Treatment of wastewater solids

Applied wastewater engineering

Michael Jon MATTLE

Content of treatment of wastewater solids

- solid waste characterisation
- screening and grit removal
- preliminary sludge processing operations
- thickening of sludge
- sludge stabilisation (anaerobic/aerobic, composting and alkaline)
- dewatering and drying
- incineration and land application
- phosphorous recovery

Treatment of wastewater solids I: characterisation and preliminary treatment

Applied wastewater engineering

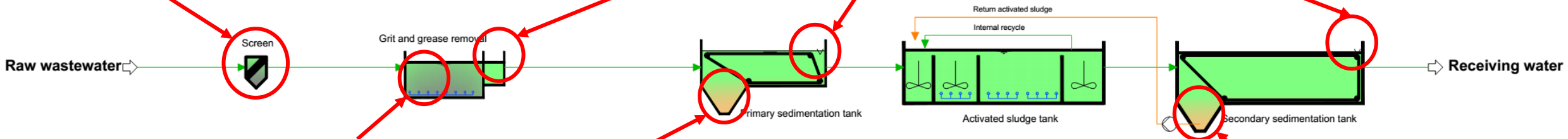
Michael Jon MATTLE

solid waste characterisation

- solid waste production

scum removal: floatable materials like vegetable and mineral oils, soaps, fats, hair, paper, cigarette tips, plastic materials, condoms,… scum from the secondary clarifier may also consist of floating bacteria

screening: removal of coarse solids and small particles with an potentially extremely offensive odour



grit removal: easily settable solids

primary sludge: generally fine but settable particles. This sludge is usually grey and slimy and has an extremely offensive odour

waste activated sludge: suspended solids generally has a brown flocculent appearance with an inoffensive “earthy” odour

Solid waste production

- Which of these solid wastes does generate the biggest volumes?

A) screenings

B) grit

C) grease

D) scum

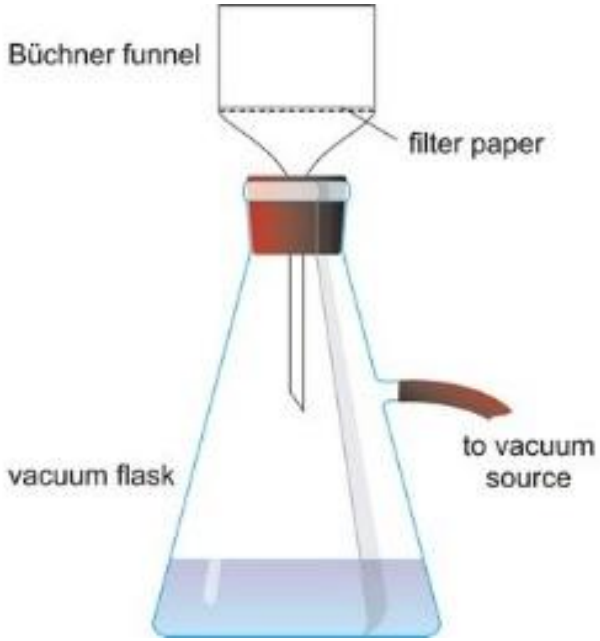
E) primary sludge

F) secondary sludge

https://web.speakup.info/room/join/11535

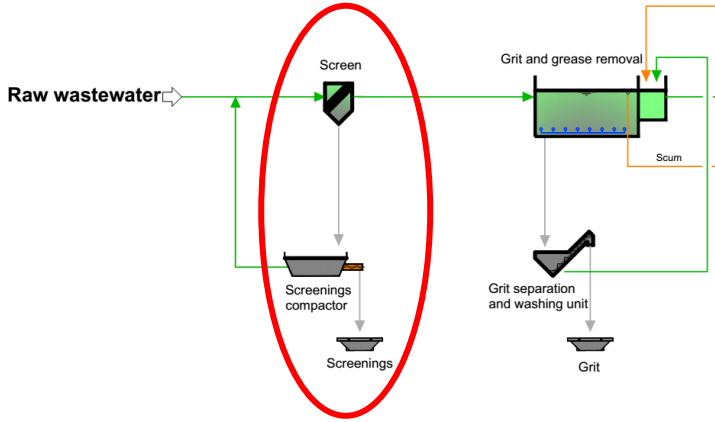
Solid waste characterisation

- TS (total solids):
  - Residue remaining after a wastewater sample has been evaporated and dried at a specified temperature (≈ 105 °C)
- TVS (total volatile solids):
  - Those solids that can be volatilised and burned off when the TS are ignited (500 ± 50 °C)
- TSS (total suspended solids; generally used for wastewater characterisation):
  - Portion of the TS retained on a filter (generally 0.45 µm), measured after being dried at a specified temperature (≈ 105 °C)
- VSS (volatile suspended solids; generally used for wastewater characterisation):
  - Those solids that can be volatilised and burned off when the TSS are ignited (500 ± 50 °C)



Screening of wastewater

- generally first treatment stage of a wastewater treatment plant: coarse screening (> 8 mm up to 50 mm)
- remove coarse materials from flow stream
  - avoid damage or clogging of other equipment
  - increase reliability of treatment plant
  - minimal treatment for storm water overflows
- fine screening (≤ 8 mm) is optional for additional reduction of solids that could clog further down in the treatment process (e.g. membranes of membrane bioreactors or biofiltres)

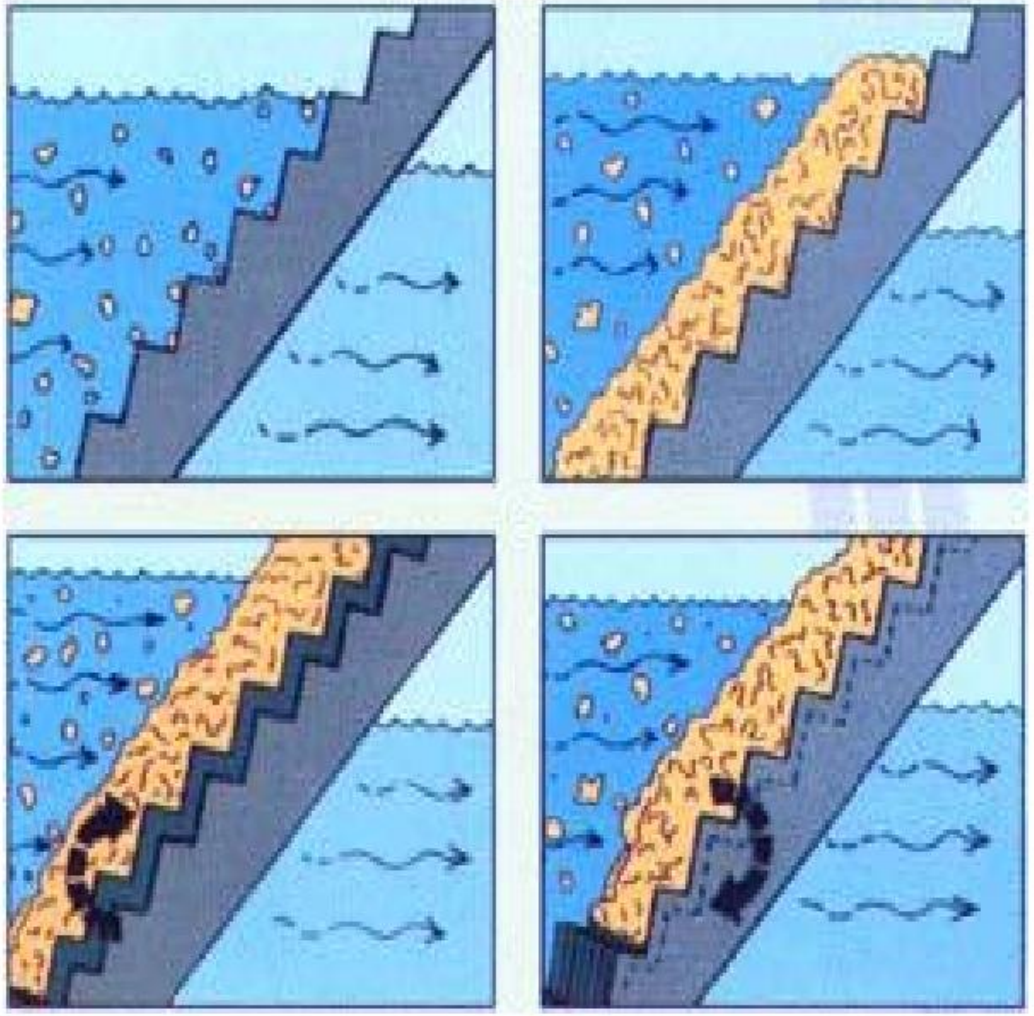


step screen

Screening of wastewater

- materials retained are called screenings: paper, plastic, faeces, wrongly disposed garbage (e.g. textiles)
- contains also debris such as gravel, metal pieces and depending on the period of the year leaves
- screenings have low moisture content (TS content: 8 to 15 %) compared to other wastewater solids
  - coarse screenings have a higher moisture content than fine screenings
- often more than 90 % of TS is organic (> 80 % cellulose)

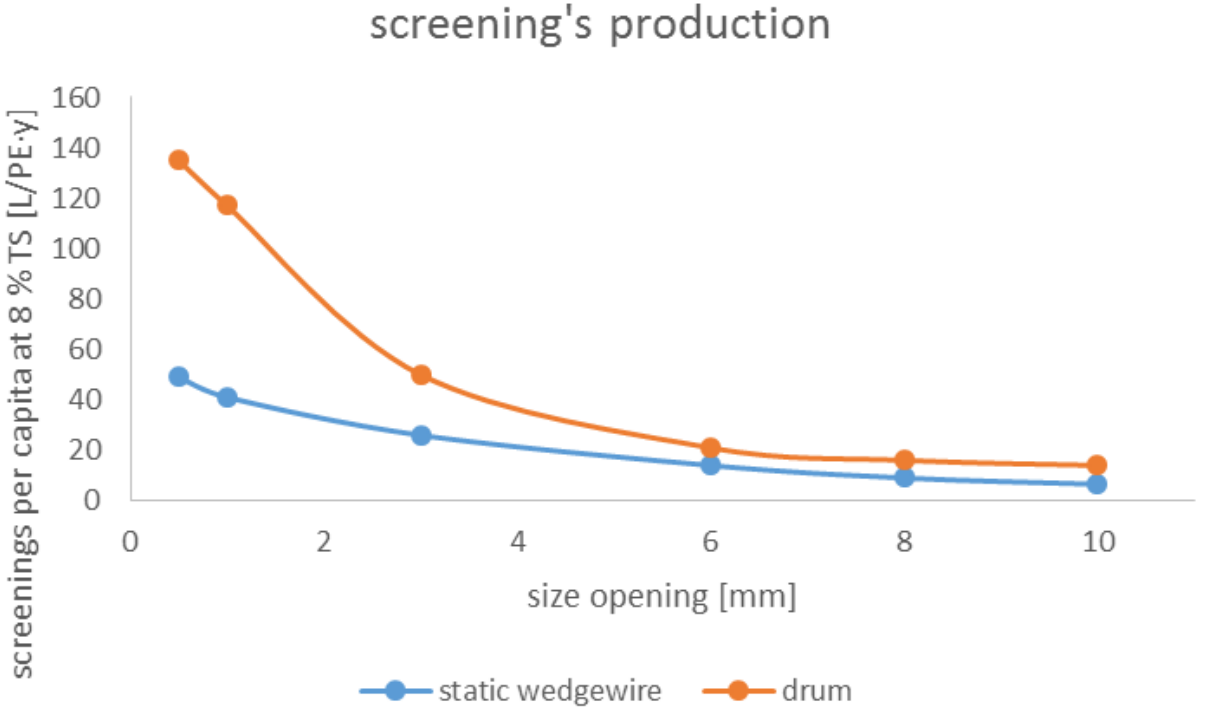
→ bad odour problems

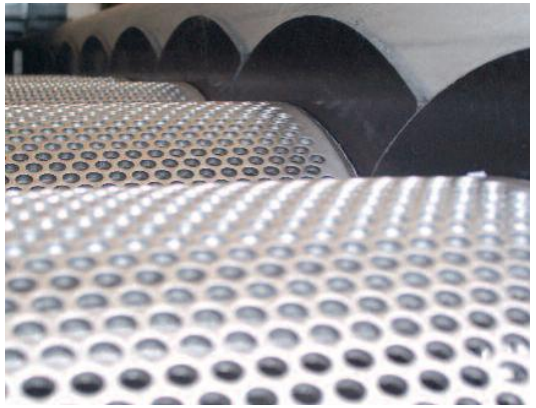


step screen

Type of screen on screenings production

- the smaller the opening of the bars or holes, the larger the volume of screenings retained
- drum screens are much more efficient in removing screenings than static wedgewire screens
- however,
  - they are hydraulically worse (water has to travel through twice)
  - the cleaning requires a lot of water
  - they are more expensive





Screenings production

- practical computation of screenings production (TS between 8 and 15 %):
  - size opening > 3 mm:
    - 30 – 300 L/1’000 m^3
  - size opening < 3 mm
    - static wedgewire screens: 200 – 400 L/1’000 m^3
    - drum screens: 400 – 800 L/1’000 m^3
- at the beginning of a heavy rain event (flushing of the sewer system), the volumes of screenings may increase substantially especially for combined sewer systems (up to 10 times) as compared to normal flow
  - additionally a security factor for rain should be added: 2 - 6

→ as for other installations in WWTP, the data from the current screen is the best source of information for the design of a new screen

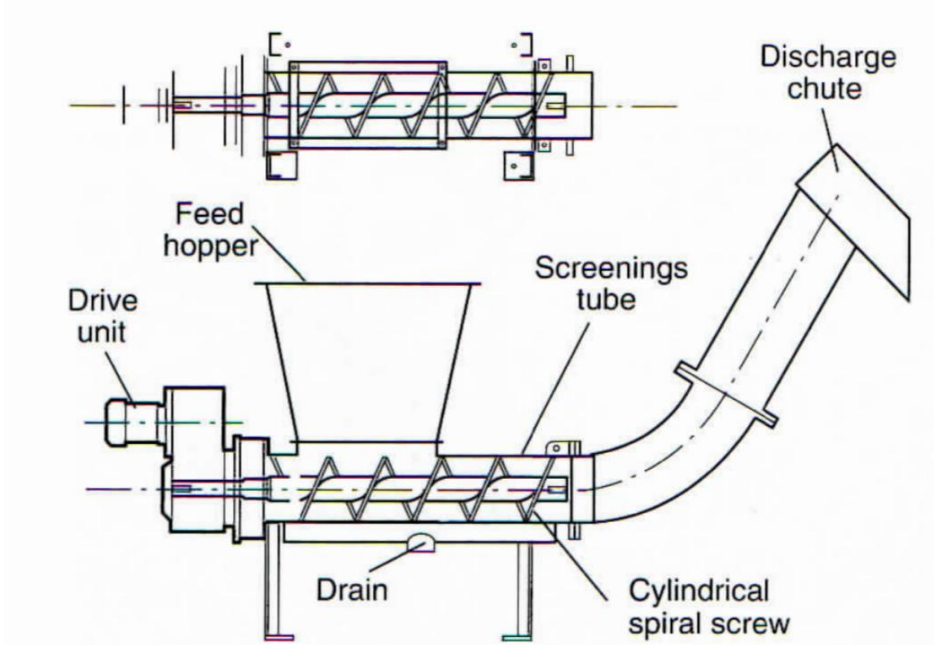
Handling of screenings

Parameter	unit	range	typical
TS	% [kg TS/kg]	8 – 54	30
calorific value	MJ/kg	2 – 10	4.7 (35 % TS)
TVS	%	73 – 98	87
AOX	mg/kg	3 – 250	80
lead	mg/kg	1 – 63	22
copper	mg/kg	13 – 220	56
zinc	mg/kg	47 – 940	246
…			

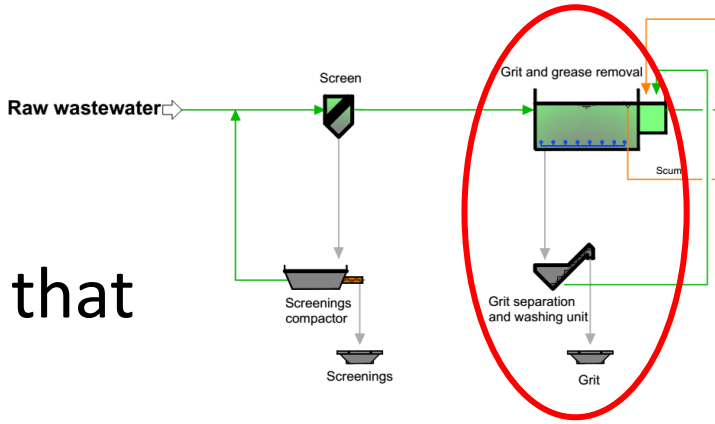
- screenings contain many toxic compounds: e.g. heavy metals, halogenated compounds,…
- fine screenings contain putrescible matter (high TVS content) such as faecal materials, grease and scum (odour problems)
  - manual handling of fine screenings should be minimized

Screenings

- screenings compactors can be used to dewater and reduce the volume of screenings:
  - increases TS to 30 – 50 %
- screenings washer and compactors are often used in Switzerland:
  - removal of organics (bad odour reduction)
  - volume reduction up to 80 % may be obtained
- screenings are then transported to an incineration plant or directly to landfills (depending on legislation)



Grit and grease removal



- grit consists of sand, gravel and other heavy material that settle more quickly than organic material (e.g. glass)
  - residence time is short (≈ 5 - 20 min) compared to other installations
- in the collection system grit particles may come into contact with organic matter and surface active agents that can adhere to the particles

→ it putrefies quickly if not correctly handled

parameter	unit	range
specific volume	L/(PE·year)	2 - 5
specific weight	kg TS /(PE·year)	3 – 7.5
total solids	% [kg TS/kg]	40 - 70
total volatile solids (TVS)	% of TS	10 - 50

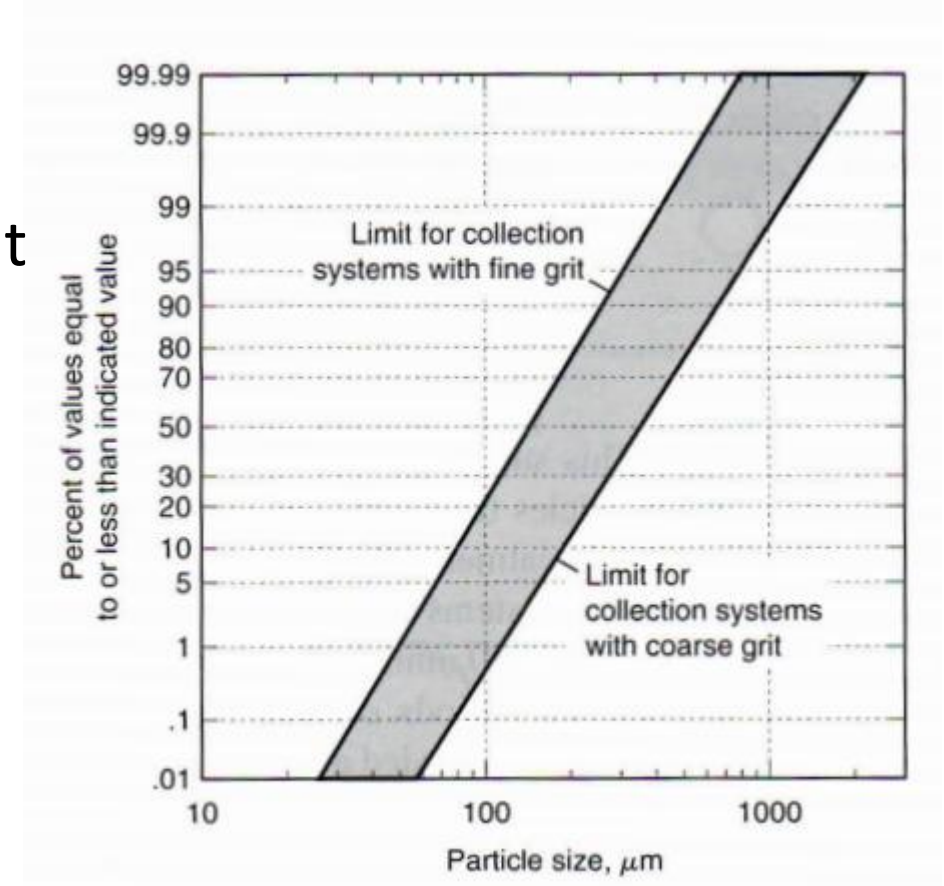
- all values depend highly on the site
- may contain considerable amount of organic material

Grit removal

- grit has to be removed in order to protect aeration basins, digesters and pipes from heavy deposits
- the removal of grit also reduces the abrasion of moving mechanical equipment further down in the treatment train (e.g. pumps, centrifuges, heat exchangers,…)

grit diameter	removal efficiency
0.3 mm	95 %
0.2 mm	85 %
0.15 mm	75 %
0.1 mm	50 %
< 0.07 mm	< 10 %

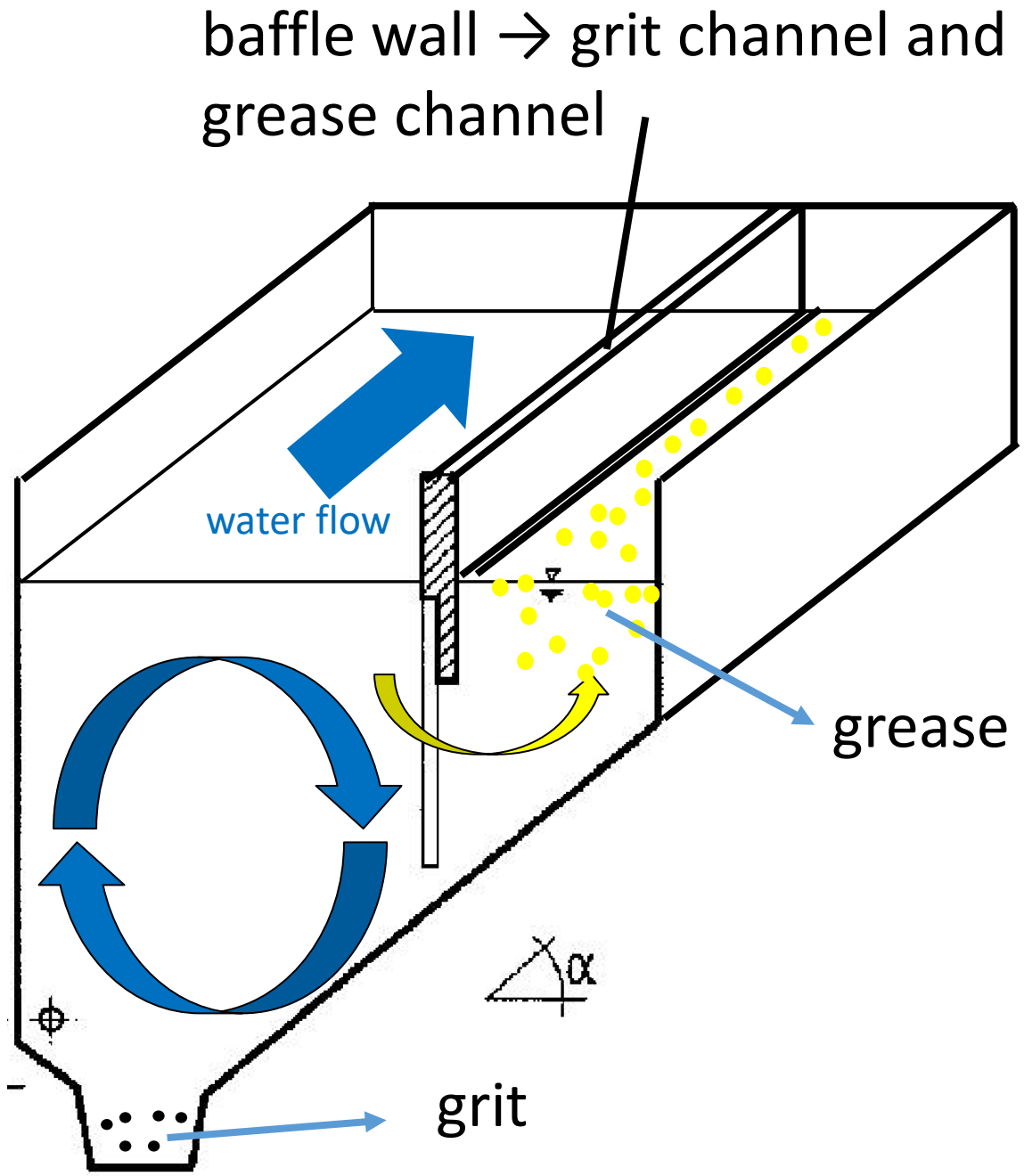
average achievable removal efficiencies of aerated grit removal (depends on hydraulic retention time and design)



typical particle size distribution range

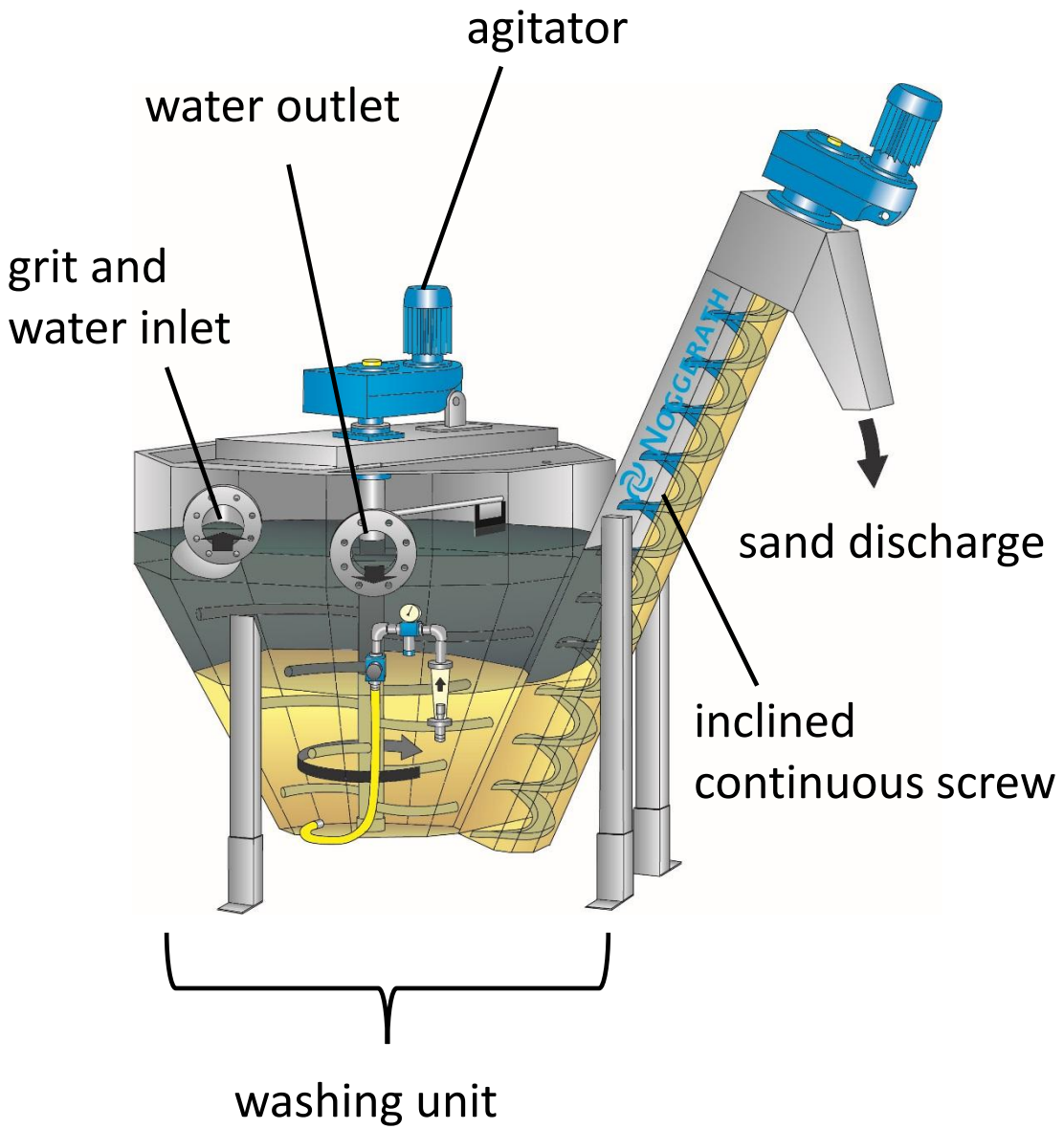
Grit and grease removal

- shape: round or rectangular
- only grit or grit and grease removal
- classical or aerated
  - it is difficult to obtain a constant flow/separation with a classical grit removal unit at different inflow speeds (no aeration)
  - aeration allows a constant separation (independent of flow rate) of grit and organic material due to constant spiral flow
  - aeration produces turbulences which separate part of the organic material from the grit
  - aeration allows grease removal in separate channel



Grit washing and drying

- without washing unit:
  - volatile solids often higher than 20 %
  - water content about 50 %
- with washing unit:
  - volatile solids < 5 %
  - roughly 1/3 of weight without washing unit
- grit may be reused if sufficiently washed and dried: e.g. roads, paths, landscape building, building materials (depending on legislation)
- otherwise it is transported to landfills or incineration plants

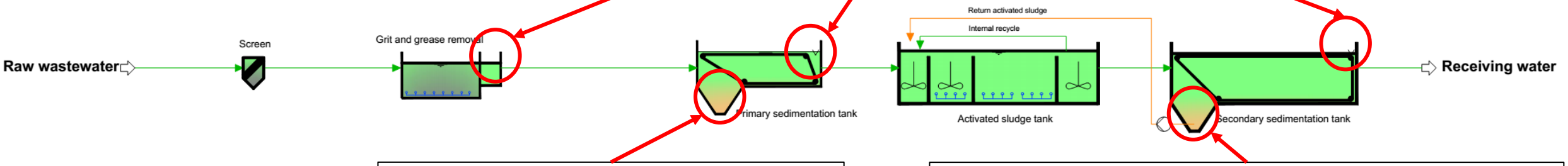


Grit and grease removal

Solid waste characterisation

- solid waste production

scum removal: floatable materials like vegetable and mineral oils, soaps, fats, hair, paper, cigarette tips, plastic materials, condoms,… scum from the secondary clarifier may also consist of floating bacteria

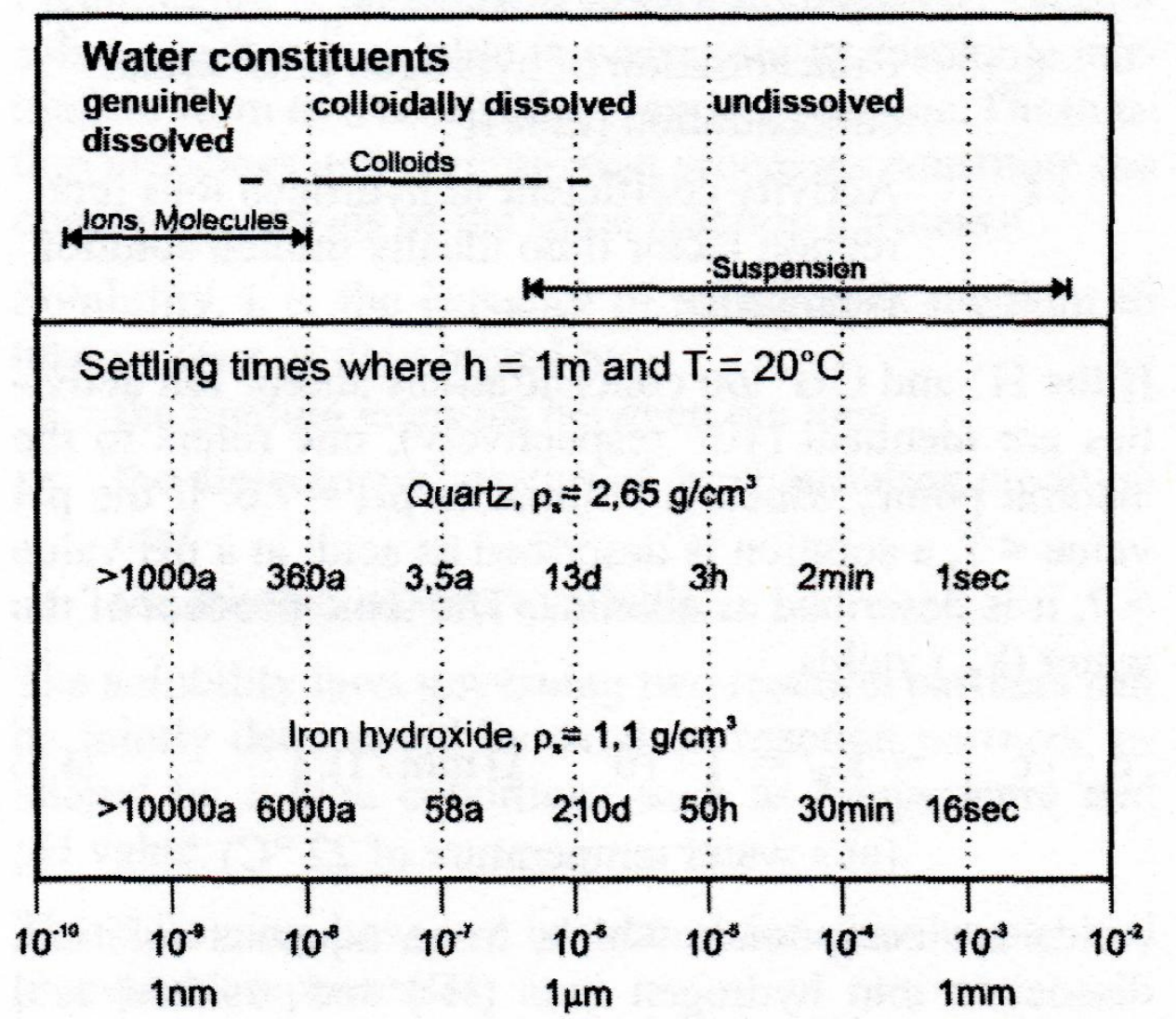


primary sludge: generally fine but settable particles. This sludge is usually grey and slimy and has an extremely offensive odour

waste sludge: suspended solids generally has a brown flocculent appearance with an inoffensive “earthy” odour

Water constituents removal

- clarifiers remove particles down to the range of mm range (≈ 0.1 mm)
- smaller water constituents may be removed by
  - smaller particles: rapid sand filtration
  - colloids: coagulation and sedimentation/rapid sand filtration (or ultrafiltration)
  - molecules and ions: tight membrane filtration (with or without coagulation)



Typical sludge composition

	untreated primary sludge (PS)		waste activated sludge (WAS)	
parameter	range	typical	range	typical
total solids (TS) % [kg TS/kg]	1-6	3	0.4-1.2	0.8
total volatile solids TVS (% of TS)	60-85	75	60-85	70
grease and fats (% of TS)	5-8	6	5-12	8
protein (% of TS)	20-30	25	32-41	36
nitrogen (N, % of TS)	1.5-4	2.5	2.4-5	3.8
phosphorous (P_2O_5, % of TS)	0.8-2.8	1.6	2.8-11	5.5
cellulose (% of TS)	8-15	10	-	
iron (not as sulphide)	2-4	2.5	*	
silica (SiO_2, % of TS)	15-20	-		
pH	5-8	6	6.5-8	7.1
alkalinity (mg/L as $CaCO_3$)	500-1'500	600	580-1'100	790
organic acids (mg/L as HAc)	200-2'000	500	1'100-1'700	1'350
energy content, kJ/kg TVS	23'000-29'000	25'000	19'000-23'000	20'000

PS more concentrated than WAS

PS has higher volatile solids (VS) than WAS

PS contains less nutrients than WAS
→ fertiliser

* no value given as dependent on $FeCl_3$ dosing for phosphorous removal

PS contains more energy than WAS

Typical sludge composition

metal	range of dry solids, mg/kg TS
arsenic	1.18 – 49.2
cadmium	0.21 – 11.8
chromium	6.74 – 1160
cobalt	0.87 – 290
copper	115 – 2580
iron	1575 – 299’000
lead	5.81 – 450
manganese	34.8 – 14’900
mercury	0.17 – 8.3
molybdenum	2.51 – 132
nickel	7.44 – 526
selenium	1.1 – 24.7
tin	7.5 – 522
zinc	216 - 8550

Table: typical metal content in wastewater solids

- most metals that enter a wastewater treatment plant exit it as sludge
  - metal concentrations depend on implementation of pretreatment installations at industries
- untreated sludge also contains many pathogenic microorganisms and potentially prions (e.g. bovine spongiform encephalopathy (BSE): mad cow disease)
- high concentrations of heavy-metals, pathogens and other pollutants may have a negative impact on agriculture

→ sludge can no longer be used for land application in Switzerland since 2006

Objectives of sludge treatment

- reduce water content (from percent range up to 30 % or higher)
  - less volume required for storage/treatment
  - less energy needed to heat the sludge (e.g. digestion)
  - less weight of sludge (e.g. transport)

- reduce bad odour of sludge
  - more comfortable working environment for employees
  - reduced nuisances to neighbours
  - less waste air treatment required

- remove dangerous or disturbing materials
  - e.g. fibres that disturb good functioning of digesters
  - pathogens that may cause infections

Objectives of sludge treatment

- reduce water content (from percent range up to 30 % or higher)
  - thickening
  - dewatering
  - drying
  - composting

- reduce bad odour of sludge
  - anaerobic digestion
  - aerobic stabilisation
  - alkaline stabilisation
  - reed beds

- remove dangerous or disturbing materials
  - screening and grinding of sludge
  - anaerobic/alkaline/aerobic stabilisation and reed beds (pathogens)

Wastewater solids stabilisation

- Which of these wastewater solids are stabilised by digestion (several answers possible)?

A) screenings

B) grit

C) grease

D) scum

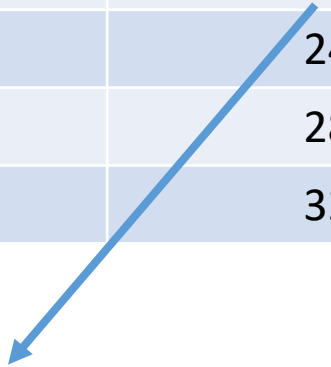
E) primary sludge

F) secondary sludge

https://web.speakup.info/room/join/11535

Quantities of primary sludge total solids (TS)

Primary sludge production				
minimal 2h-residence time (dry weather)	85th percentile	50th percentile	yield	TVS fraction
[h]	[g TSS/(PE·d)]	[g TSS/(PE·d)]	[%]	[%]
0.5	30	24	43	75
1.0	35	28	50	75
2.0	40	32	57	75



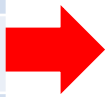
population equivalent (PE) :

- 70 g TS in influent wastewater for 85th percentile
- ≈ 56 g TS in influent wastewater for 50th percentile (≈ 80 %)

Quantities of waste activated sludge (only C-treatment)

only carbon removing activated sludge plant (minimal sludge age 5 days)					
residence time in primary clarifier	temperature	sludge production		total volatile solids (TVS) fraction	
		85th percentile	50th percentile	85th percentile	50th percentile
[h]	[°C]	[g TSS/(PE·d)]	[g TSS/(PE·d)]	[%]	[%]
0.5	10	56	43	77	76
0.5	15	52	40	75	75
0.5	20	49	38	74	73
1.0	10	50	38	76	76
1.0	15	47	36	75	74
1.0	20	44	34	73	73
2.0	10	44	34	76	75
2.0	15	41	32	74	74
2.0	20	39	30	73	72

- reduced waste activated sludge production and reduced volatile solids fraction at higher temperatures



- higher mineralisa-tion of sludge at higher temperatures

Quantities of waste activated sludge (C- + N-treatment)

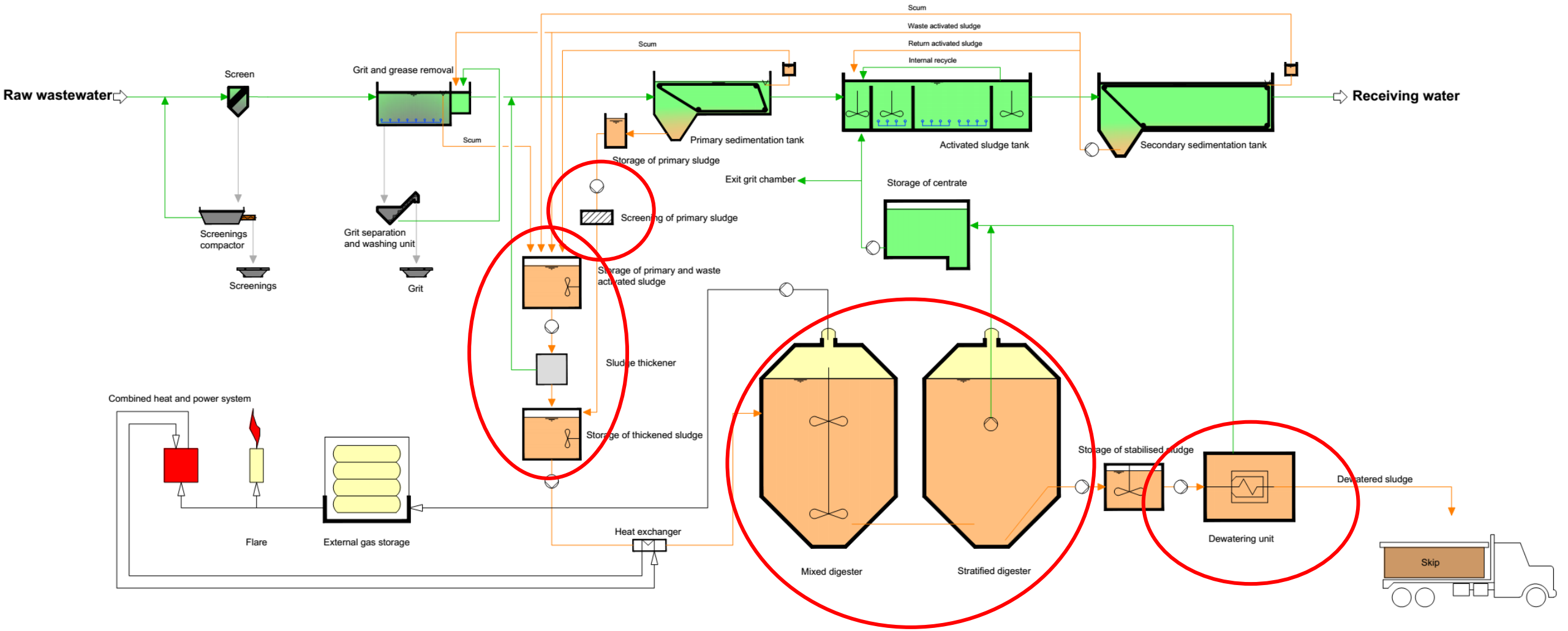
nitrifying activated sludge plant (minimal sludge age 10 days)					
residence time in primary clarifier	temperature	sludge production		total volatile solids (TVS) fraction	
		85th percentile	50th percentile	85th percentile	50th percentile
[h]	[°C]	[g TSS/(PE·d)]	[g TSS/(PE·d)]	[%]	[%]
0.5	10	49	37	73	73
0.5	20	43	34	70	70
1.0	10	43	33	73	72
1.0	20	39	31	70	70
2.0	10	29	29	72	71
2.0	20	28	28	69	71

- lower sludge production and lower volatile solids fraction than without nitrogen treatment due to higher mineralisation of sludge (higher sludge age)

Sludge characteristics (total solids (TS) content)

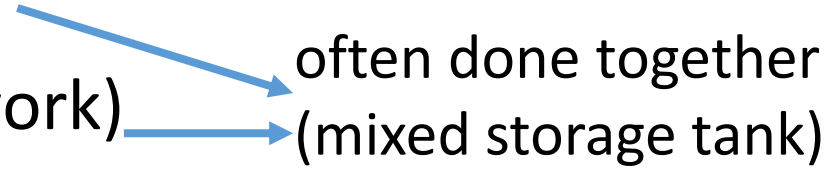
operation or process application	total solids (TS) concentration (%) [kg TS/kg in %]	
	range	typical
primary sludge	1 - 6	3
primary and waste activated sludge	0.5 – 3	1.5
primary sludge and trickling filter humus	4 – 10	2
primary sludge with iron addition for phosphorous removal	0.5 – 3	2
waste activated sludge with primary settling	0.5 – 1.5	0.8
waste activated sludge without primary settling	0.8 – 2.5	1.3
trickling filter humus	1 – 3	1.5
rotating biological contactor waste sludge	1 -3	1.5

Sludge treatment in wastewater treatment plants



Preliminary sludge processing operations

- provide a relatively constant and homogeneous feed to subsequent processing facilities
- prevent clogging and reduce wear of pumps
- these operations include:
  - screening (remove large materials)
  - grinding (reduce size of large materials; rather rarely done in Switzerland)
  - degritting (if no grit removal facility is ahead of the primary sedimentation tank)
  - blending (sludge is mixed to produce a consistent characteristics of sludge)
  - storage (minimize fluctuations, reparation work)



Preliminary sludge processing operations

- screening has the advantage to remove nuisance materials rather than only reducing its size (grinding)
- screening may be done similarly to wastewater screening (e.g. step screening) but may also be done with inline screens (e.g strainpress see figure) which contain a dewatering and compacting zone
- screenings removed: paper, plastic, aluminium foil, wood, gum, textiles (fibres),…