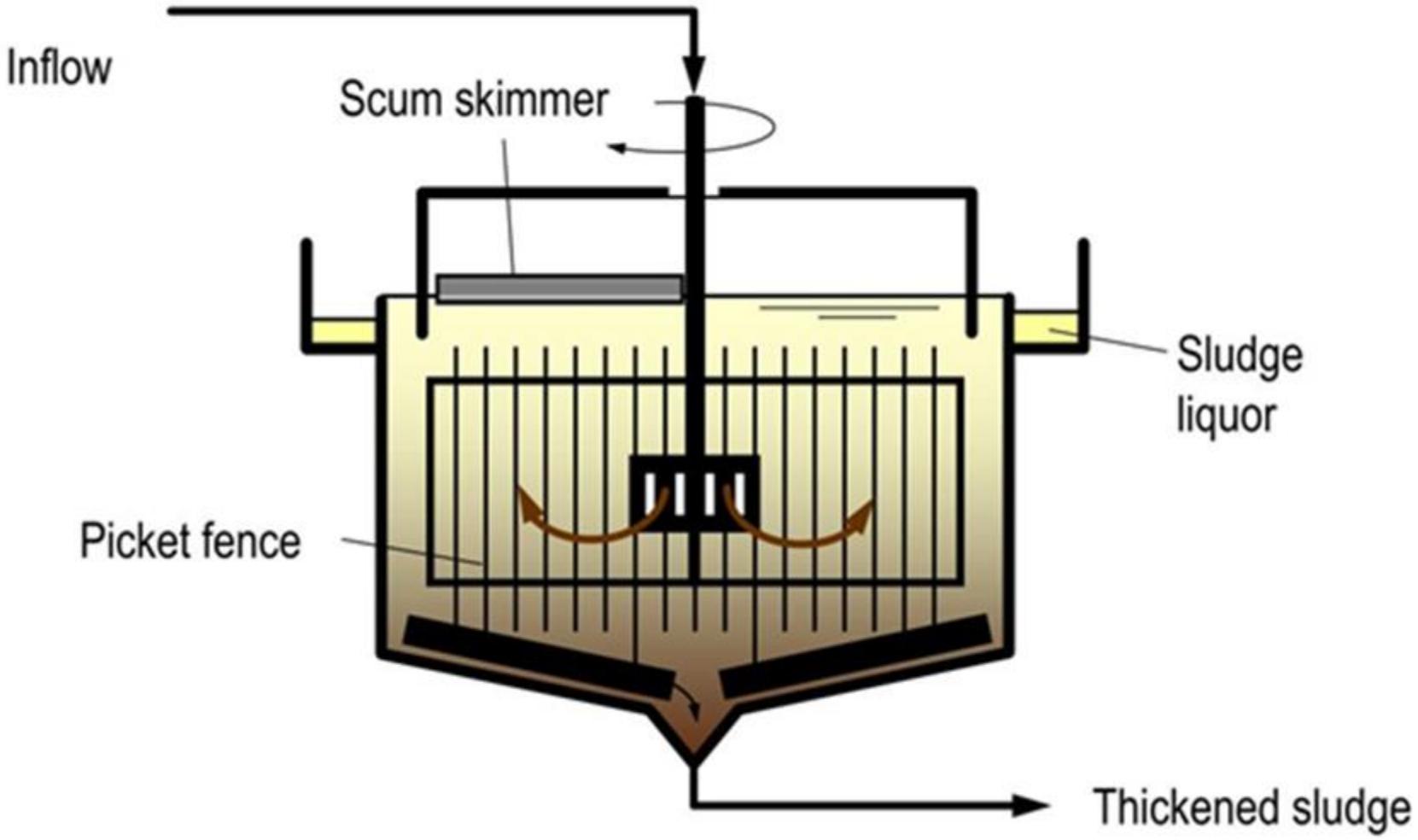
Generalized layout of sludge treatment



Thickening

- By gravity (settling)
- Flotation (by air bubbles)
- Filtration
- Centrifuges

Gravity thickener



Gravity thickener

Thickening by flotation

Dissolved air flotation (DAF) provides thickening of sludges (i.e., thickens the sludge) by encouraging the solids to float to the surface, rather than allowing them to sink as in gravity thickening

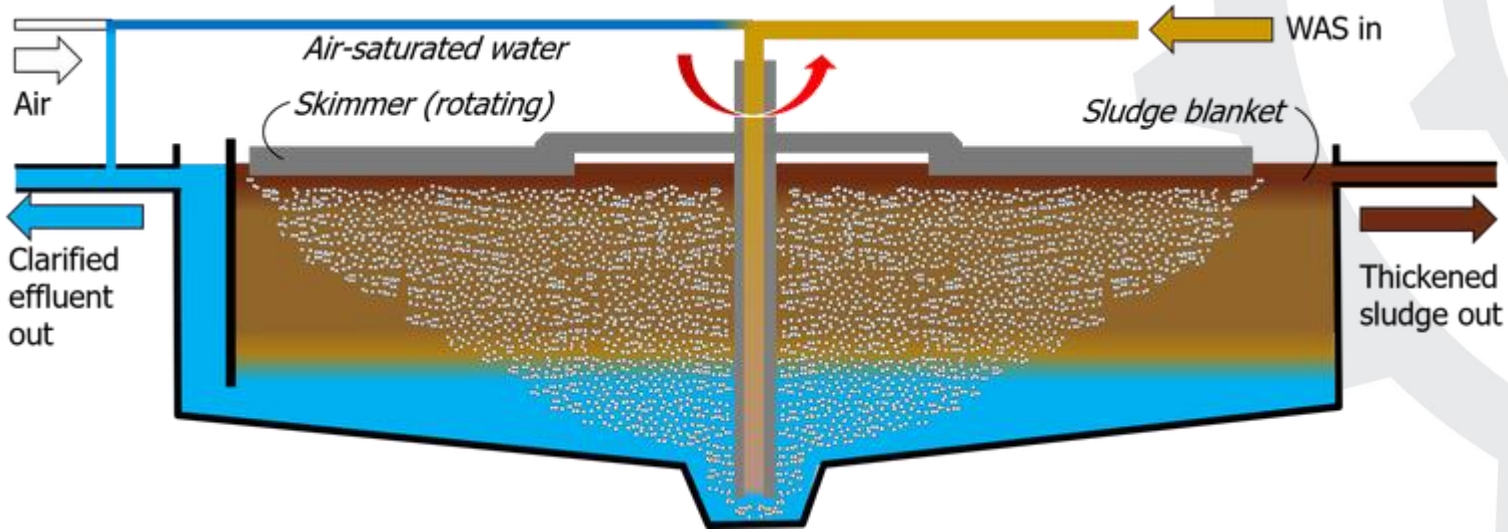


Plate and frame filter press

1 suspension inlet,
2 press forces,
3 filtrate outlet,
4 separating chambers,
5 filter cloth,
6 filter frame,
7 filter plate,
8 filter cake

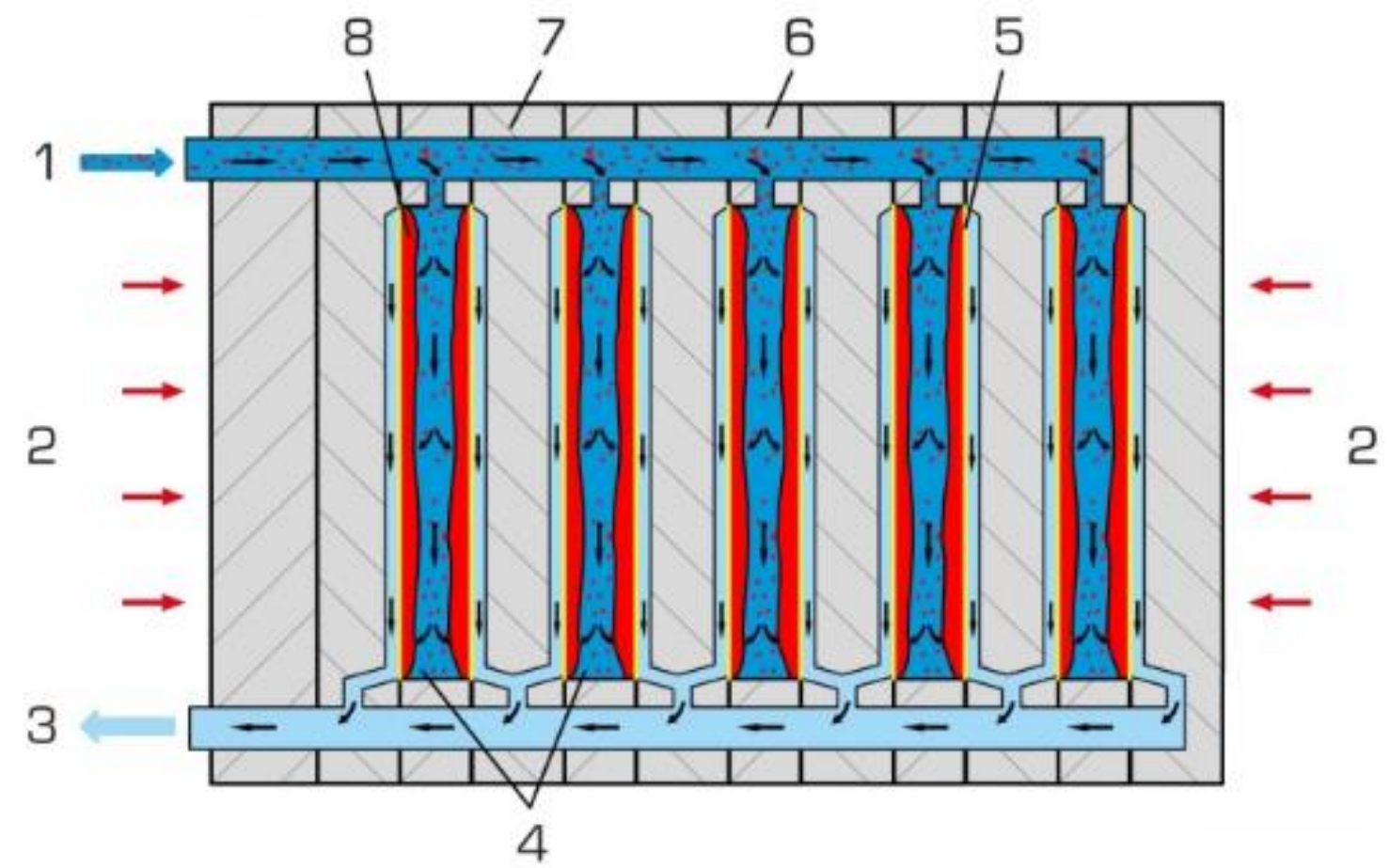
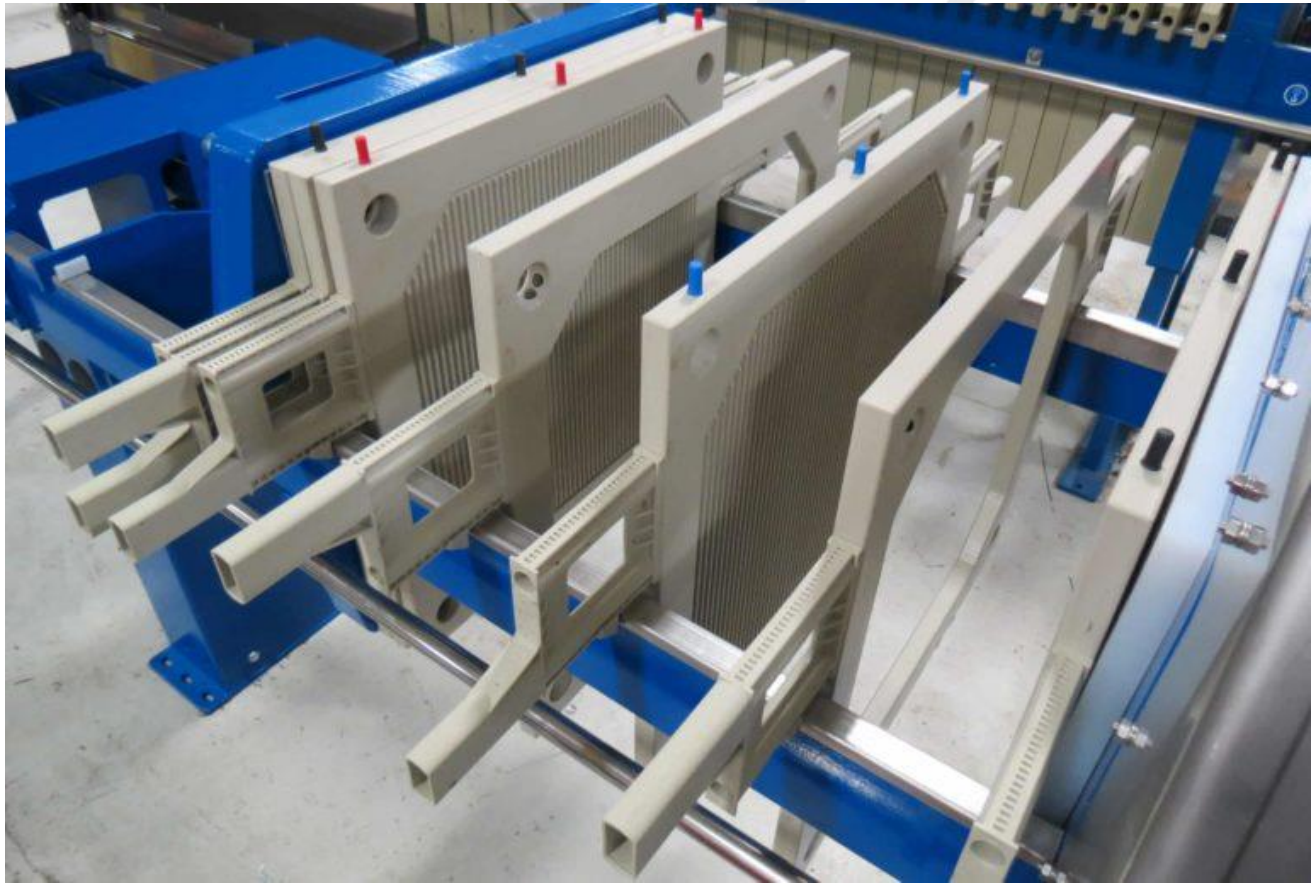


Plate and frame filter press



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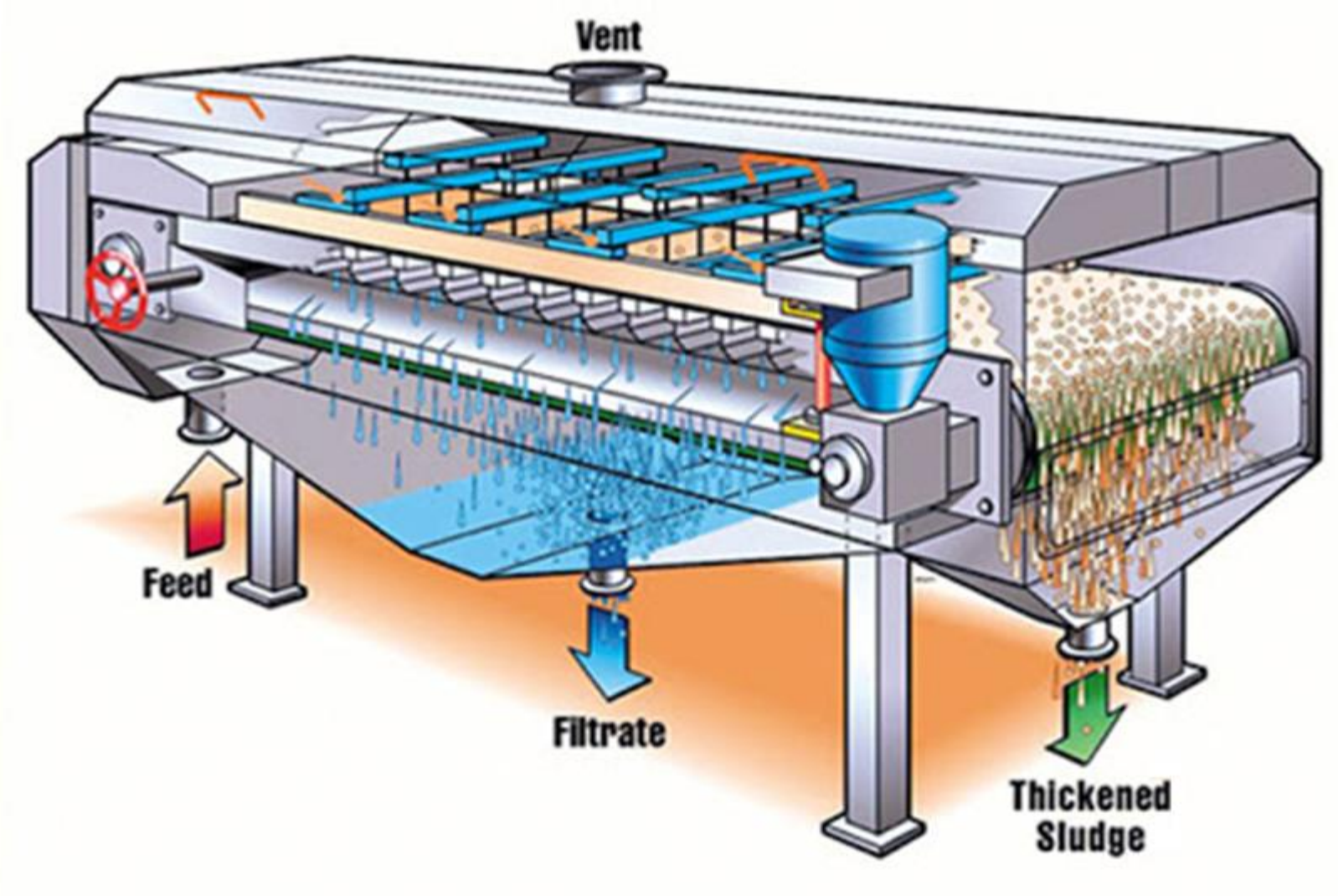
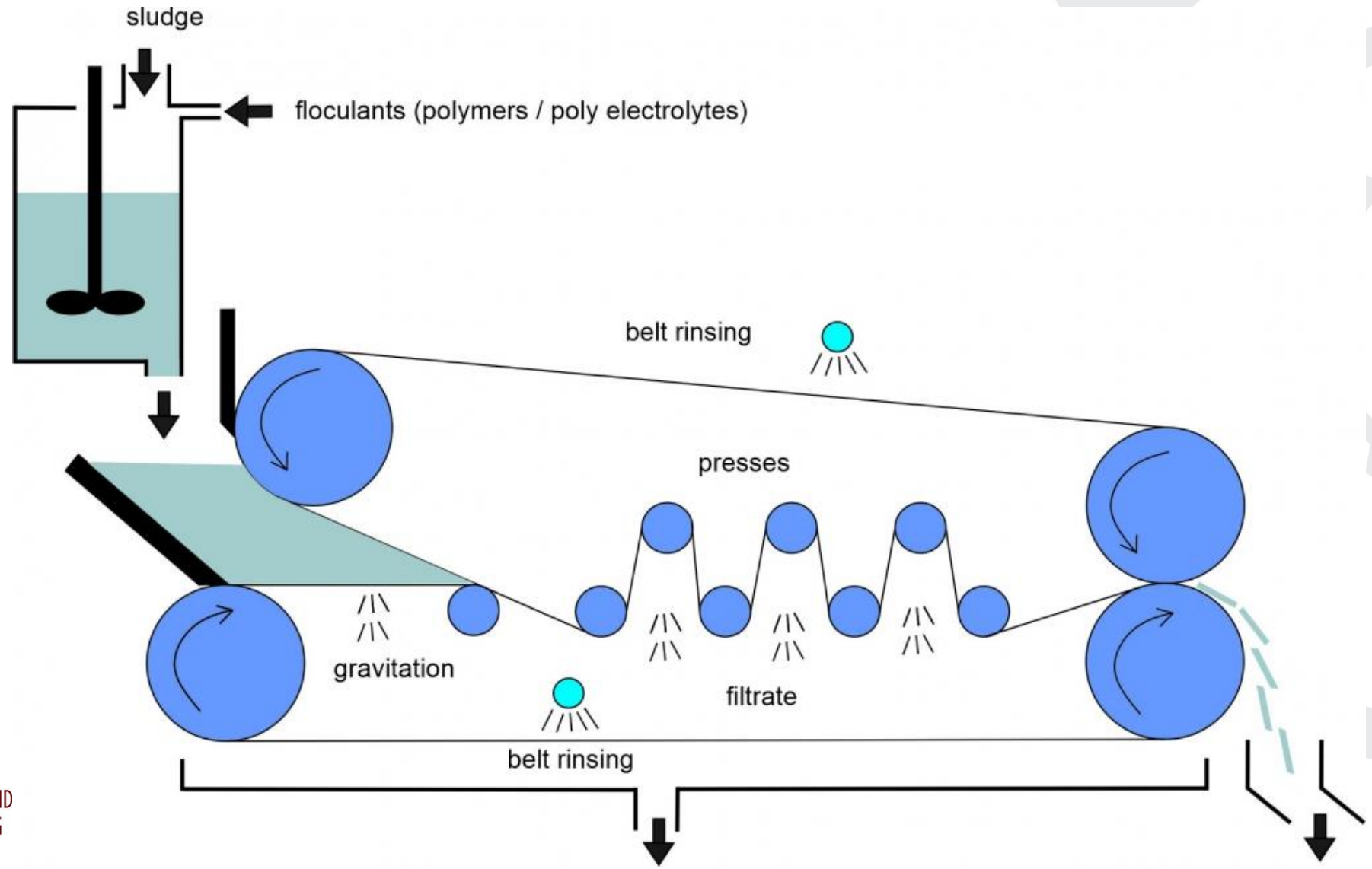
Gravity belt thickener



Gravity belt thickener

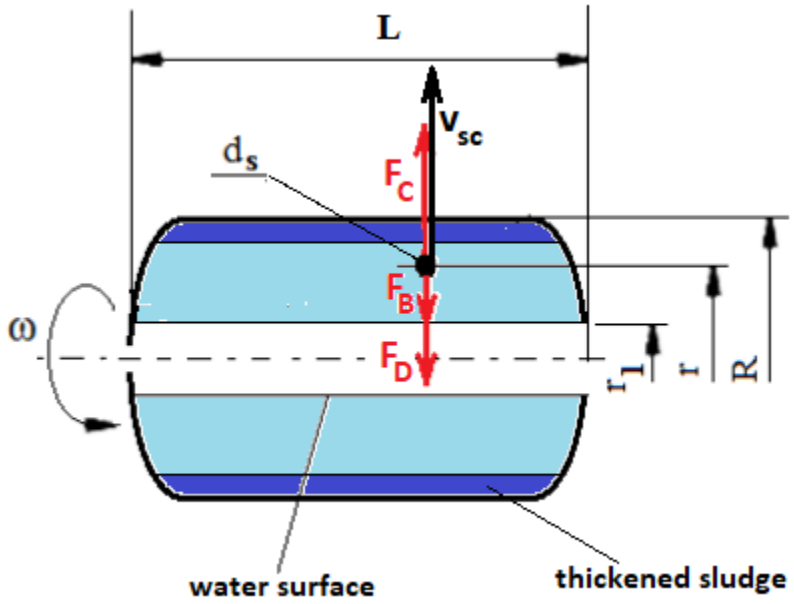
Double belt filter press



Double belt filter

Double belt filter

Centrifugal settling



Forces:

Centrifugal force	$F_C = m_s r\omega^2 = \frac{{d_s}^3\pi}{6}\rho_s r\omega^2$
Buoyancy force	$F_B = \frac{{d_s}^3\pi}{6}\rho_F r\omega^2$
Drag force	$F_D = 3\pi d_s v_{sc}\mu_F$

d_s	diameter of solid particle
ρ_s	density of solid particle
ρ_F	density of fluid
μ_F	dynamic viscosity of fluid
ω	angular velocity of the drum
r	radius
v_{sc}	centrifugal settling velocity

$$F_c = F_B + F_D$$

$$\frac{{d_s}^3\pi}{6}\rho_s r\omega^2 = \frac{{d_s}^3\pi}{6}\rho_F r\omega^2 + 3\pi d_s v_{sc}\mu_F$$

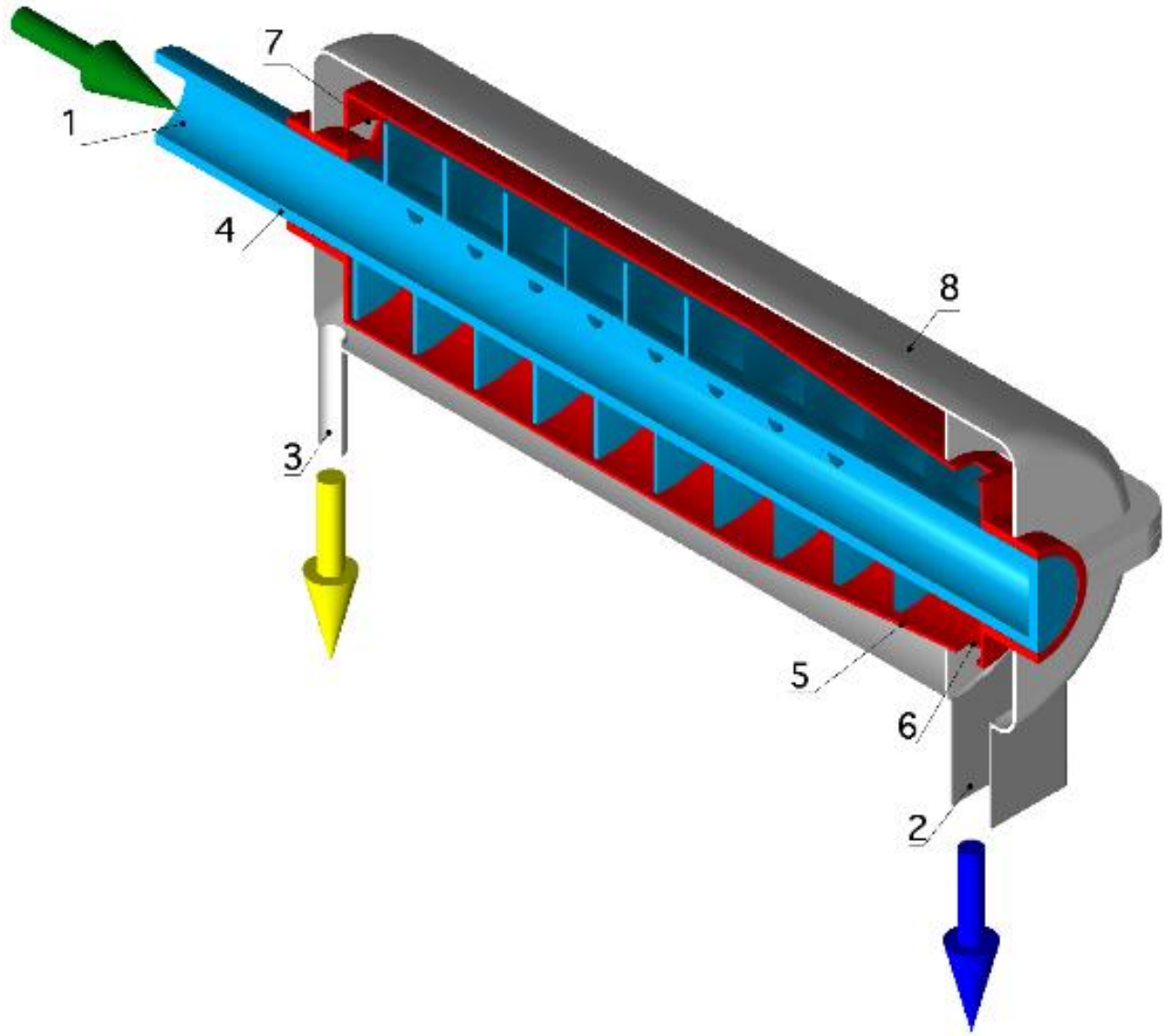
$$v_{sc} = \frac{{d_s}^2(\rho_s - \rho_F)r\omega^2}{18\mu_F}$$

relative centrifugal force

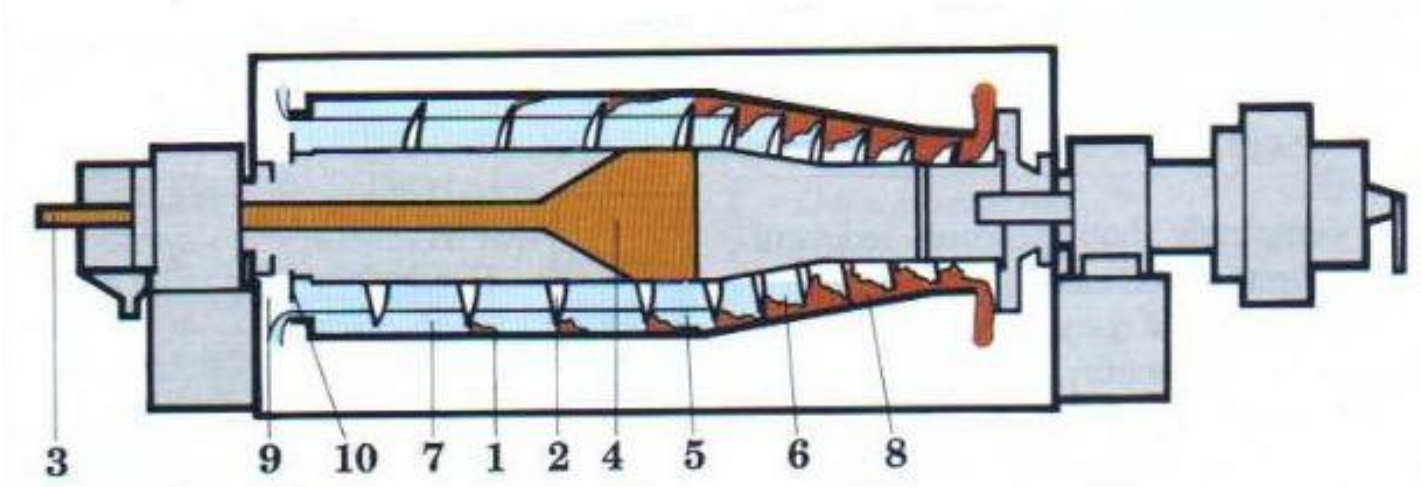
$$RCF = \frac{r \cdot \omega^2}{g}$$

Decanter centrifuge

1. Sludge in
2. Thickened sludge out
3. Sludge water out
4. Rotating hollow shaft with screws
5. Rotating centrifuge drum
6. Thickened sludge outlet hole
7. Sludge water overflow
8. Housing



Decanter centrifuge



1. Cylindroconical bowl
2. Helical extraction screw (scroll)
3. Feed
4. Distributor
5. Ring space
6. Settled product
7. Liquid level
8. Drying zone
9. Clarified liquid
10. Adjustable tresholds

Decanter centrifuge

Conditioning

The purpose of sludge conditioning is to provide a rigid sludge structure of porosity and pore size sufficient to allow drainage and dewatering. Preparation process before dewatering.

Sludge stabilization

Stabilization of wastewater sludge is a common method applied

a. to eliminate growth of pathogens
b. To eliminate offensive odors

prior to dewatering and disposal.

Conditioning methods

- Physical
- Chemical
- Biochemical (aerobic, anaerobic)

Physical conditioning

- **Pasteurization:** Heating up to 60-80 °C, then constant temperature for 15-30 minutes
- **Thermal conditioning:** T=180-220 °C, ~30 min. Total cell destruction.
- **Freezing (natural)**
- **Sludge washing**

Chemical conditioning

- *Organic coagulants* (polyelectrolites)

- *Inorganic coagulants* (e.g., $FeCl_3$,$FeSO_4$, $Al_2(SO_4)_3$, CaO).

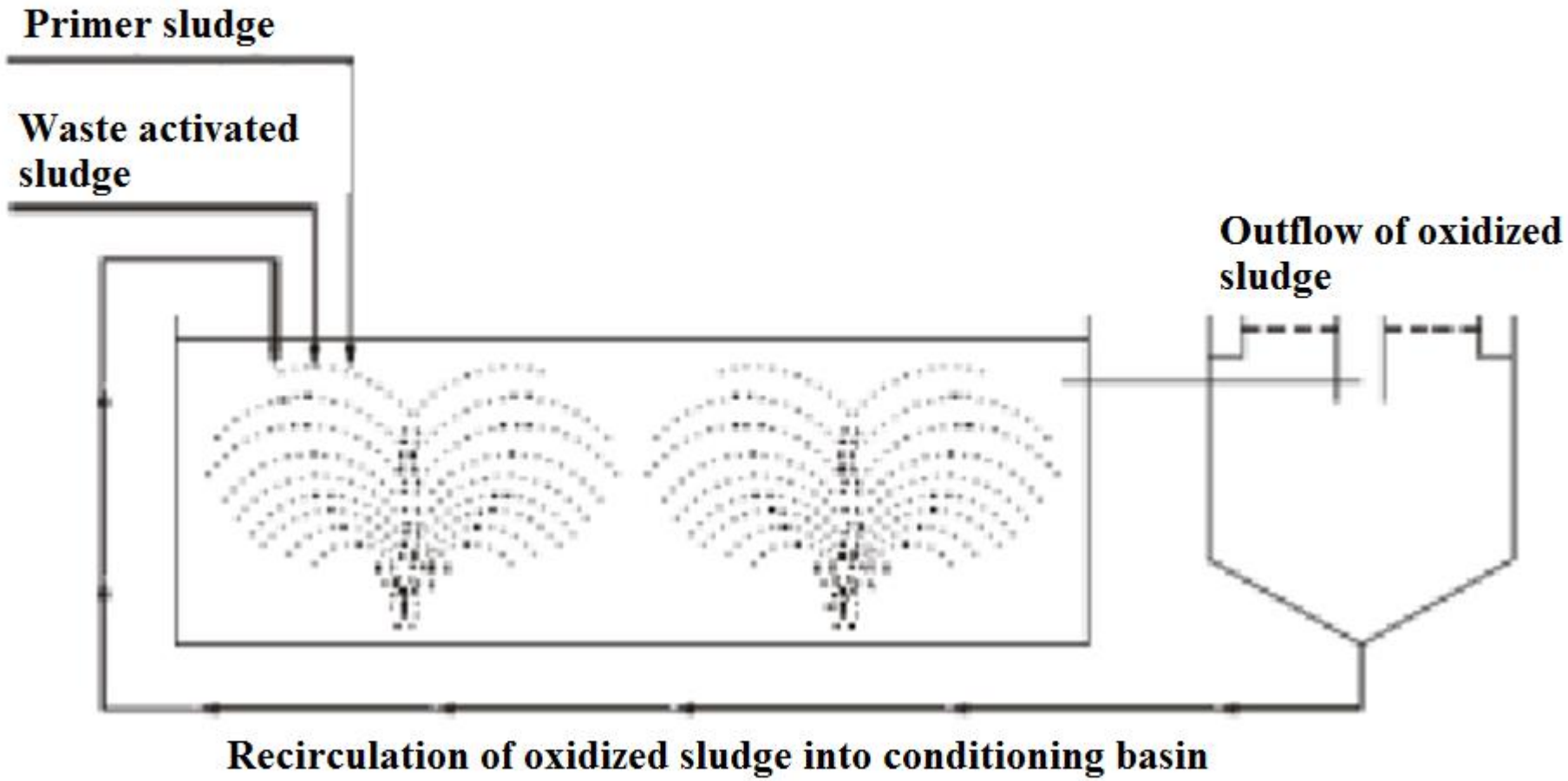
Biochemical conditioning

- Aerobic conditioning
- Anaerobic conditioning

Aerobic sludge conditioning

Direct oxidization of biodegradable compounds and micro cells in open basins.

Like activated sludge biological systems



Aerobic sludge conditioning

- Aerobic sludge conditioning is defined as the biological oxidation of organic sludges under aerobic conditions (in the presence of O_2).
- The microbes digest solids from primary sedimentation processes, and those from secondary treatment processes like those attached to the microbial flocs from activated sludge and biofilters (trickling filters).

Aerobic sludge conditioning

Advantages

- Fewer operational problems
- Less daily maintenance
- Lower BOD concentrations in supernatant liquor
- Lower capital costs

Disadvantages

- Aerobic digestion does NOT produce methane as a by-product.
- Higher energy requirements – lot of aeration and mixing required.
- Conditioned sludge has lower solids content, thus volume of sludge to be dewatered is much larger

Aerobic sludge conditioning

Anaerobic biochemical conditioning = DIGESTION

Products

- Digested sludge	bio-fertilizer for agriculture
- Biogas	heat energy
	electric energy
	(gas engine, furnace)

BIOGAS

Mixture of methane (60-65% CH_4) and carbon dioxide (30-35% CO_2).

It can be produced by fermentation of

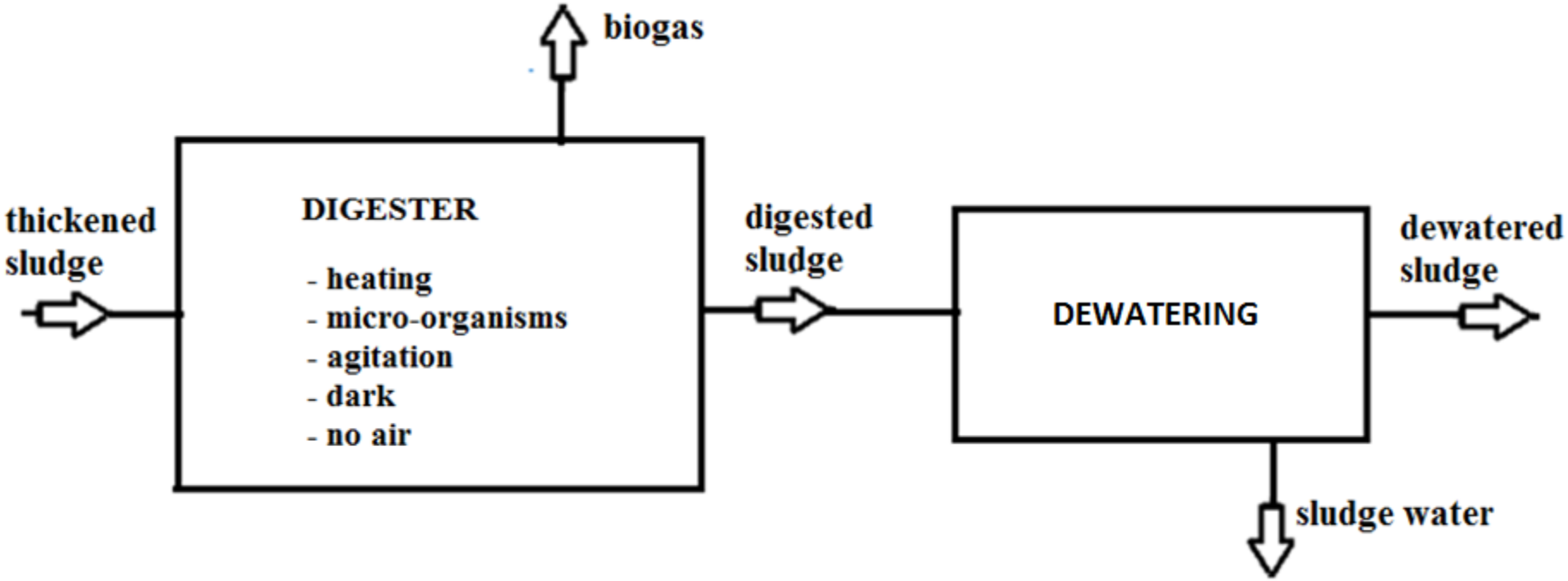
- communal wastewater sludge,
- agriculture solid wastes,
- other organic wastes.

Temperature of digestion

- Cold digestion T < 15 ^{0}C (50-180 days)
- Heated digestion T = 32 - 58 ˚C

mesophilic digestion T= 32- 38 °C
(15-25 days)
thermophilic digestion T= 55- 58 °C
(5-12 days)

Sludge digestion



Shape of the reactor (digester)

- Cylindrical
- Conical bottom
- Conical cover
- Egg-shaped

DIGESTERS
Mixing

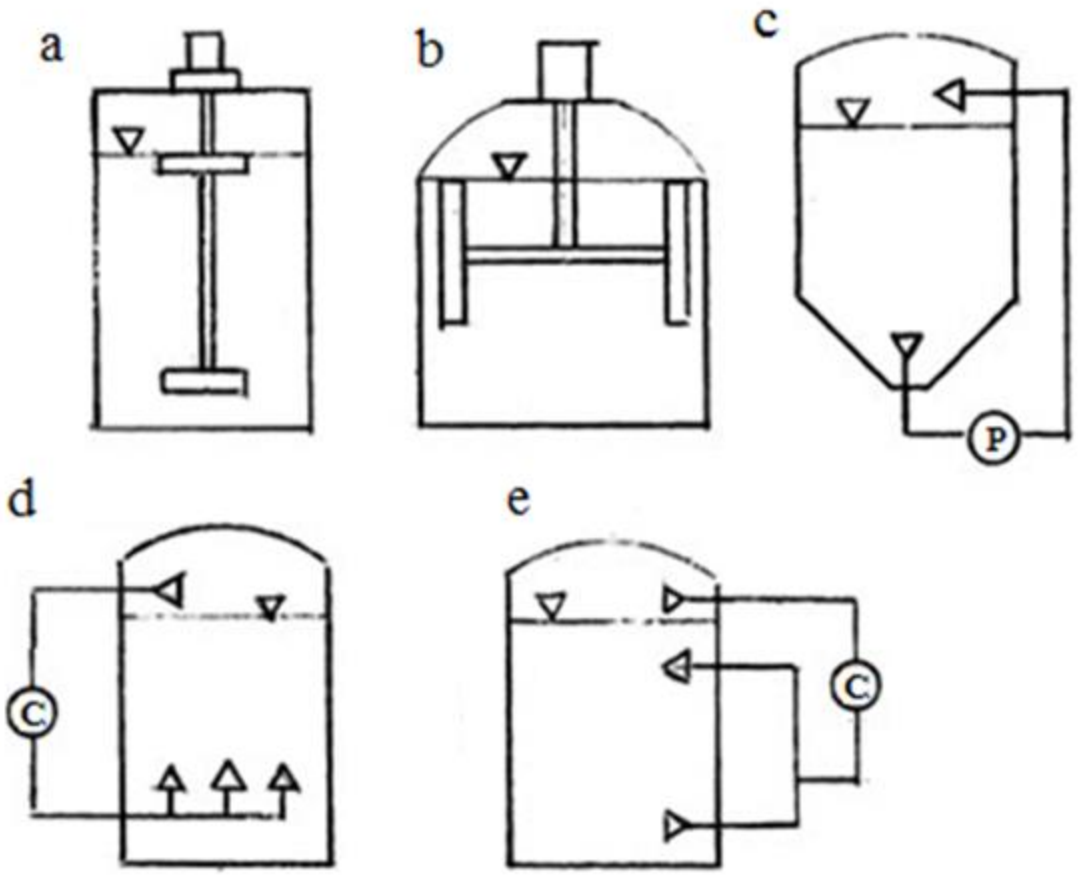
The aim of mixing:

- Compensate of temperature differences in the reactor
- Mixing of bio sludge and raw sludge
- To prevent settling or floating of solid particles

Mixing possibilities:

- With biogas
- Mechanical agitator
- Sludge recirculation

DIGESTERS
Mixing



a. mechanical mixing
b. mechanical mixing
c. pump agitation
d. biogas mixing
e. biogas and liquid mixing

Agitators in digester

Agitators in digester

Giantmix FR SP

Giantmix BG2

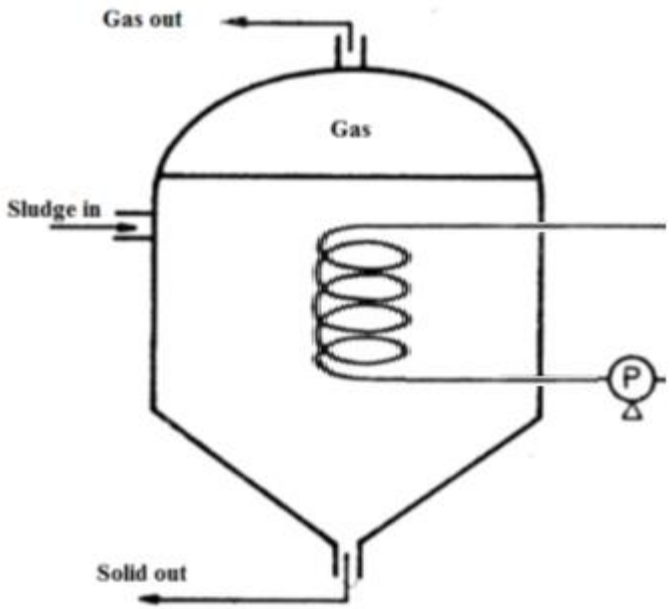
Optimic 2G

Digester agitation by outer pump

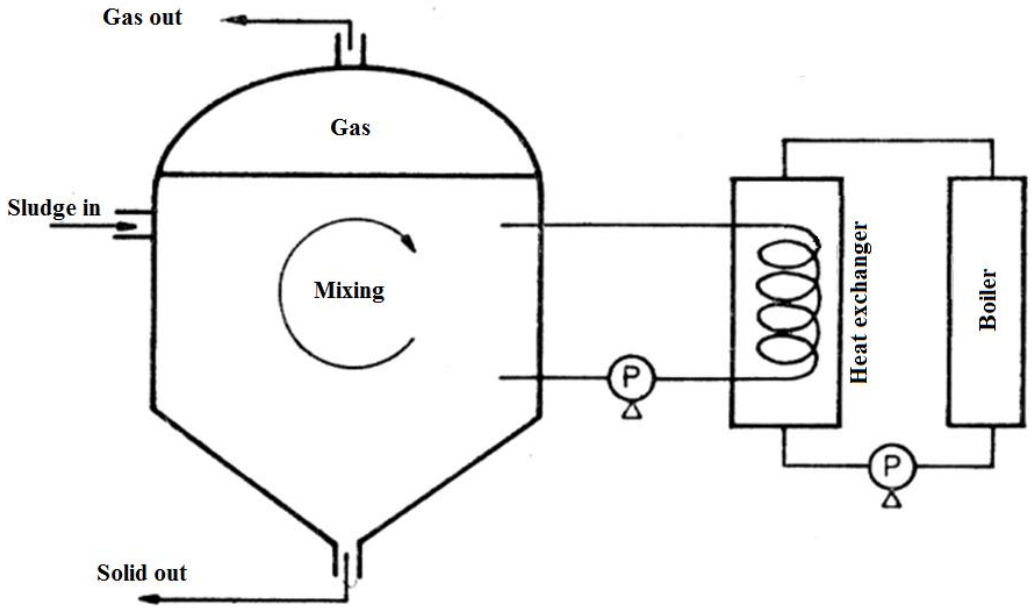
Vaughan Chopper pump

DIGESTER HEATING

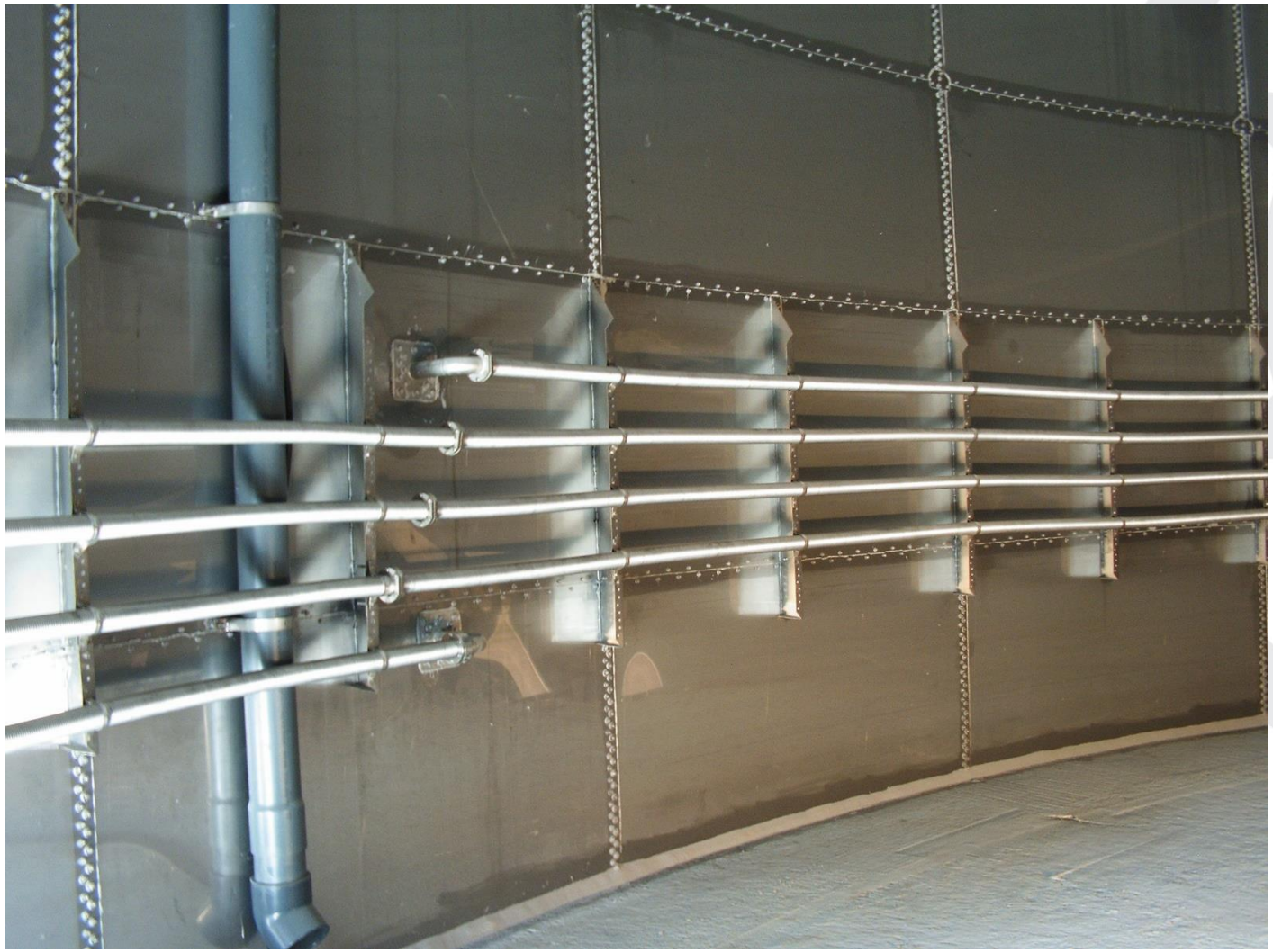
Heating coil



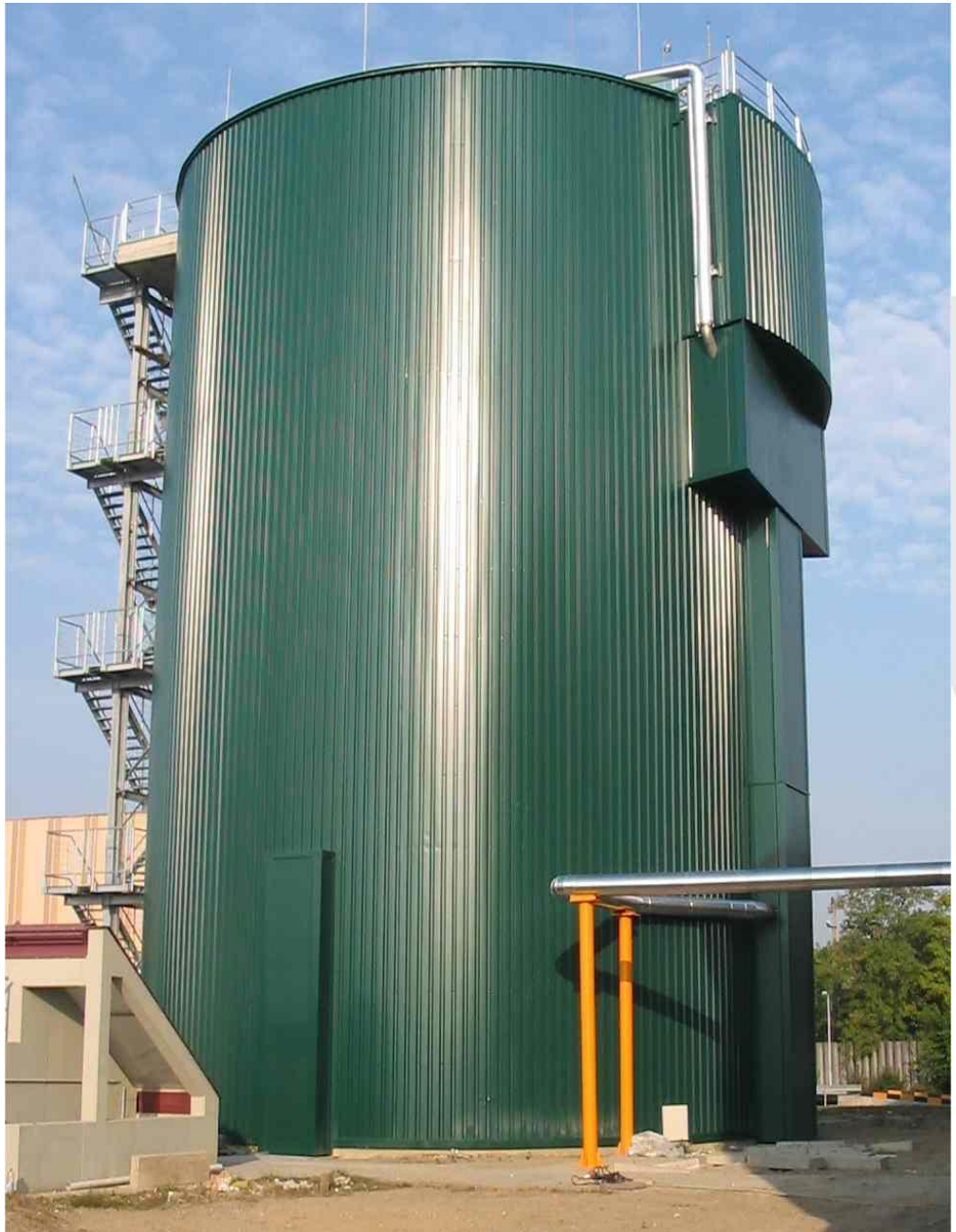
Outside heat exchanger



DIGESTER HEATING
Heating coil



Digesters and gas tanks



Biogas tanks (Budapest)

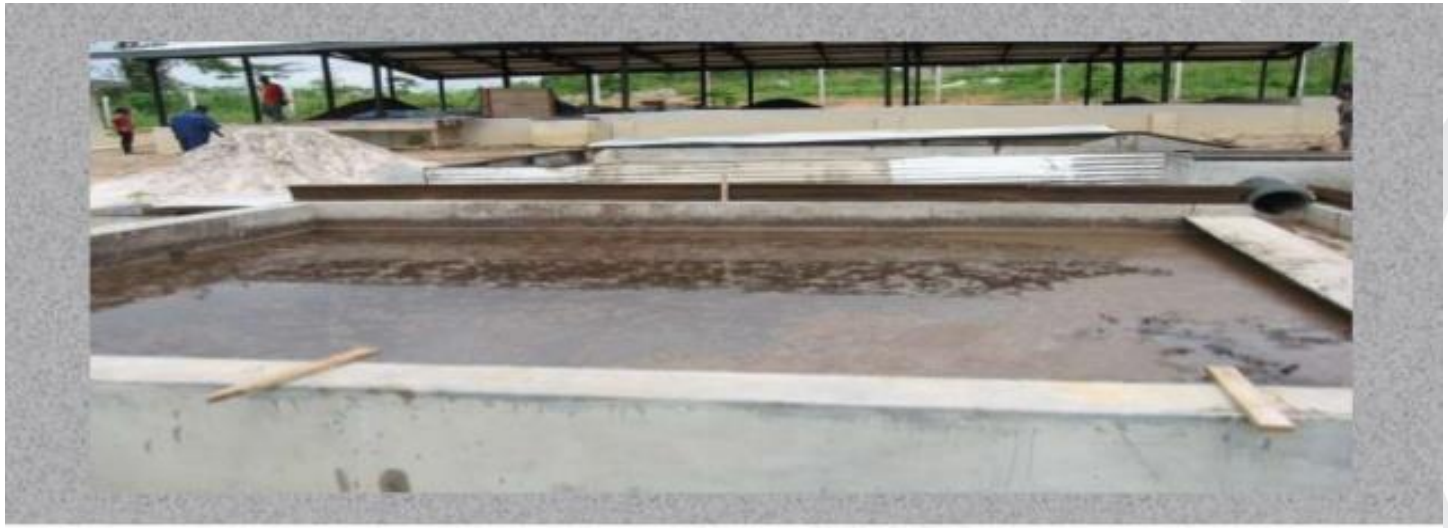
Biogas furnaces

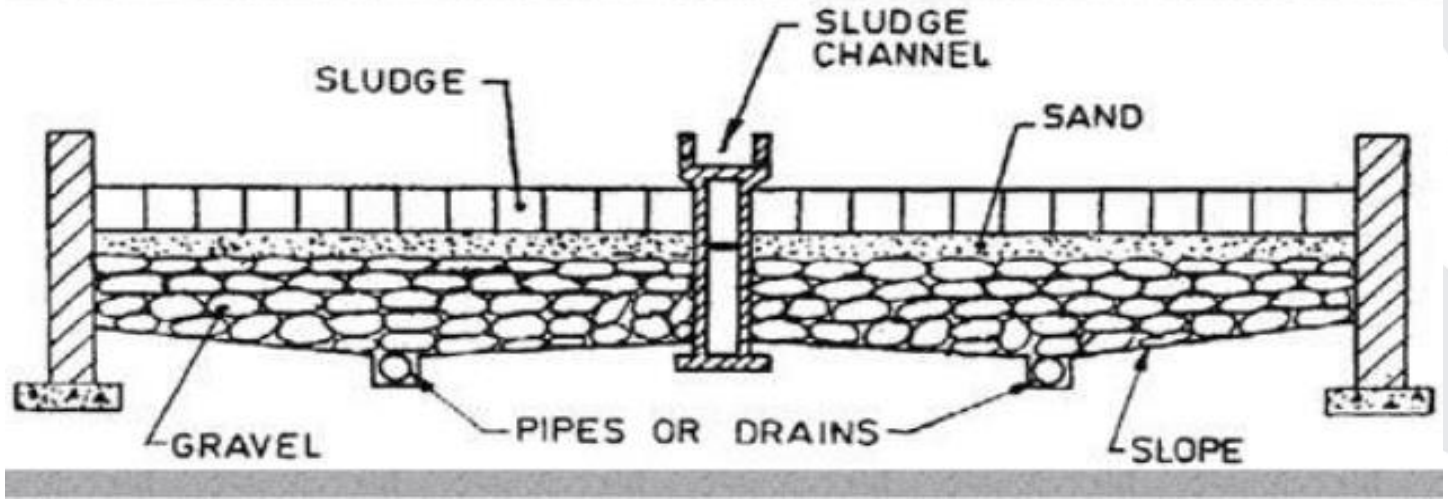
Biogas engine

Sludge dewatering (after conditioning)

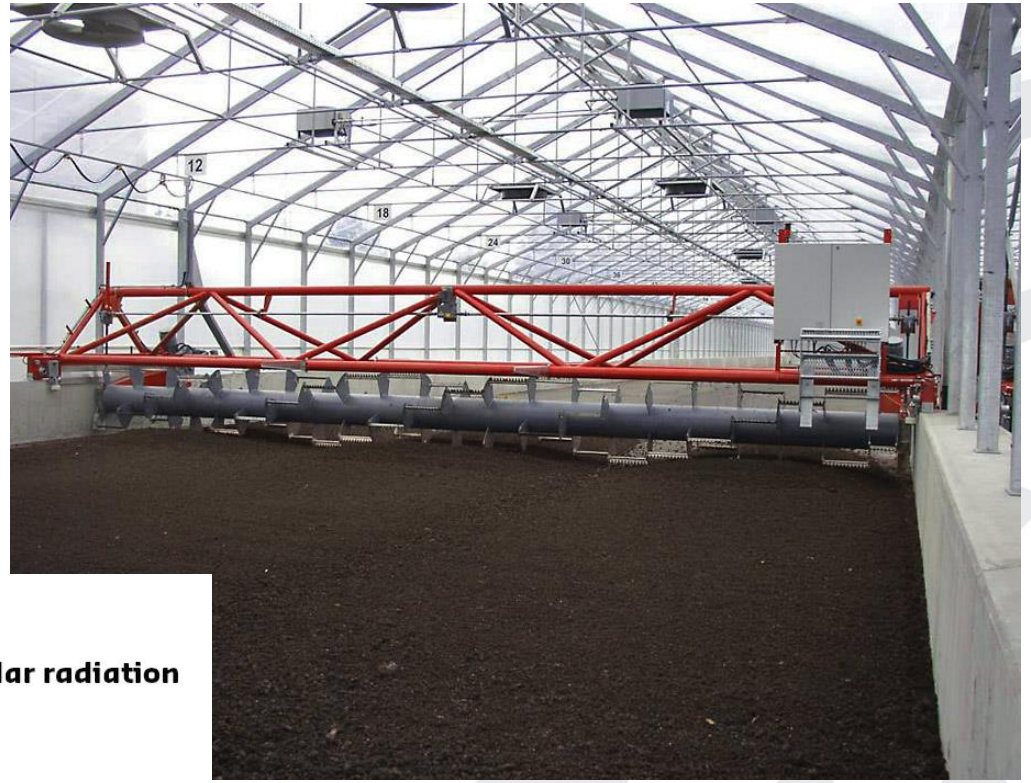
- Filters
- Centrifuges
- Natural dewatering

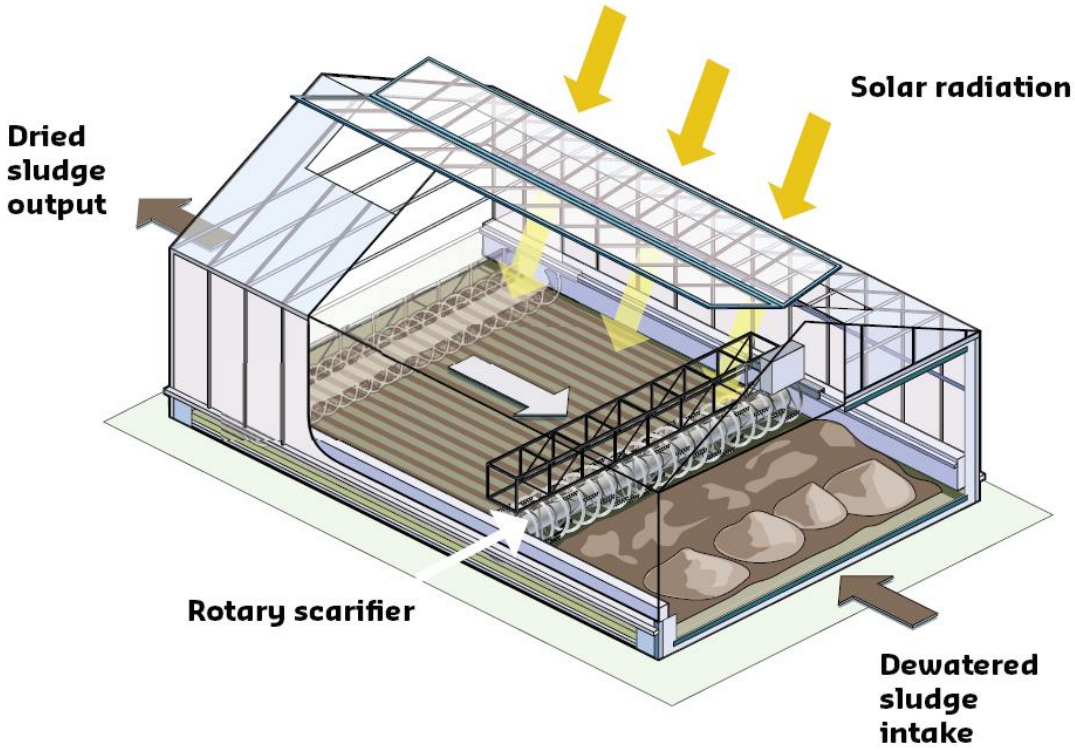
Natural drying of sludge





Solar drying of sewage sludge





Operating principle of solar drying by Heliantis

Continuous drying of sludge

8% ds

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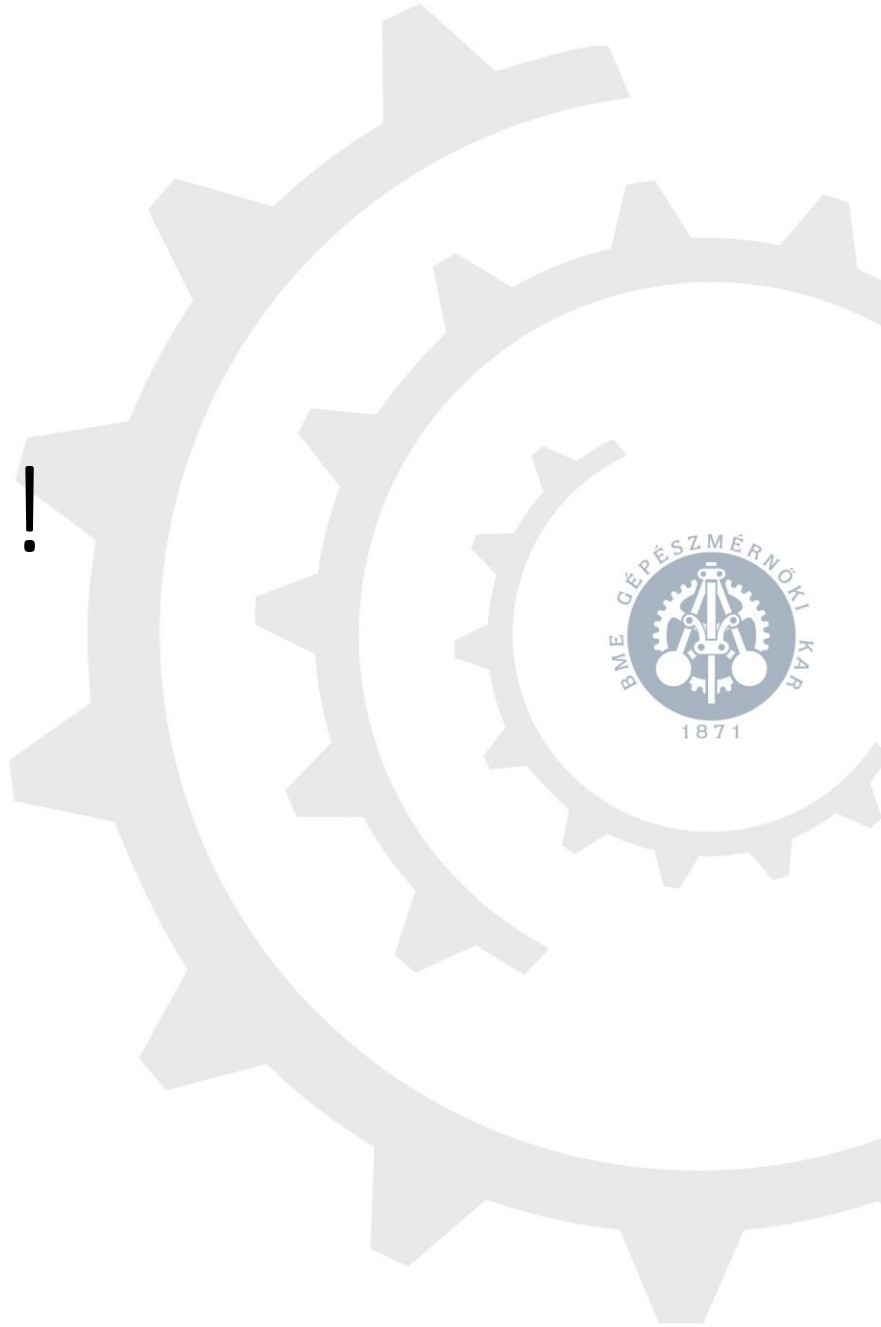
18% ds

23% ds

30 % ds (can be insinerated)

Thank you for your attention!



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