

# Treatment of wastewater solids II: thickening of sludge

Applied wastewater engineering

Michael Jon MATTLE

# Sludge thickening

- solids content of primary sludge, waste activated sludge, or mixed sludge varies considerably
- thickening is a process to increase the solids content of sludge by removing a portion of the liquid fraction
  - reduced storage/treatment capacity required for thickened sludge
  - reduced energy consumption if heating is required during further sludge treatment
  - filtrate/centrate returned to the wastewater treatment train
- achieved by physical means with or without the addition of polymers (flocculants)
- thickened sludge can be handled as a liquid: density  $\approx 1$ 
  - whereas dewatering produces a solid



# Sludge thickening

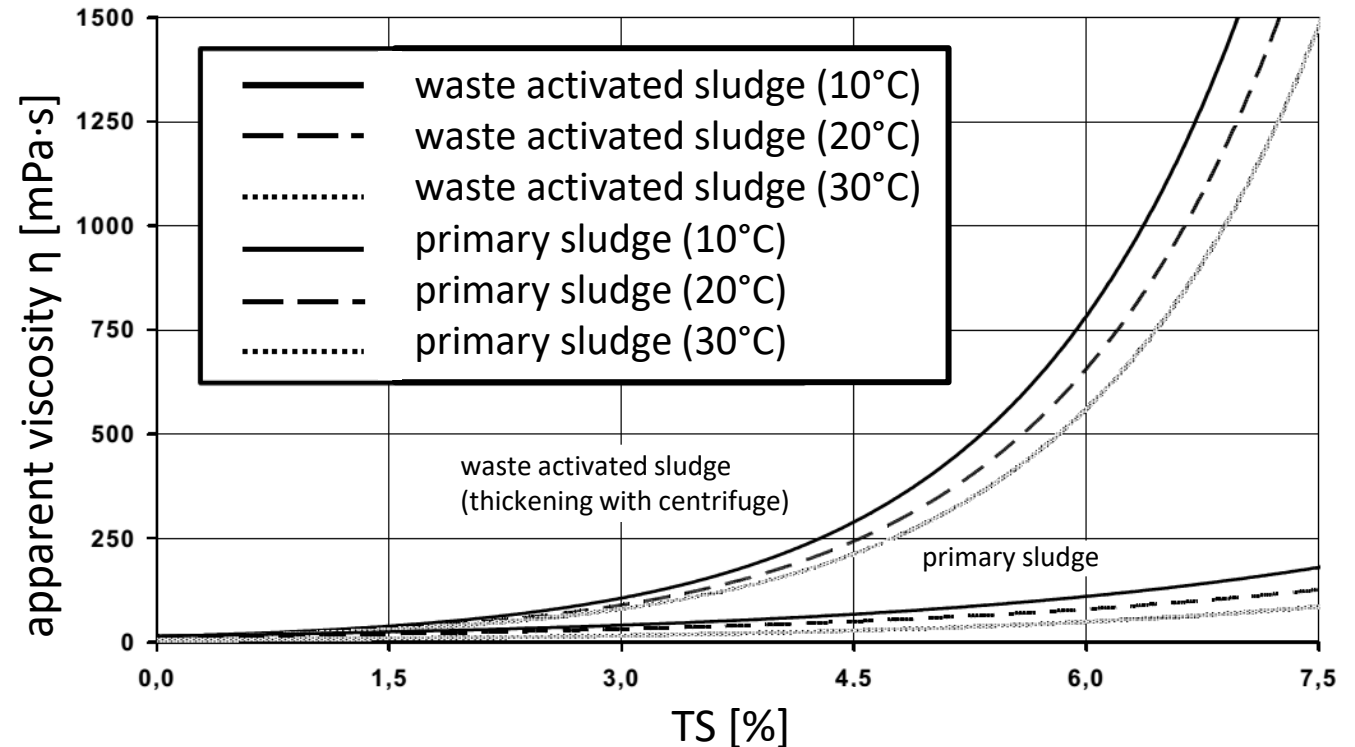
- volume reduction

➔ reduced volumes necessary to treat sludge

- however, viscosity increases with increasing solids content (especially for waste activated sludge)

➔ viscosity has to be low enough to allow pumping, mixing and stabilisation processes

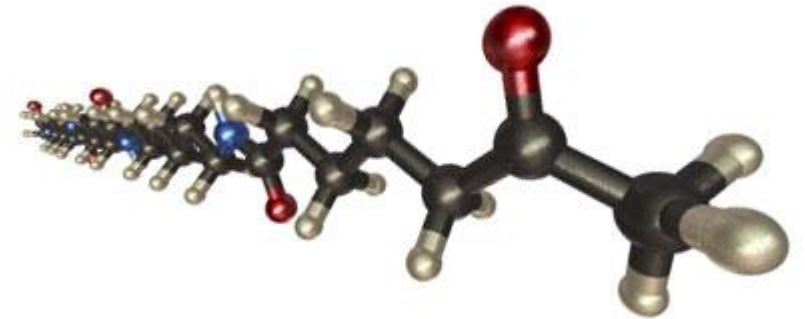
➔ total solids content ideally around 6 %



Bau, K. Schriftenreihe WAR 1986

# Chemical conditioning

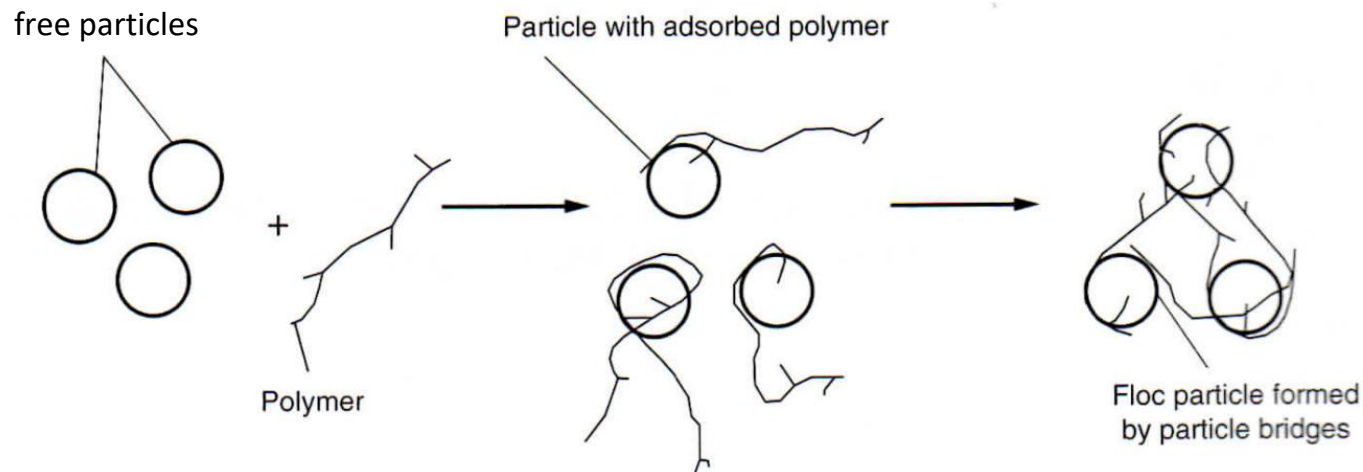
- flocculants help improve solids and water separation
- mostly done using polymers
  - chemical conditioning with inorganic chemicals (e.g. ferric chloride or aluminium chloride) is less frequently used
- type and dosage of polymer depends on
  - properties of sludge
  - mixing conditions
  - thickening or dewatering device used
  - desired final solids content



molecular weight	relative molecular weight
very high	> 6'000'000 – 18'000'000
high	1'000'000 – 6'000'000
medium	200'000 – 1'000'000
low	< 200'000

# Chemical conditioning: addition of polymers

- formation of larger particles
  - charge neutralisation: polymers act as coagulants that neutralise or lower the charge of the particles (cationic, anionic or non-ionic polymers)
  - polymer bridge formation: a bridge is formed when more than one particle adsorbs on the same polymer



➔ most wastewater treatment plants use polymers for improved solid - water separation, especially for dewatering of sludge but also for mechanical thickening

# Chemical conditioning: addition of polymers

- polymers can be purchased as solids or already in liquid form

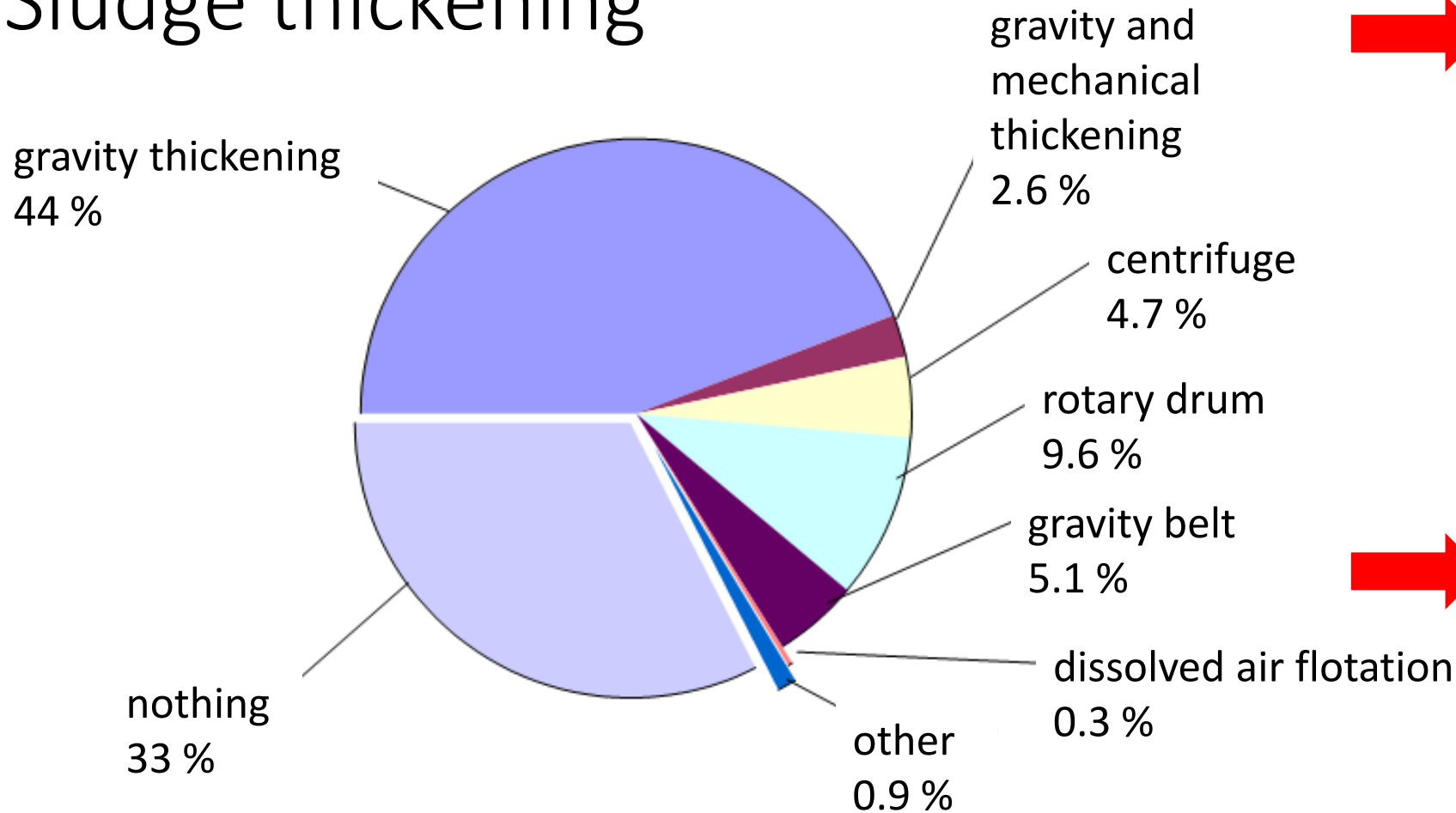
state	product	description
solid	powder, granules	polymer content 95 %
liquid	emulsion (contains water and oil)	polymer content 25 % to 50 % rest: water, oil and emulsifier
	dispersion (contains oil and little water)	polymer content up to 50 % rest: mainly oil, water (less than 10 %) and stabilisers

➔ a maturation period of at least 45 minutes is needed once the polymer product is mixed with dilution water

➔ matured polymer solution should be used ideally within 4 to 6 hours but at least within 24 hours



# Sludge thickening



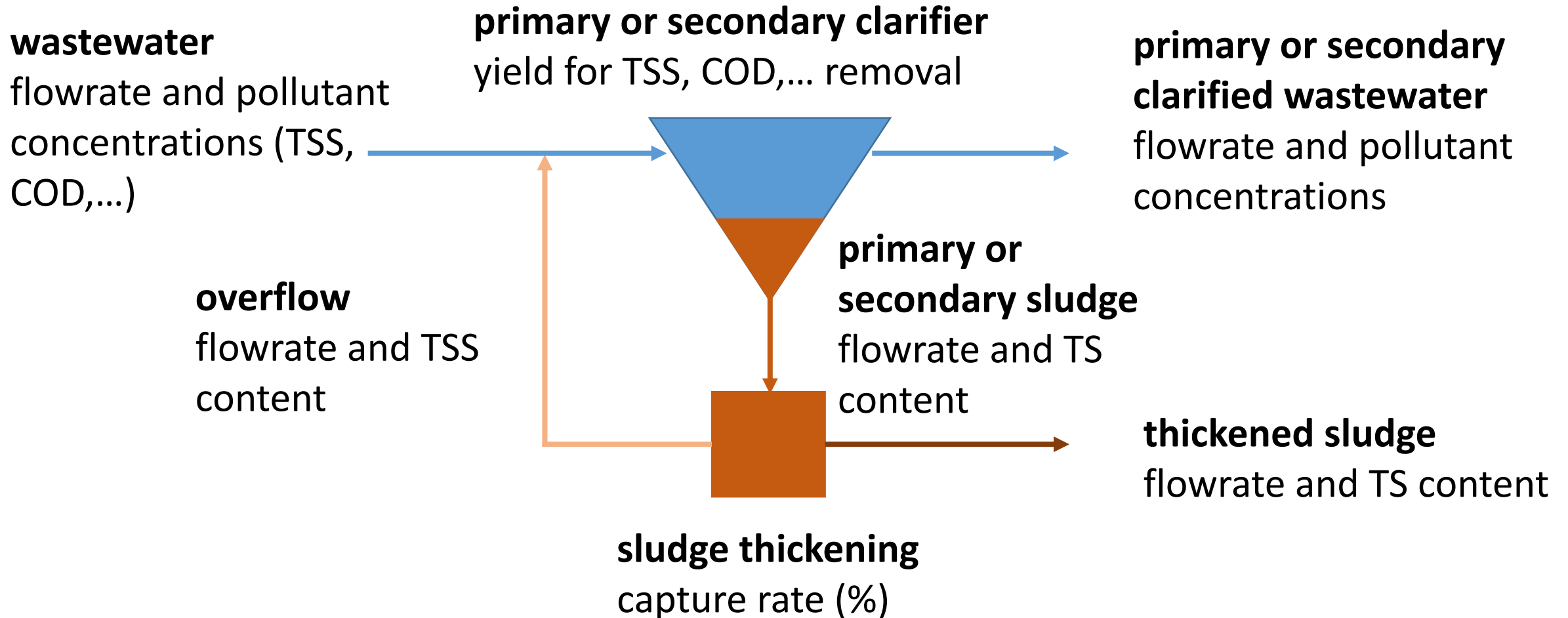
the proportion of mechanical thickening is higher in Switzerland (e.g. gravity belt thickening)



however, gravity thickening is very rare

statistical analysis of waste active sludge thickening in Germany 2003 (DWA)

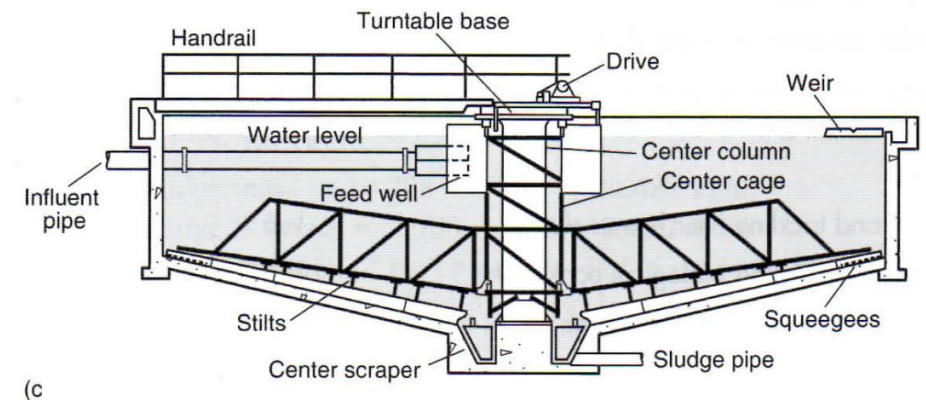
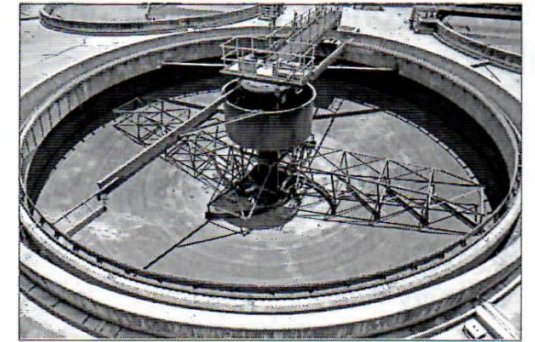
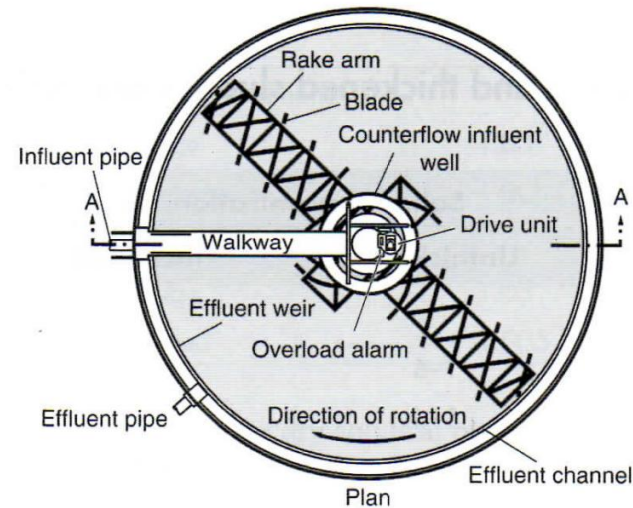
# Sludge thickening



**→ this is a dynamic system!**

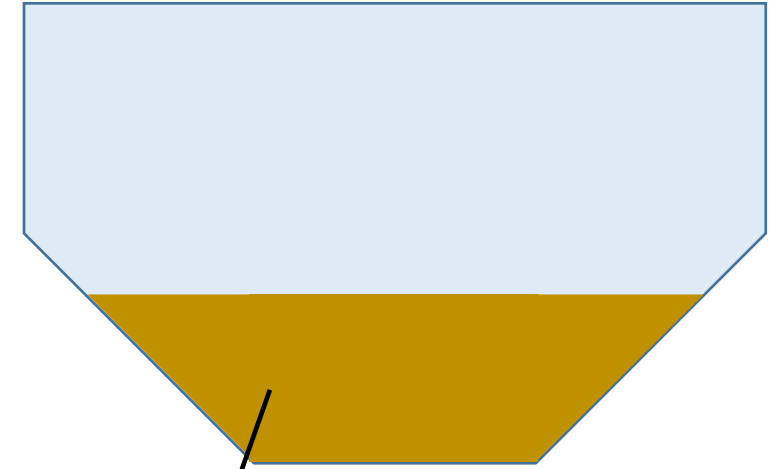
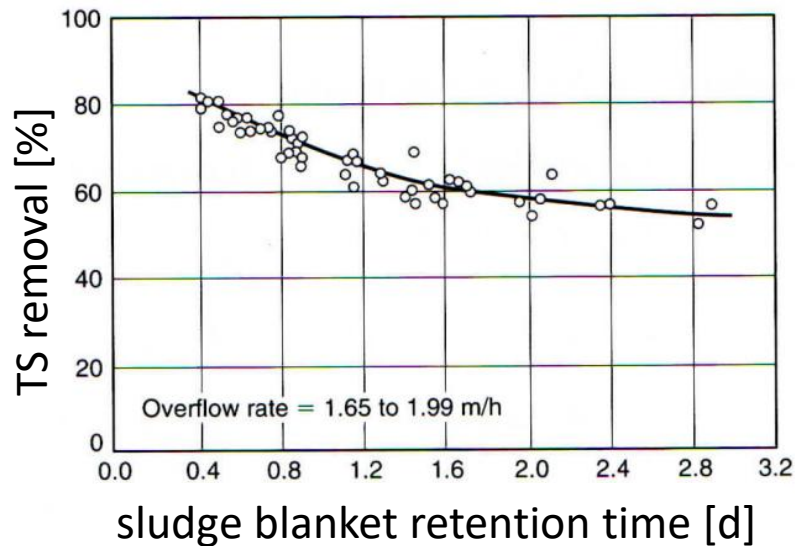
# Gravity thickening

- natural gravity force separates sludge particles (heavier than water) from water
- relatively simple process
  - sludge blanket at the bottom
  - sludge gently stirred which allows water to escape and sludge densification
  - supernatant removed and generally pumped back to the primary settling tank



# Gravity thickening

- 'competition' between:
- capture rate (%) : quantity of solids in thickened sludge (kg TS) divided by quantity of solids in unthickening sludge (kg TS)·100%
- solids content of thickened sludge



sludge blanket: the thicker (higher sludge retention time), the higher the solids content of the thickened sludge, but also of the supernatant

# Typical design parameters for gravity thickening

- solids loading rate:

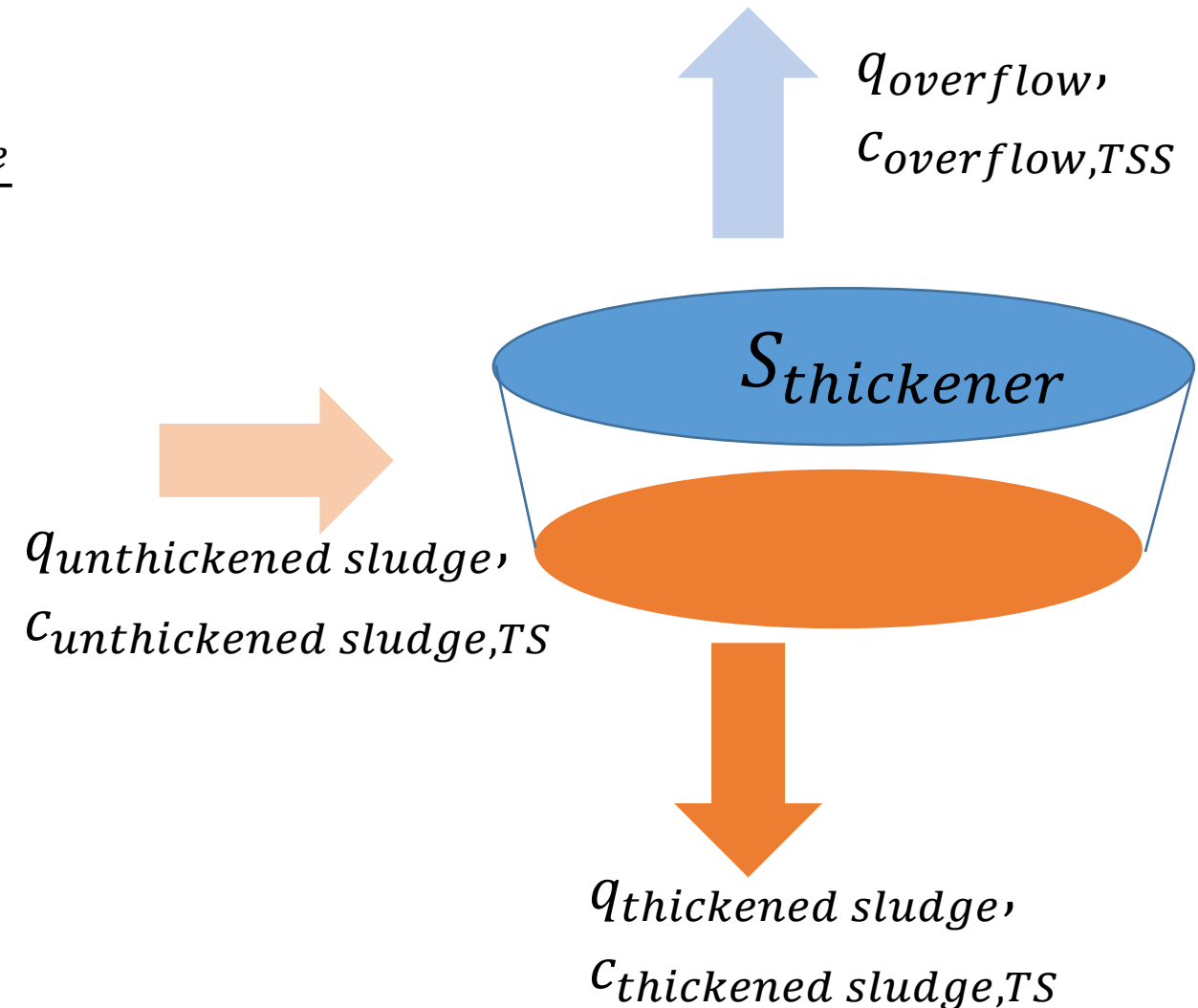
$$= \frac{Q_{unthickened\ sludge} \cdot C_{unthickened\ sludge}}{S_{thickener}}$$

$$= \frac{m^3/d \cdot kgTS/m^3}{m^2} = \frac{kgTS/d}{m^2}$$

- overflow rate:

$$= \frac{Q_{overflow}}{S_{thickener}}$$

$$= \frac{m^3/d}{m^2} = \frac{m}{d}$$



# Typical design parameters for gravity thickening

sludge sedimentation characteristics	sludge type	solids loading rate	maximum hydraulic overflow	solids concentration, % TS [kg TS/kg]	
		[kg TS/m <sup>2</sup> ·d]	[m <sup>3</sup> /m <sup>2</sup> ·d]	unthickened	thickened
bad	waste activated sludge	20 -50	4 - 8	0.5 – 1.5	2 – 3
intermediate	primary and waste activated sludge digested sludge	40 – 80	6 - 12	0.5 – 4	2 - 7
good	primary sludge	up to 100	15 – 31	1 – 6	3 - 10

# Gravity thickener overloaded

- What would you suggest if your gravity thickener is overloaded (too high loading rate and overflow rate) ?
  - A) I would try to extract more concentrated sludge from the primary or secondary clarifier
  - B) I would try to extract more diluted sludge from the primary or secondary clarifier
  - C) I would decrease the sludge extraction from the gravity thickener
  - D) I would increase the sludge extraction from the gravity thickener


<https://web.speakup.info/room/join/81979>



# Gravity thickening

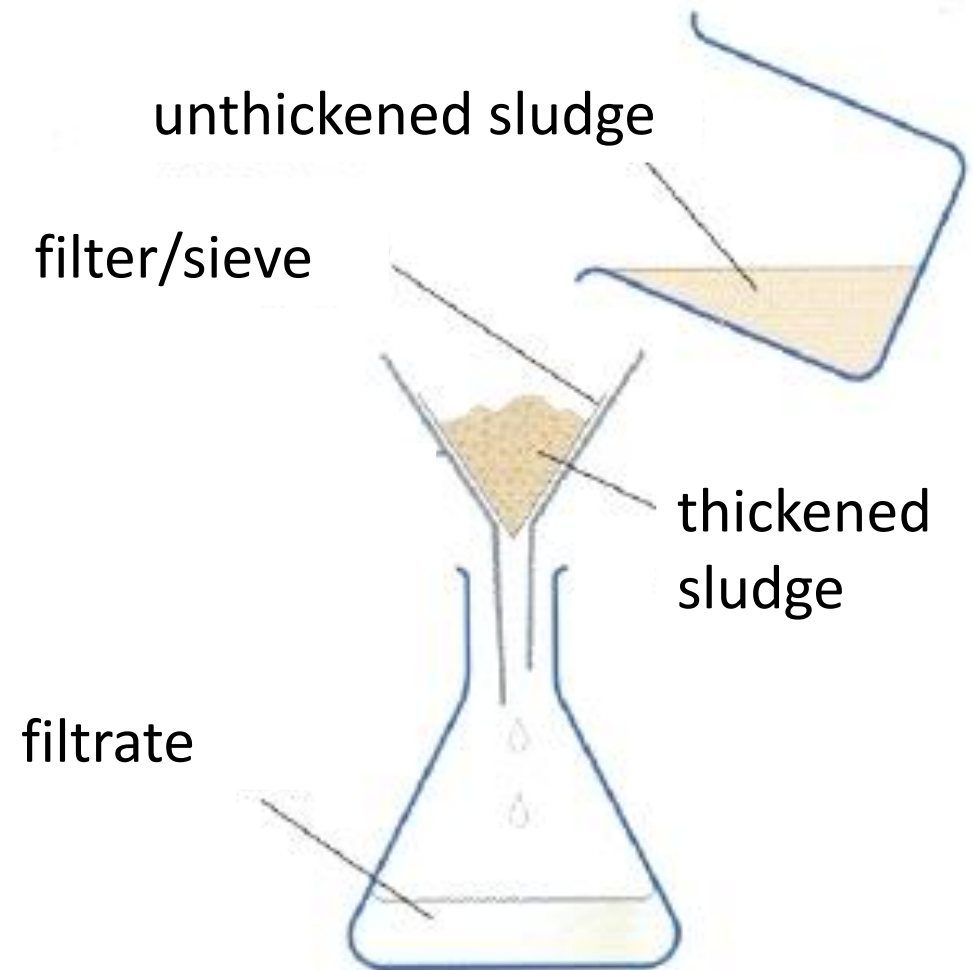
- process not very stable and reproducible (important variations in final dry solid content → very rarely used in Switzerland but still common abroad)
  - heat fluxes and digestion can occur, these processes may disturb good settling
    - retention time of unstabilised sludge should be below 1.5 days
    - occasional chlorine addition
    - addition of dilution water (maintain aerobic conditions)

 conduct pilot-testing if possible to determine design criteria

 mechanical sludge thickening is a more stable and reproducible process

# Mechanical thickening using natural gravity force

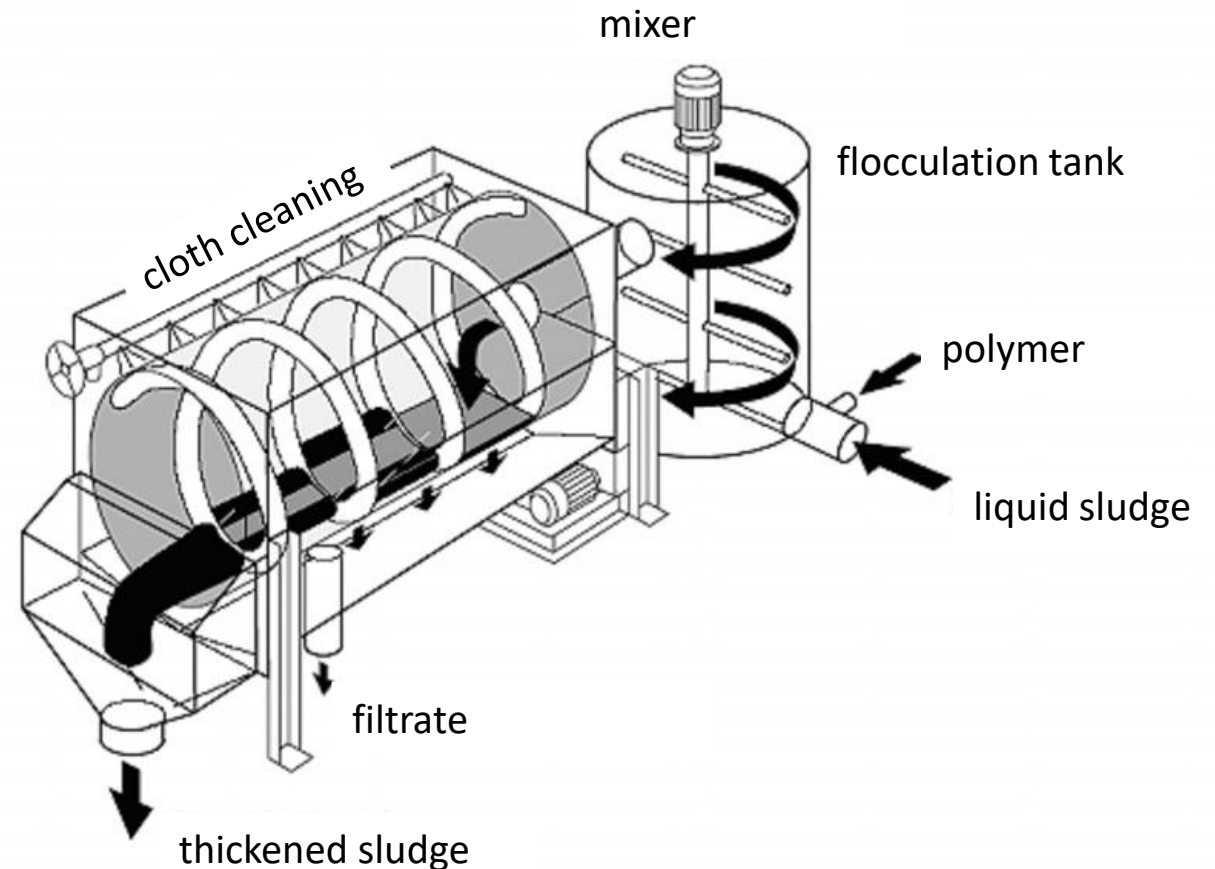
- physical separation of sludge and water by filtering/sieving
- natural gravity forces used for thickening
- several types of instruments based on same principles
- addition of polymers required to produce sludge flocks



# Mechanical thickening using natural gravity force

## rotary drum thickening

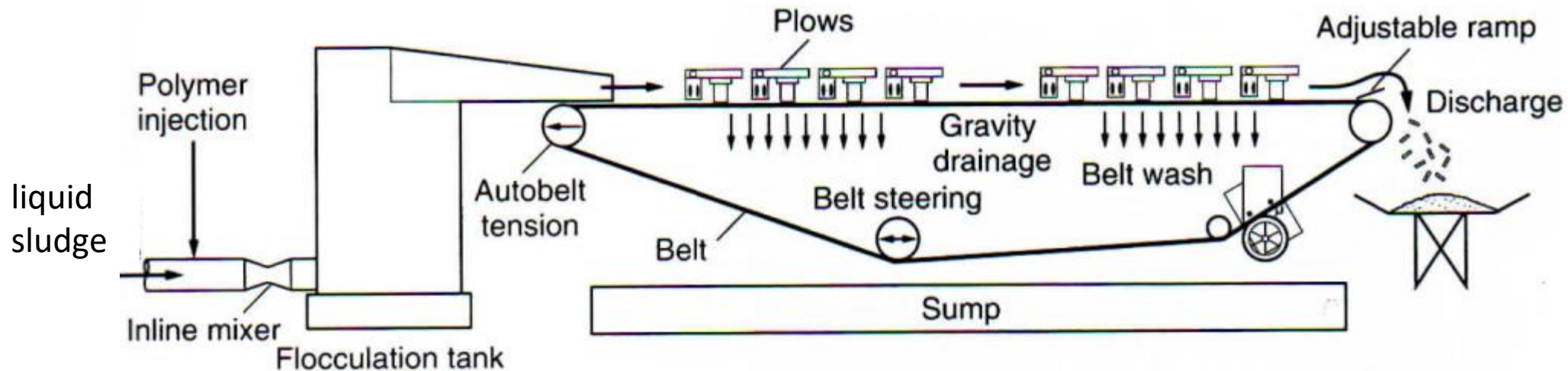
- cloth/screen retains sludge but allows water to pass (filtrate)
- rotation of drum moves sludge forward
- rotation of drum mixes sludge and improves thickening (water removal)
- cloth clogging is prevented by spraying water on it



# Mechanical thickening using natural gravity force

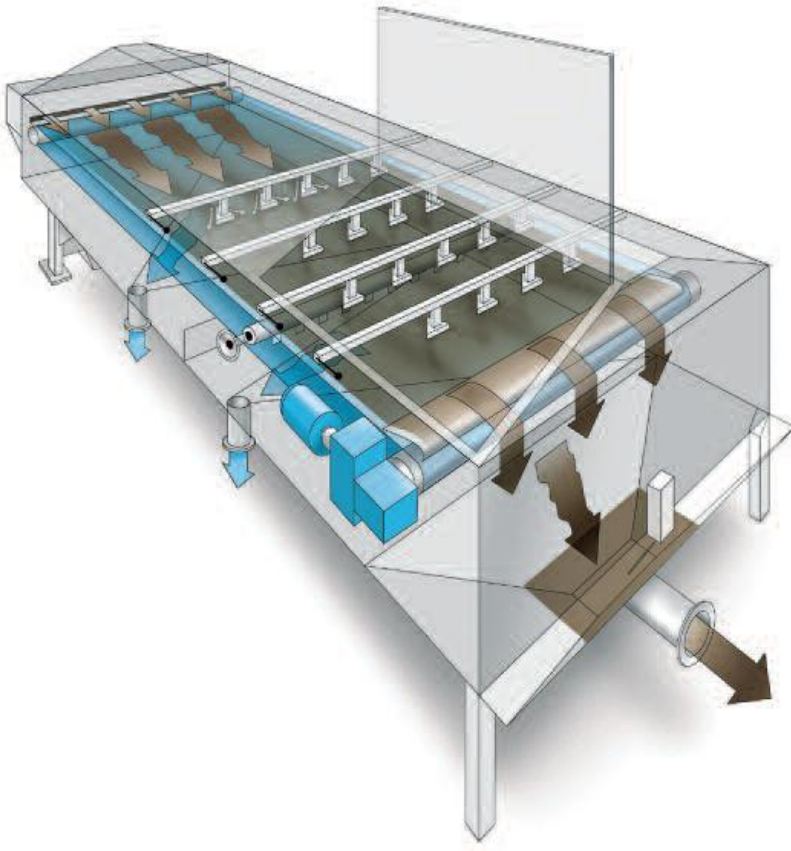
## gravity-belt thickening

- belt retains sludge but allows water to pass through
- 'fixed' plows move sludge around to improve the thickening process
- belt is washed in the lower part



# Mechanical thickening using natural gravity force

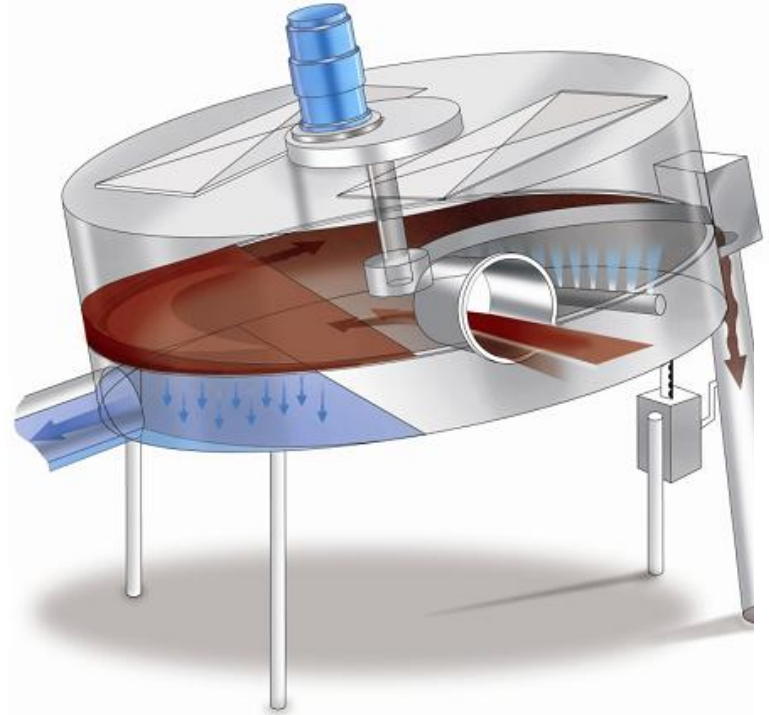
- hydraulic loading rates for gravity-belt thickeners (influent sludge at 0.5 – 1 %)



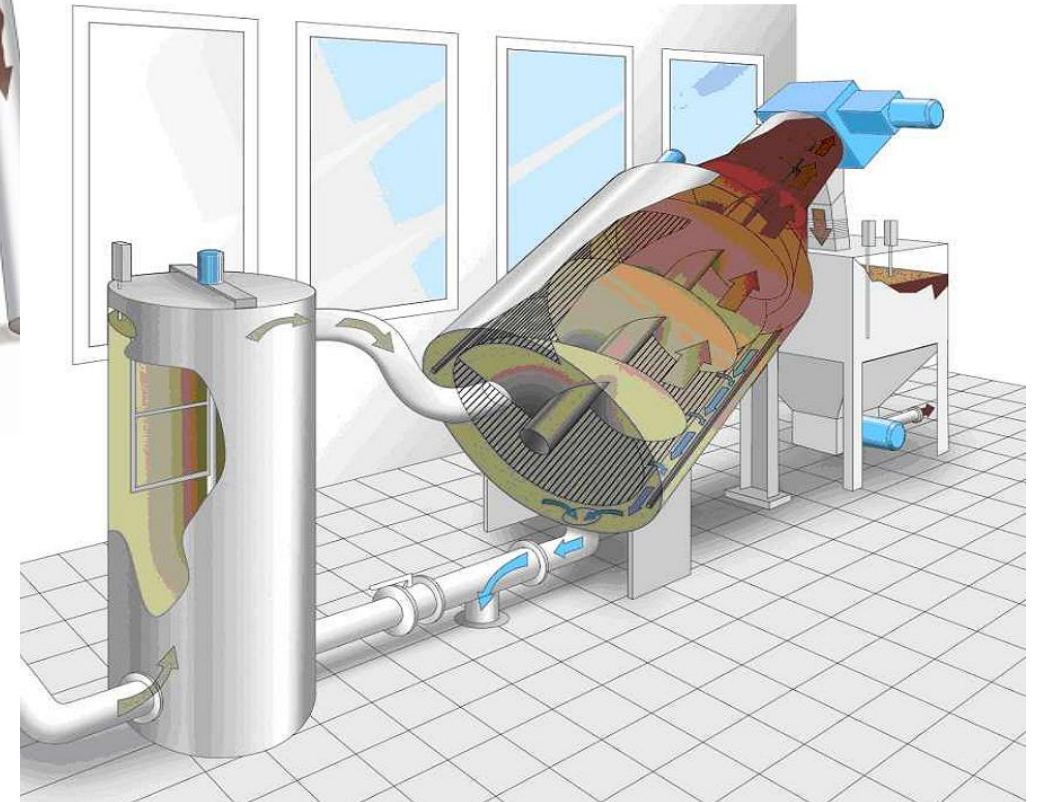
belt size (effective dewatering width)	hydraulic loading range
[m]	[l/s]
1.0	6.7 – 16
1.5	9.6 – 24
2.0	12.7 – 32
3.0	18 - 47

# Mechanical thickening using natural gravity force

- disc thickener

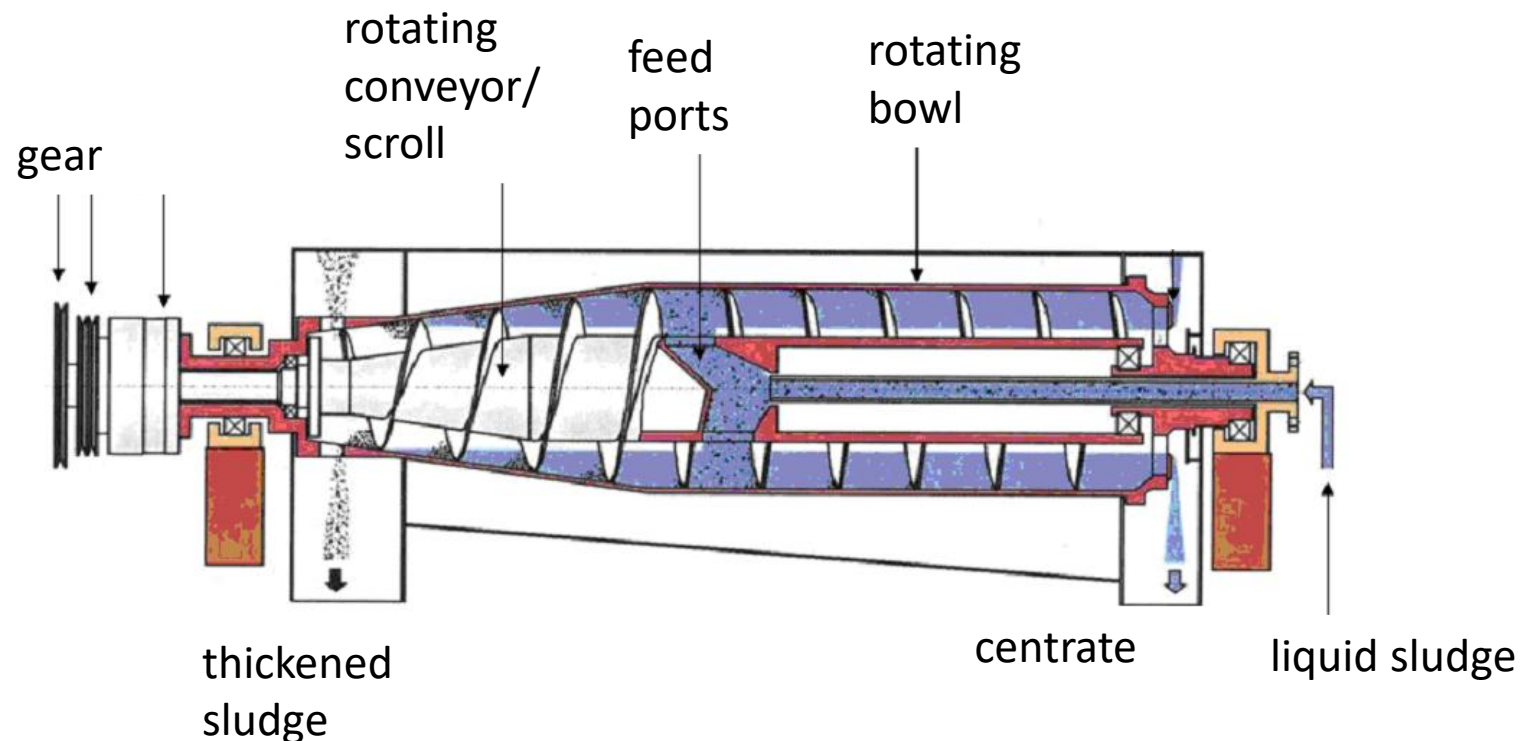


- screw thickener



# Centrifugal thickening (artificial gravity force)

- centrifugal thickening creates an artificial gravity field to separate sludge and water more efficiently
- solids concentrate on the periphery due to rotation of bowl
- a helical scroll (rotation at different speed) moves accumulated sludge toward tapered end (cone)
- additional solids thickening in the cone
- additional solids thickening in the cone

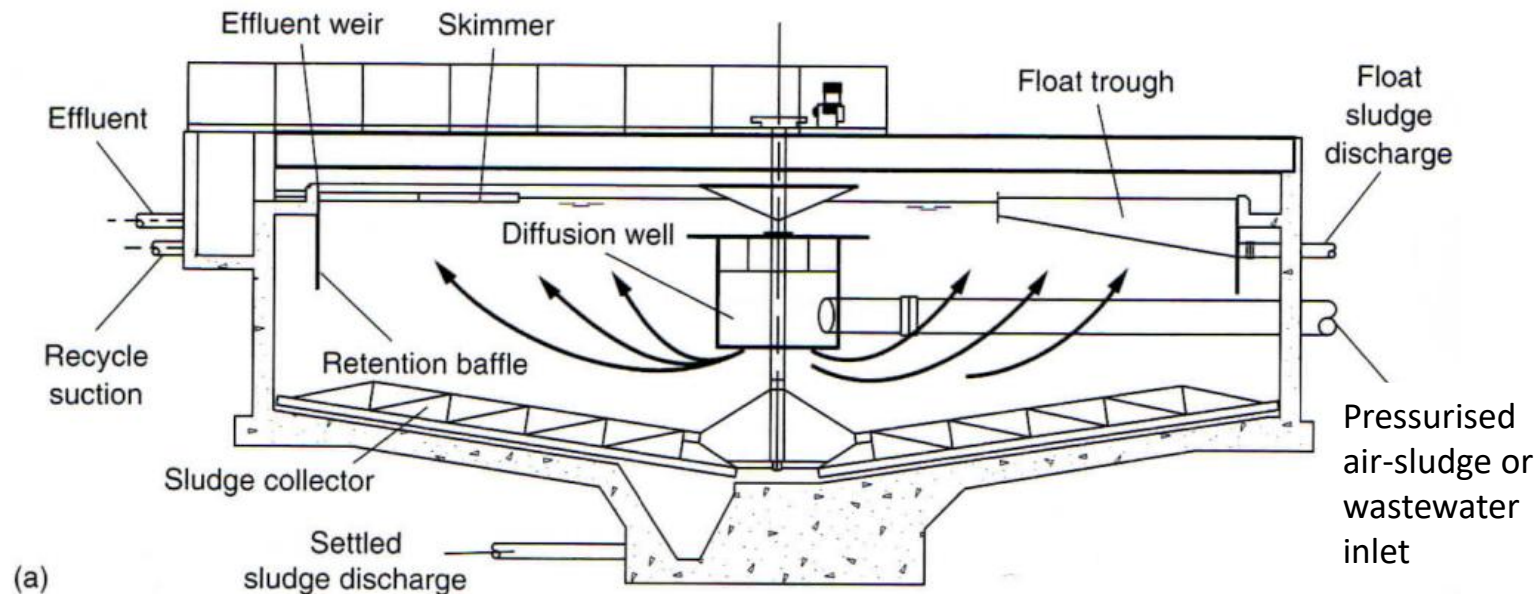


# Centrifugal thickening (artificial gravity force)

- polymers may be employed but are not needed for thickening
- maintenance and revision investments are generally high
- power costs may be substantial
- only employed in larger facilities
  - limited space requirements
  - skilled operators available
- centrifuges can be used to thicken and dewater sludge at the same time

# Flotation thickening

- air introduced to sludge under elevated pressure before entering flotation unit
- fine air bubbles form when solution is depressurised (once in flotation unit) and move sludge to the top
- sludge is removed at the surface (skimmer) and at the bottom (sludge collector)



# Flotation thickening

- smaller than gravity thickeners (higher surface loading rates)
- capture rate improved when using polymer (from 85 to 98 or 99 %)

type of sludge	surface loading rate [kg/m <sup>2</sup> ·h]	
	without chemicals	with polymers
mixed liquor (no clarification) waste activated sludge	1.2 – 3	up to 10
settled waste activated sludge	2.4 – 4	up to 10
primary and waste activated sludge	3 – 6	up to 10
primary sludge only	4 – 4	up to 12

# Summary of sludge thickening

		gravity thickening		flotation	mechanical thickening	
		without polymers	with polymers		using natural gravity force	centrifuge
primary sludge	% TS [kg TS/kg]	5 – 10	-			
mixed sludge	% TS [kg TS/kg]	4 – 6	5 – 8		5 – 8	5 – 8
waste activated sludge	% TS [kg TS/kg]	2 – 3	3 – 4	3 – 5	5 – 7	5 – 8
polymer use	kg/t TS	0	0.5 – 3	0	3 – 7	0 – 1.5
specific energy use	kWh/m <sup>3</sup>	< 0.1	< 0.1	0.6 – 1.2	< 0.2	1 – 1.4
specific energy use	kWh/t TS	< 20	< 20	100 – 140	< 30	180 – 220

- flotation and centrifugal thickening consume substantially more energy than other thickening methods
- capture rates 85 – 92 % without polymer use and 92 – 96 % with polymer use
- solids content of approximately 6 % are ideal for digestion
- density of thickened sludge (6 %)  $\approx 1$

# Economical comparison

- costs calculated (DWA) for waste activated sludge thickening for a wastewater treatment plant with 100'000 population equivalents (PE)
- cost of further treatment (e.g. digestion) or transport were taken into account for comparison

