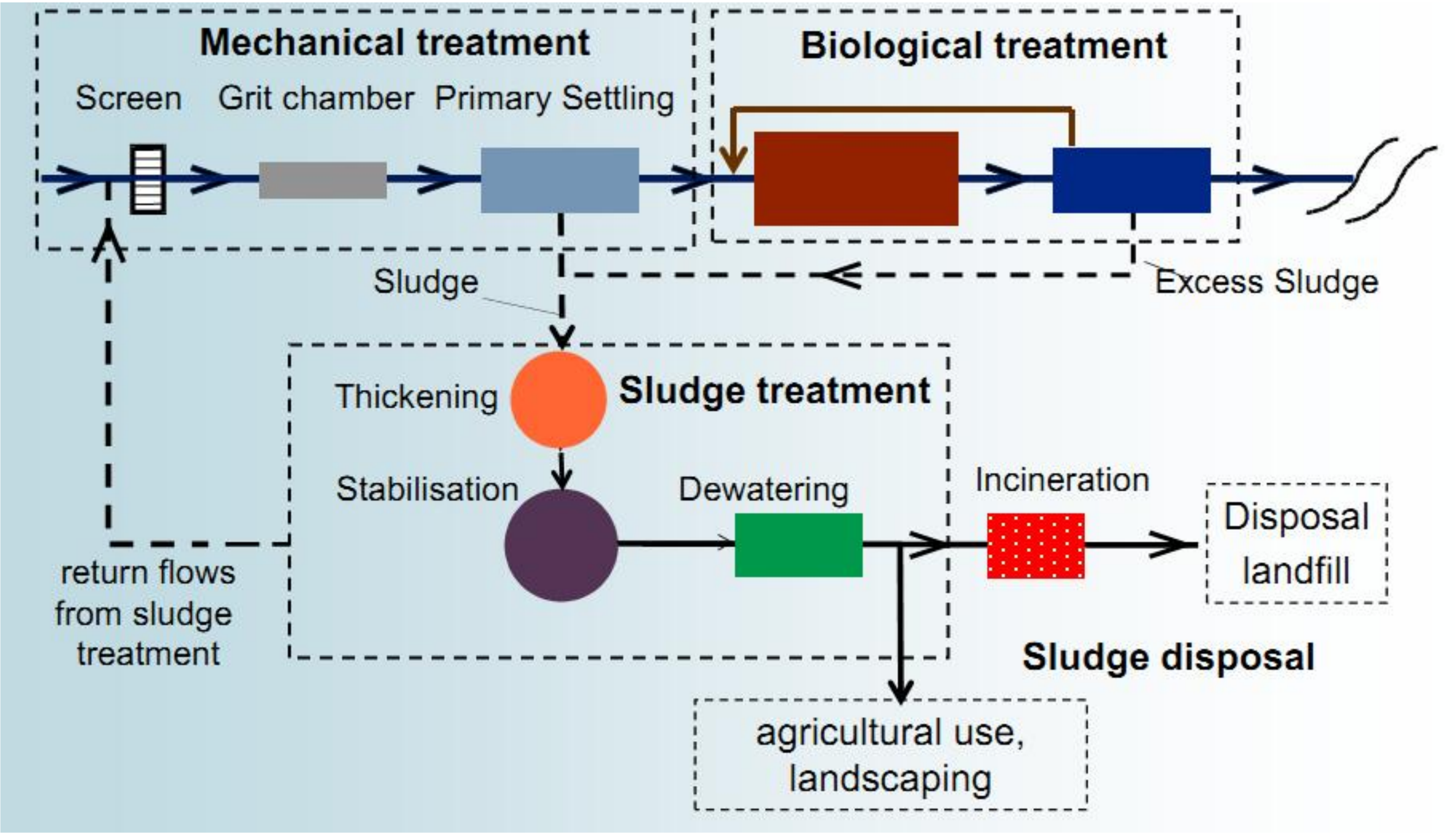
Lecture 18

Sludge treatment

Conventional wastewater treatment plant configuration



[DEX Summer School, 2011]

Types of sludge

Types of sludge	Sewage sludge	Water-containing and seperable substances from wastewater (except screenings, sievings and sands)
according to their source	Preliminary sludge	Sludge, that is separated solely from the water which runs into the sewage plant during the first part of the cleaning process (mechanical wastewater treatment) by physical method
	Secondary sludge	Sludge, that is separated during the second part of the cleaning process (biological wastewater treatment), e.g. excess sludge, trickling filter sludge
	Tertiary sludge	Sludge from the third step of the cleaning process (e.g. precipitation, fining pond)
	Mixed sludge	Mixture of primary and secondary sludge, the common form of occurrence of sludge in the local sewage plants
according to their development	Primary sludge	Sludge, that is removed from the primary sedimentation tank. This sludge could retain different sludge types besides the primary sludge, due to the used technique
	Excess sludge	Increase of active sludge, that develops during the biological process, which has to be removed
	Trickling filter sludge	Increase of biological sludge, that develops during trickling filter process, is normally removed during the final purification
	Precipitation sludge	Sludge from the precipitation and/or flocculation
according to their stability	Raw sludge	Untreated sludge
	Stabilized sludge	Sludge, whose treatment achieves at least one of the two main aims of stabilization (advanced reduction of odorous substances and organic solid sludge material)
	Digested sludge (anaerobic stabilized sludge)	Sludge, that is stabilized through digestion to the technical digestion limit

Amount of sludge per inhabitant [g DS/(I·d)]

Primary sludge

1. **According to Imhoff:**

   Specific primary sludge = 45 g DS/(I·d)

   DS = Dry solids [kg/(I·d)]: Mass of dried solids in sludge
   I = Inhabitant

2. **According to ATV A131:**

   The amount of primary sludge depends on the detention time in the primary treatment.

Amount of sludge per inhabitant [g DS/(I·d)]

Excess sludge after the primary treatment (without precipitation)

1. **According to Imhoff:**

   ES_C = 25 g DS/(I·d)

2. **According to ATV A131:**

   ES, according to the following equation and table, depends on:

   - X_{DS}/C_{BOD} (small X_{DS} → small ES)
   - Sludge age (high SRT → small ES)
   - Temperature (10 °C higher → 10% less ES)

$$ES_C = \underbrace{0.75}_{\text{detached growth}} + \underbrace{0.6 \cdot \frac{X_{DS}}{C_{BOD}}}_{\text{from DS}} - \underbrace{\frac{(1-0.2) \cdot 0.17 \cdot 0.75 \cdot SRT \cdot F_T}{1+0.17 \cdot SRT \cdot F_T}}_{\text{dying}} \left[\frac{\text{kg DS}}{\text{kg BOD}}\right]$$

with: $F_T = 1.072^{(T-15)}$

Amount of sludge per inhabitant (g DS/I·d)

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Precipitation sludge (simultaneous precipitation with preliminary treatment; Excess sludge production from phosphorus removal) ES_P

1. According to Imhoff:

ES_P = 15 g DS/(I·d)

2. According to ATV A131:

specific ES_P depends on:

- amount of P that is necessary for cytogenesis is about 25% (it doesn't need to be precipitated)
- precipitant (Fe, Al, sodium aluminate, etc.) e.g. amount of sludge = 2.5 g DS/g Fe
- β-value = mostly 1.5 [mol Fe /mol P]

$$ES_P = (1-0.25)\cdot\left(1.6\,\frac{gP}{I\cdot d}\cdot 1.5\,\frac{molFe}{molP}\cdot\frac{56\,\frac{gFe}{molFe}}{31\,\frac{gP}{molP}}\cdot 2{,}5\,\frac{gDS}{gFe}\right)\approx 11.0\left[\frac{gDS}{I\cdot d}\right]$$

Amount of sludge per inhabitant (g DS/I·d)

Total amount of raw sludge (with preliminary and precipitation treatments)

1. **According to Imhoff:**

   specific RS = 45 + 25 + 15 = <u>85 g DS/(I ·d)</u>

2. **According to ATV A131 based on the example of:**

   specific RS = 45 + 32 + 11 = <u>88 g DS/(I ·d)</u>

Amount of sludge per inhabitant (g DS/I·d)

Total amount of stabilized sludge = amount of sludge to be depolluted

Raw sludge consists of:

- ca. 70% organic material
- ca. 30% mineral material

The organic percentage can be reduced by stabilization (e.g. digestion). The reduction mainly depends on the detention time and temperature. These are about 50% of the organic share, the mineral portion remains the same.

Total amount of stabilized sludge per inhabitant per day:

= 88 g DS/(I·d) · ((0.3 · 1) + (0.7 · 0.5)) <u>= 57 g DS/(I·d)</u>

Amount of sludge per inhabitant (g DS/I·d)

Excess (surplus) sludge without primary treatment (without precipitation)

1. According to Imhoff:

ES_C = 70 - 80 g DS/(I·d)

2. according to ATV A131

e.g.:

X_{DS}/C_{BOD} = 70 g/60 g; SRT = 10 d; t = 10° C

$ES_{C,BOD}$ = 1.07 kg DS/kg BOD · 60 g = 64 g DS/(I·d)

Chemical consistence of sludge

Parameter	Percentage	
Carbon (TOC)	43	% TR
Oxygen	22-25	% TR
Nitrogen	4-10	% TR
Hydrogen	6	% TR
Aluminium		% TR
Phosphorus	2	% TR
Sulfur	1	% TR
Potassium	6200	mg/kg TR
Sodium	1700	mg/kg TR
Calcium	23000	mg/kg TR
Magnesia	3900	mg/kg TR

Main tasks of sludge treatment

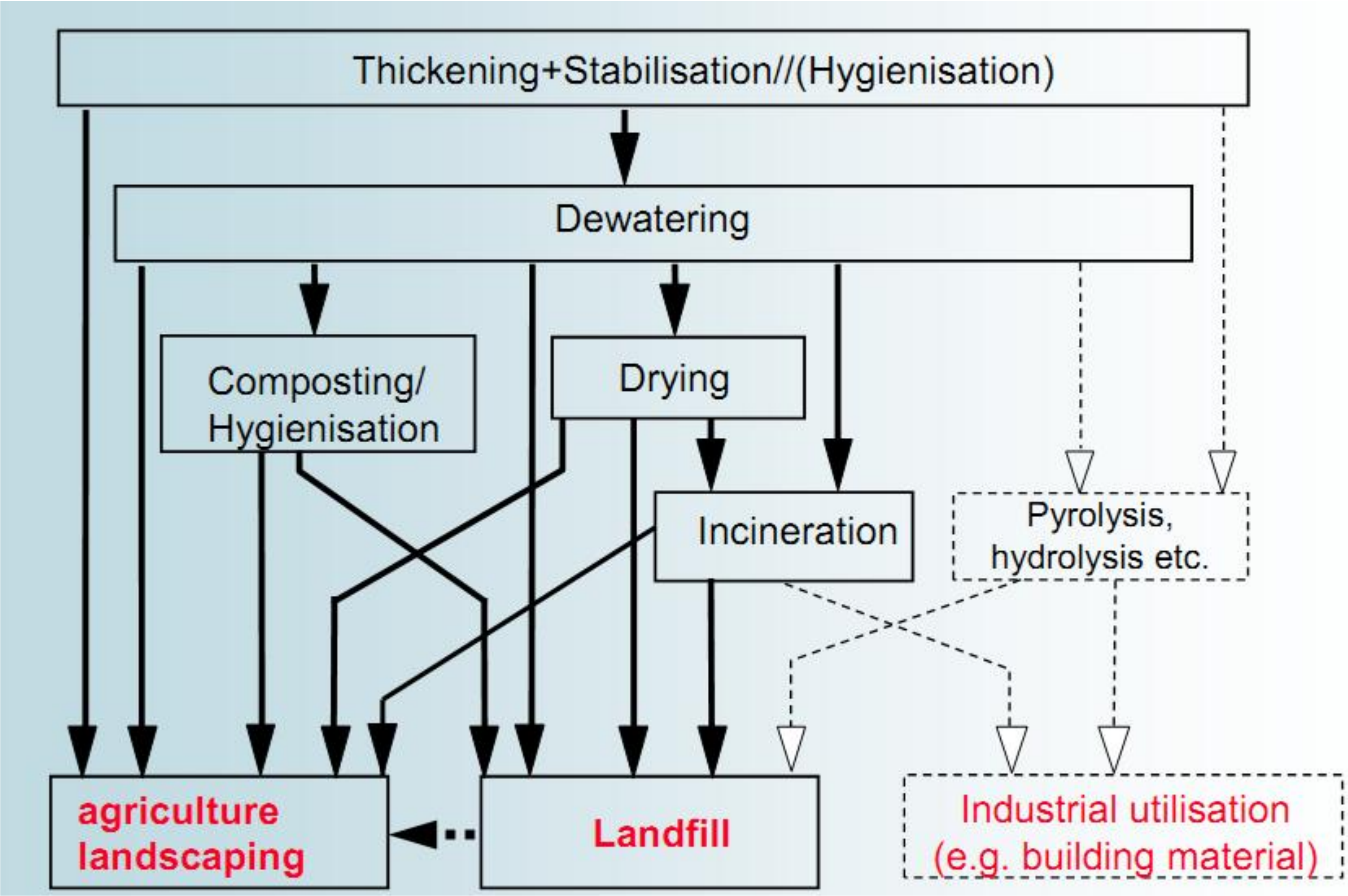
1. Thickening and stabilisation

2. Hygienisation

3. Dewatering

4. Sludge disposal

Sludge treatment and disposal options



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Sludge treatment methods

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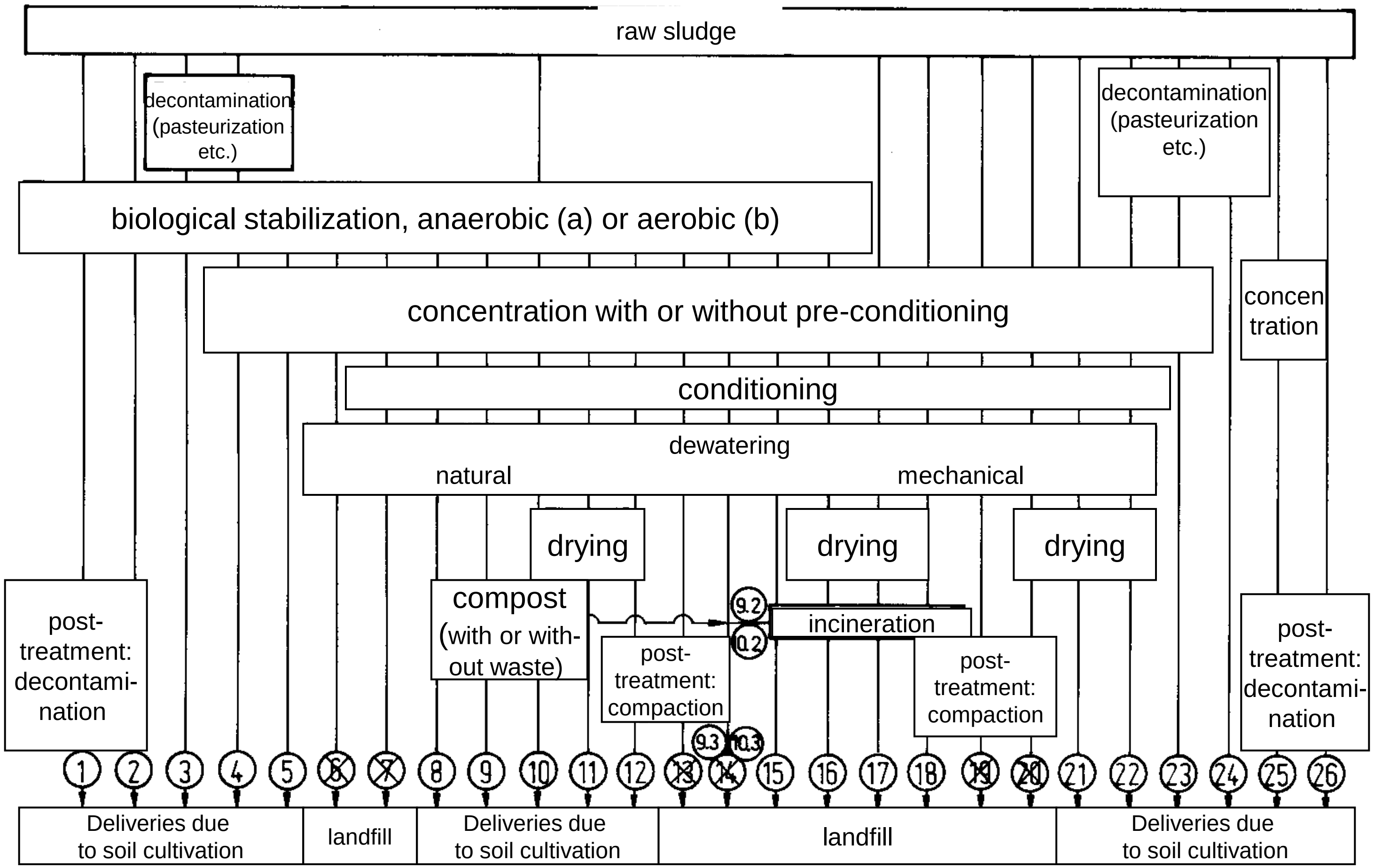


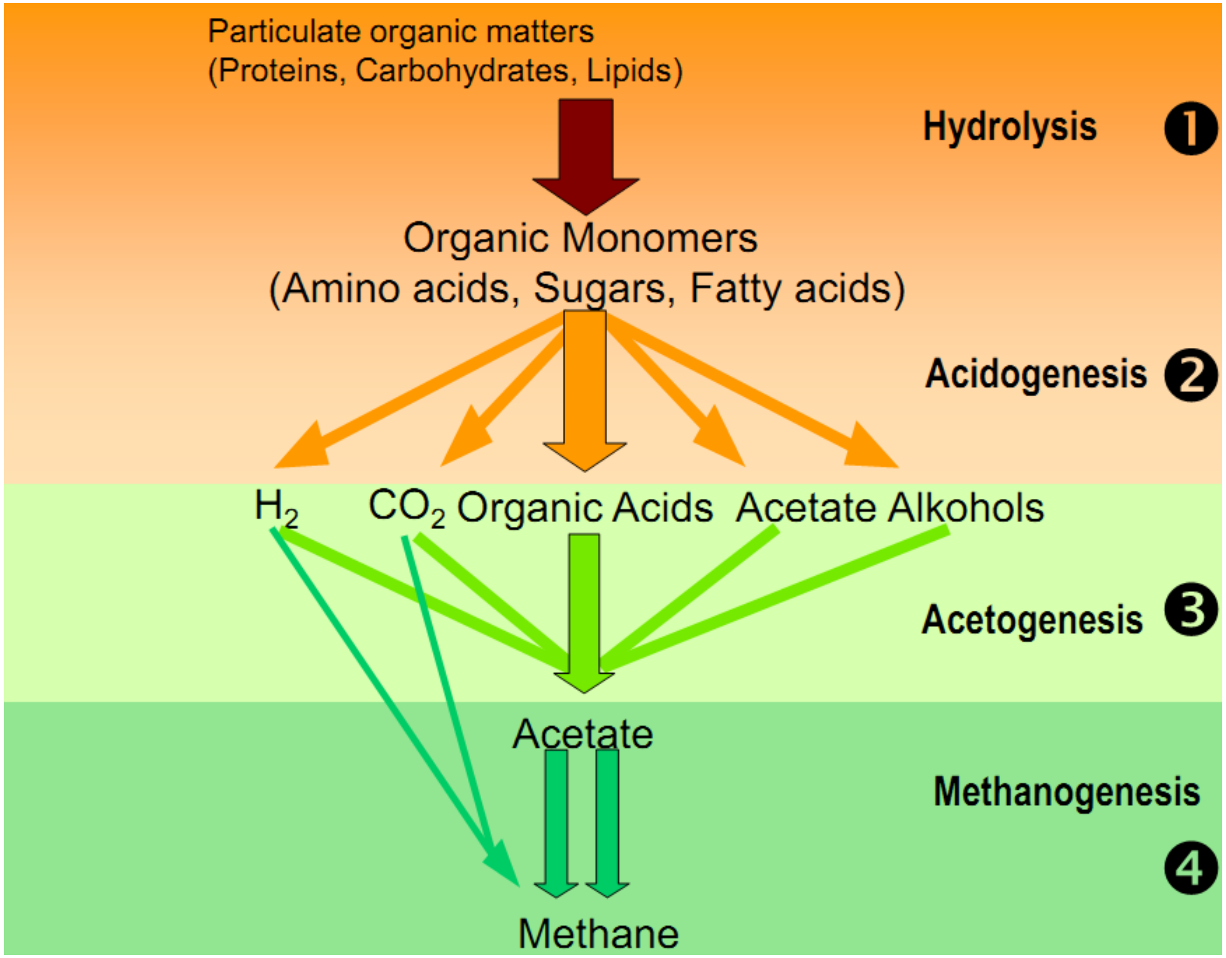
According to TA Municipal Waste important combinations and methods for the treatment, the physical exploitation or other types of disposal (environment-friendly disposal = landfill) of sewage sludge remain, general flow sheet.

Classification of biological stabilisation procedures

		Aerobic stabilisation			Anaerobic stabilisation		
Temperature range		psychrophilic 15 - 20° C	mesophilic 30 - 38° C	thermophilic 50 - 55° C	psychrophilic 15 - 20° C	mesophilic 30 - 38° C	thermophilic 50 - 55° C
Constructive design	with wastewater treatment	simultaneous in the sludge activation tank (biological reactor)	-----	-----	constructional combined with settling tank Emscher-well	-----	-----
	separated from the wastewater treatment	tank without heat insulation	heat-insulated tank		Open or closed tanks	Closed and heated tanks	

Anaerobic sludge stabilization (sludge digestion)

1. Hydrolysis
2. Acidogensis
3. Acetogensis
4. Methanogenesis



Sludge digestion

Digester requirements:

- Constant and careful intermixing of the digester's content (acetogenic and methanogenic bacteria have to live close together for a maximum metabolic rate) avoidance of hydraulic dying areas (risk of sedimentation!).

- Digesters have to be heated because normally they are working with an operating temperature of about 33 - 37^{o}C. The radiation of heat is limited by a proportion of surface and volume (e.g. module of an egg) and by an adequate heat insulation.

Sludge digestion

Digester requirements:

- The raw sludge inflow should be as constant as possible by simultaneous admixture **(inoculation)** of digesting sludge.

- Good possibility of destruction and removal of **top scum**

- **Collection** and **utilization of sewage gas**

Egg-shaped anaerobic digester

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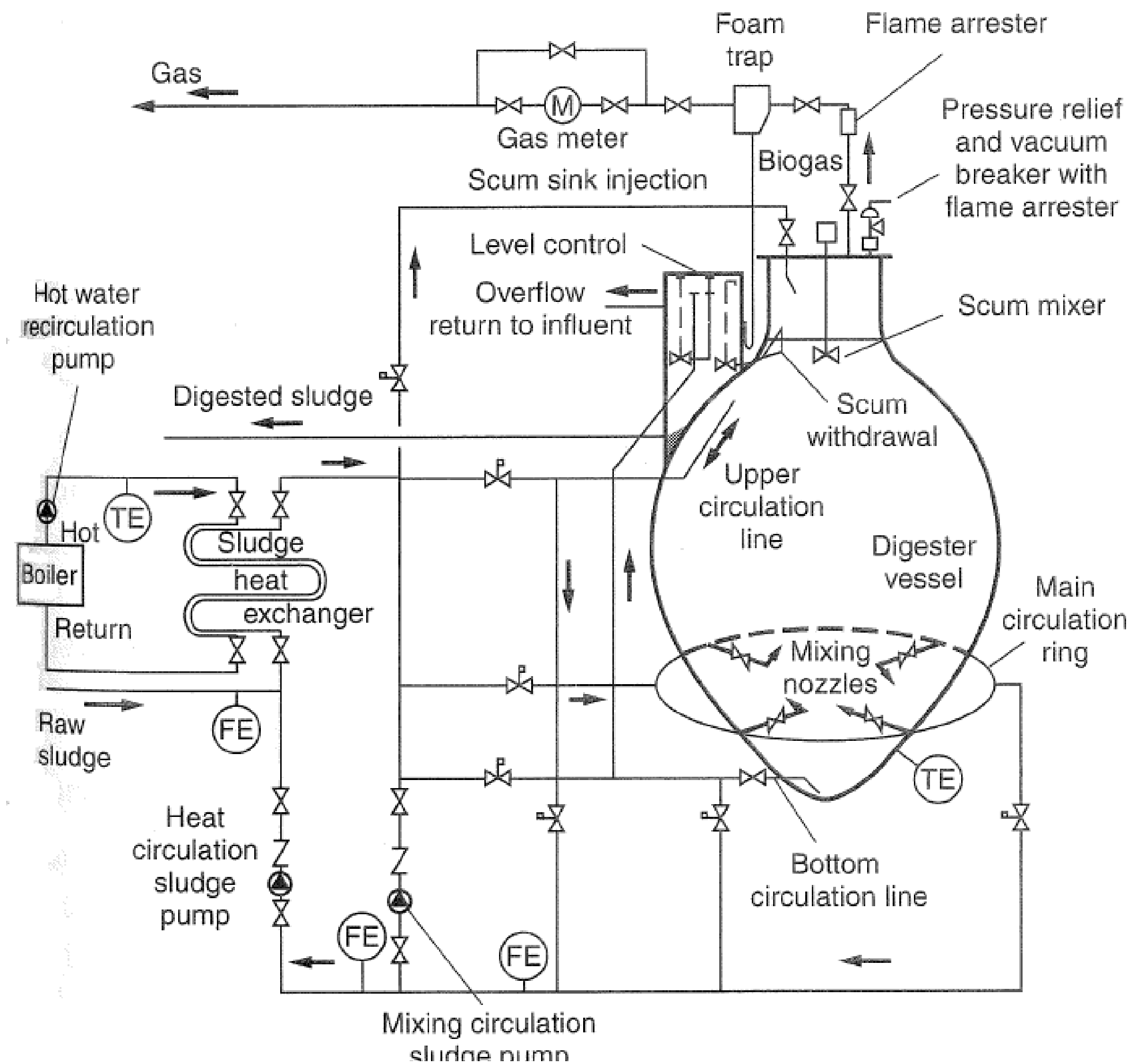


[Wastewater Engineering – Treatment and Reuse; Metcalf & Eddy]

Sludge thickening

Decrease the water content of the sludge withdrawn from the treatment plant from 98 - 99.5% to 92 - 96% in order to reduce the flow to be treated

Thickening technology:

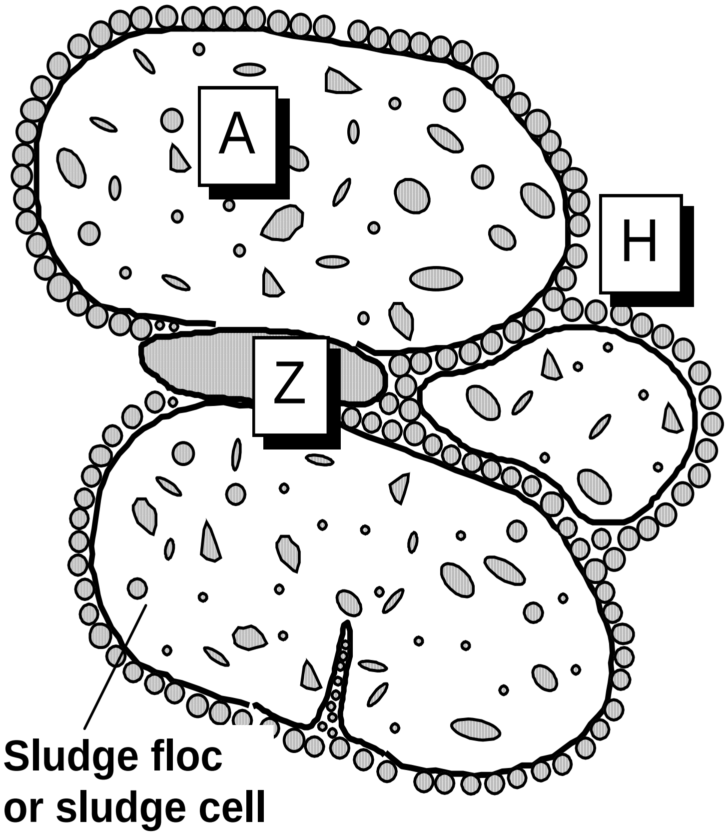
- gravity thickeners (similar to primary sedimentation)
- mechanical thickening (drum thickener, belt thickener, thickening centrifuges)

Water from thickening is called supernatant.

Sludge thickening ability depends on:

- the composition of the wastewater
- the available process engineering of the sewage treatment plant
- the operating mode of the sewage treatment plant
- the type of sludge

Types of sluge liquor



Z (~70%)	**interspace or interstice water (free water)**
H (~22%)	**adsorbed or adhesion water and capillary fixed water**
A (~8%)	**absorption or wetting water and inner water (amongst others cell sap)**
C	**chemically fixed water (not shown)**

Mode of operation and energy demand of dewatering steps

Steps of dewatering	Separation from	Achievable TR-content	Energy demand in kWh per m³ separated sludge liquor
Thickening	interspace water	2 - 10%	0.001 to 0.01
Dewatering (mostly with conditioning)	adsorbed and capillary water	up to 50%	1 to 10
Drying	inner and adsorption water	up to 99%	ca. 1.000

Sludge volume

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$$V = V_0 \cdot \frac{\left[100 \cdot S_w + WC\left(S_s - S_w\right)\right]\left(100 - WC_0\right)}{\left[100 \cdot S_w + WC_0\left(S_s - S_w\right)\right]\left(100 - WC\right)}$$

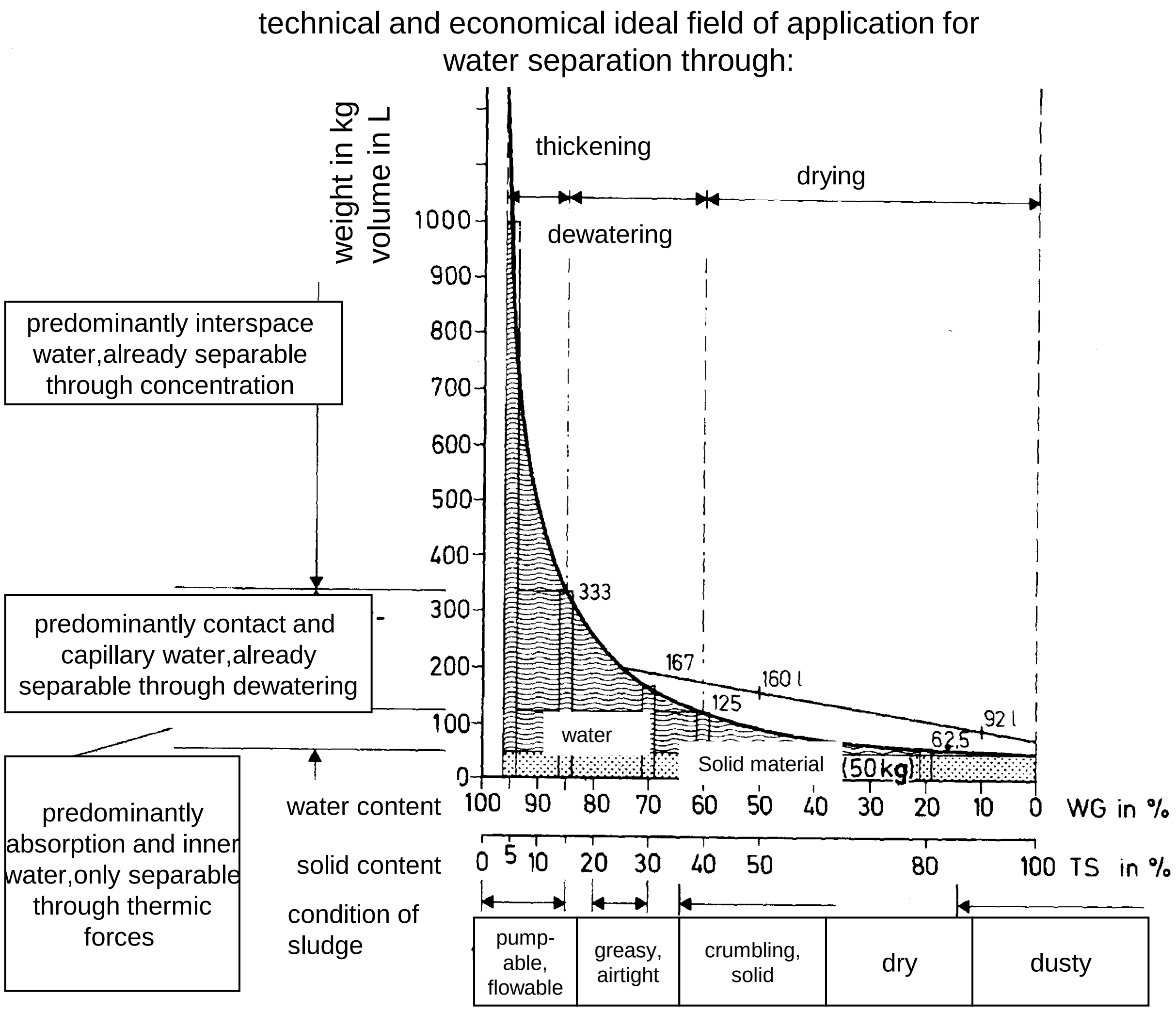
simplified:

$$V = V_0 \cdot \frac{DS_0}{DS}$$

With:

V_0	Volume of initial sludge [m³]
WC_0	Water content of initial sludge[%]
DS_0	dry solid matter in the initial sludge (dry residue) [%]
V, WC	alternatively DR equivalent in the dehydrated sludge
S_w, S_s	Density of water, Density of sludge [g/cm³]

Weight and volume decrease



Types of sludge thickening

1. Gravity thickener

Advantages:

- low operating costs
- low operation sensitivity
- storage function
- conditioning is not necessary

Types of sludge thickening

2. Mechanical thickener

- Centrifuge
- Gravity-Belt
- Rotary-Drum

Advantages:

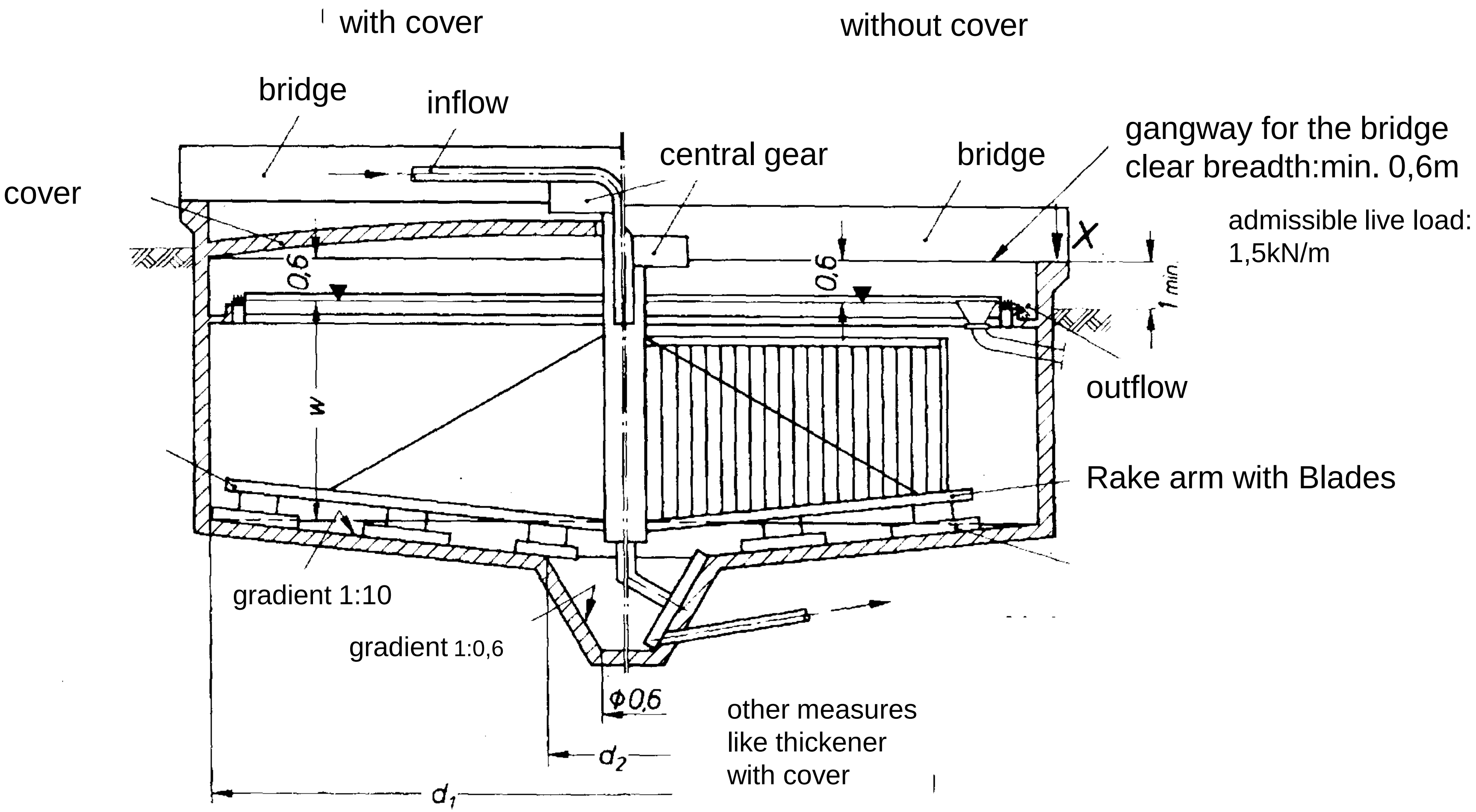
- higher thickening rate
- less space requirement

Types of sludge thickening

3. Floating thickening

- Advantageous with industrial sludge with high content of floating substances
- Rarely found in conventional wastewater plants due to its complexity

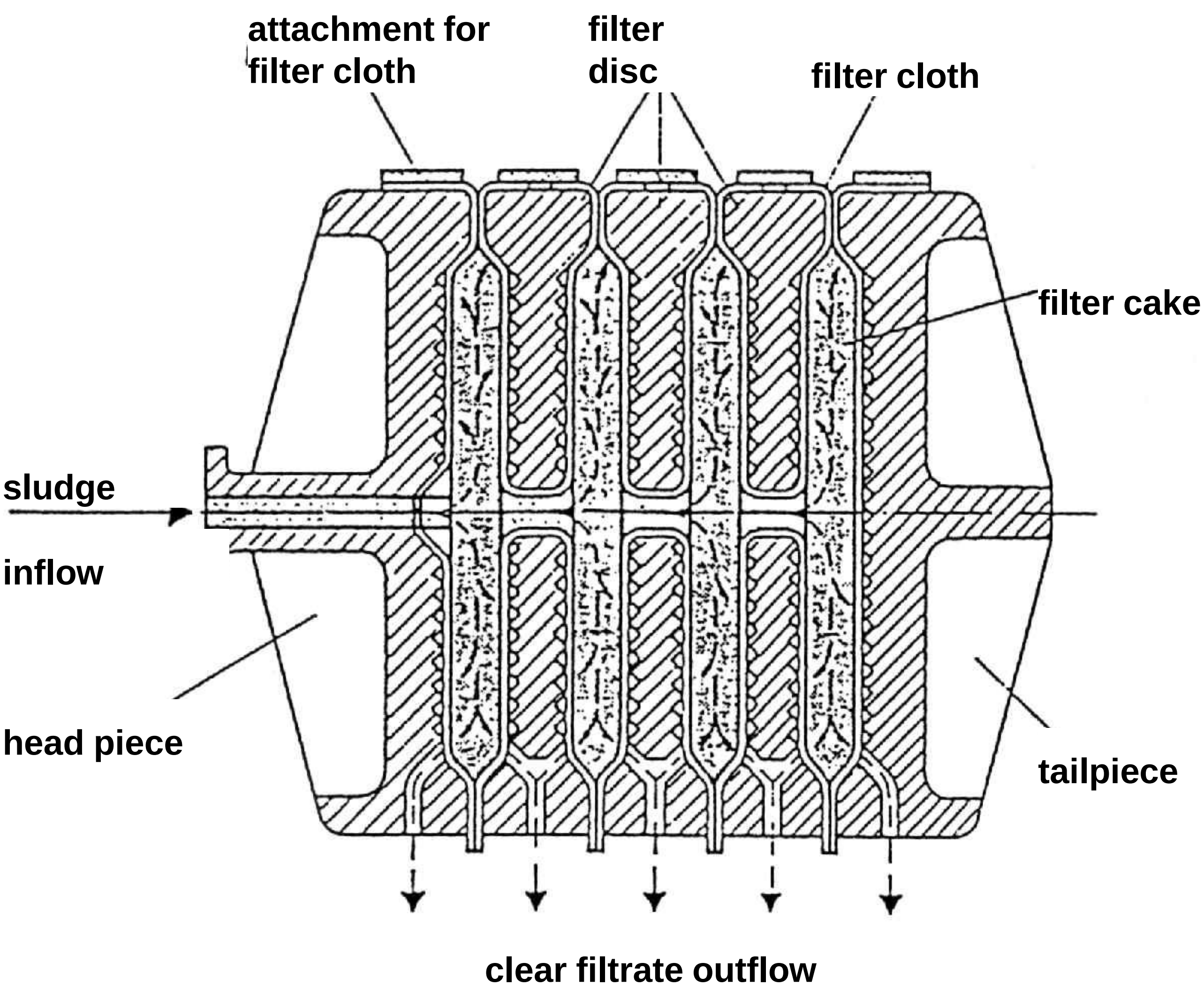
Gravity thickener



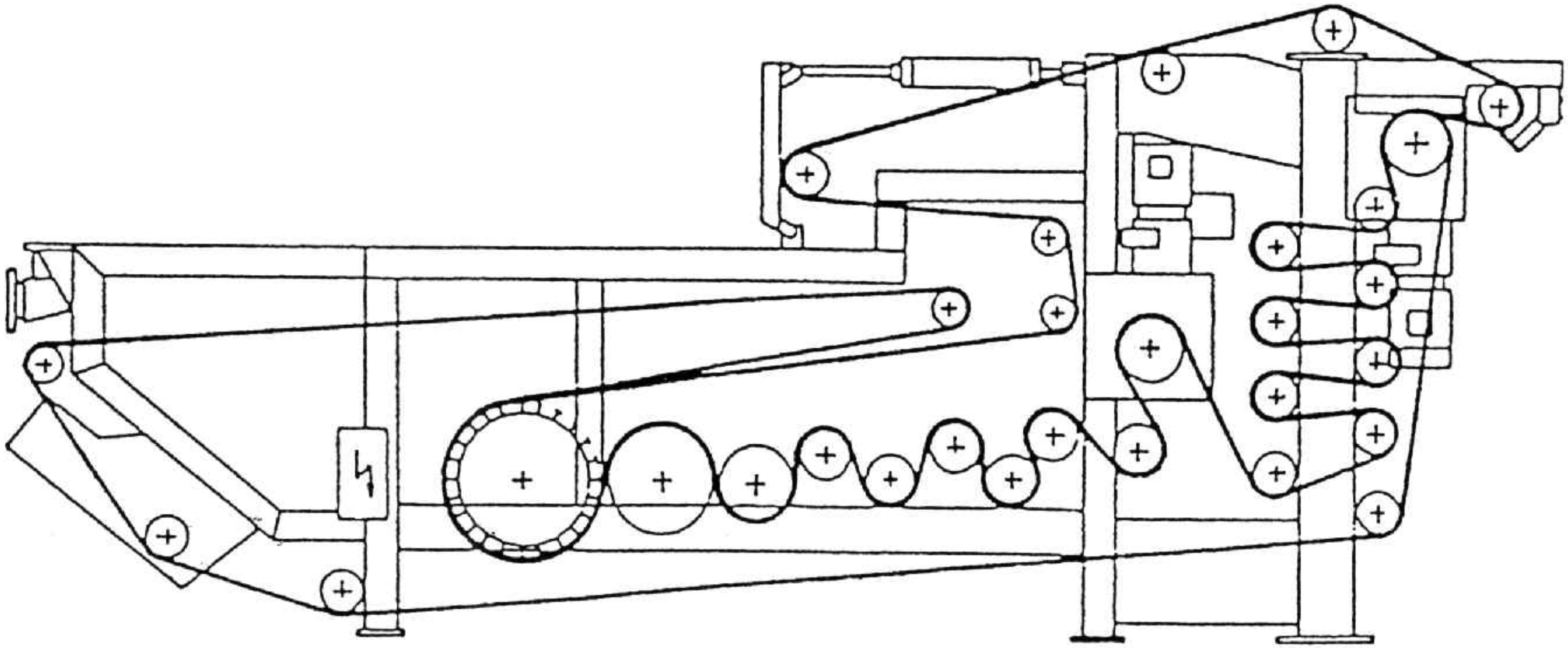
Mechanical dewatering systems

Type of dewatering	Operating mode	Concentrator
Filtration	discontinuous	chamber filter press
	continuous	belt filter press
Sedimentation	continuous	decanter/centrifuge

Chamber filter press



Gravity-belt thickener



Centrifuge

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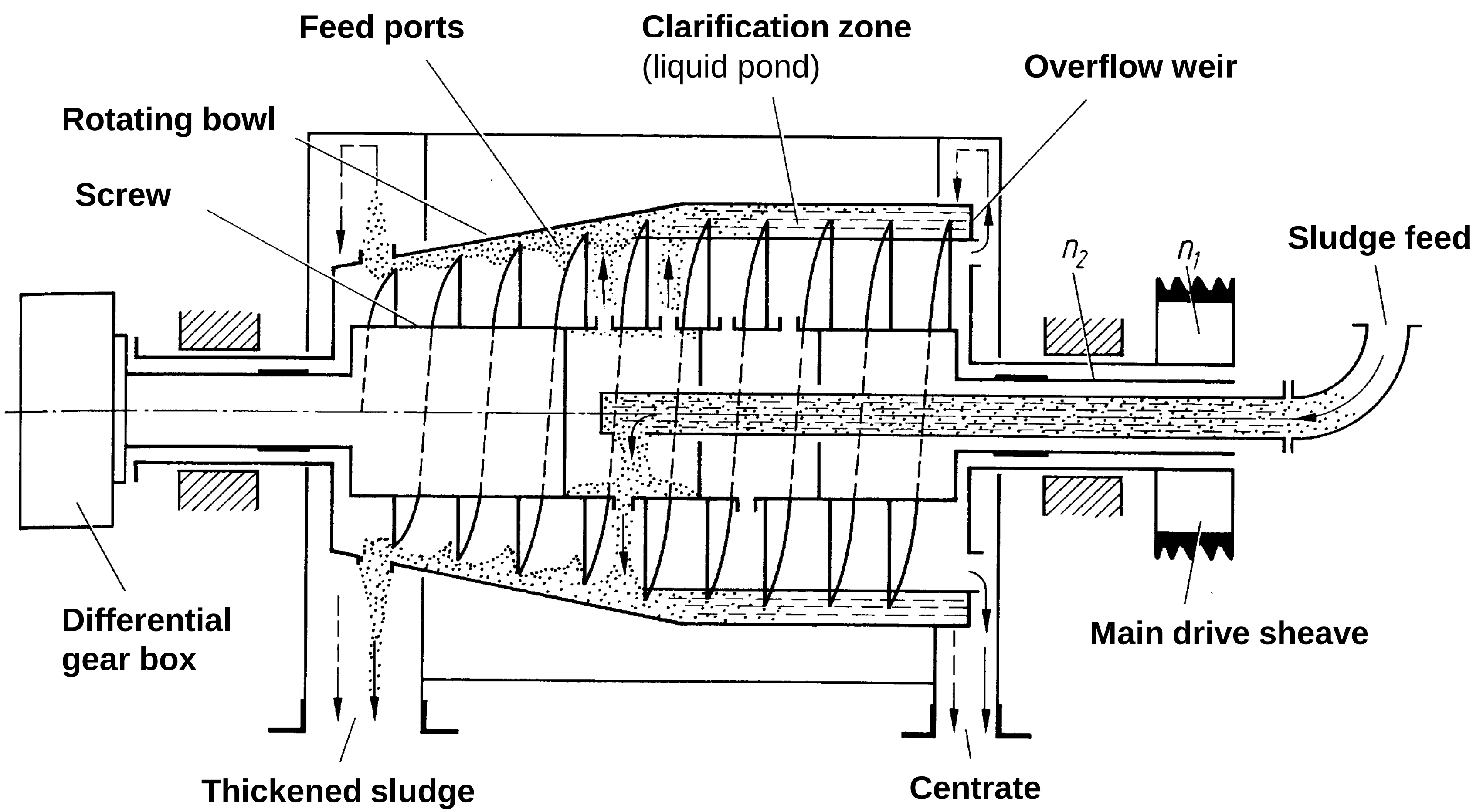

Sludge utilization/recycling and disposal

1. Sewage sludge utilization in agriculture

- Current percentage about 30% / Lower Saxony 70% (2002)
- Problem: Low acceptance because of heavy metals, endocrine substances, BSE, etc.
- Conclusion : Can be recommended if the pollutant concentration is low. The content of harmful substances should be reduced further more by the control of the indirect discharger.

Sludge utilization/recycling and disposal

2. Depositing / landfilling

- Current percentage about 60%
- Problem: The organic part of the deposited material mustn‘t be higher than 5% according to TA municipal waste since 2005.
- Conclusion: The conventional form of depositing/landfilling is no longer allowed, the sludge has to be treated thermally before.

Sludge utilization/recycling and disposal

3. Incineration

- Current percentage about 10%
- Problem: Low acceptance because of air contamination (almost solved technically) partial problems with disposal of rest material
- Conclusion: Higher importance in the future
- New ways for disposal of cinder and ashes are presently analyzed.