CENTER FOR MEMBRANE TECHNOLOGY

Forskjellige type avløpsslam, egenskaper, muligheter og utfordringer

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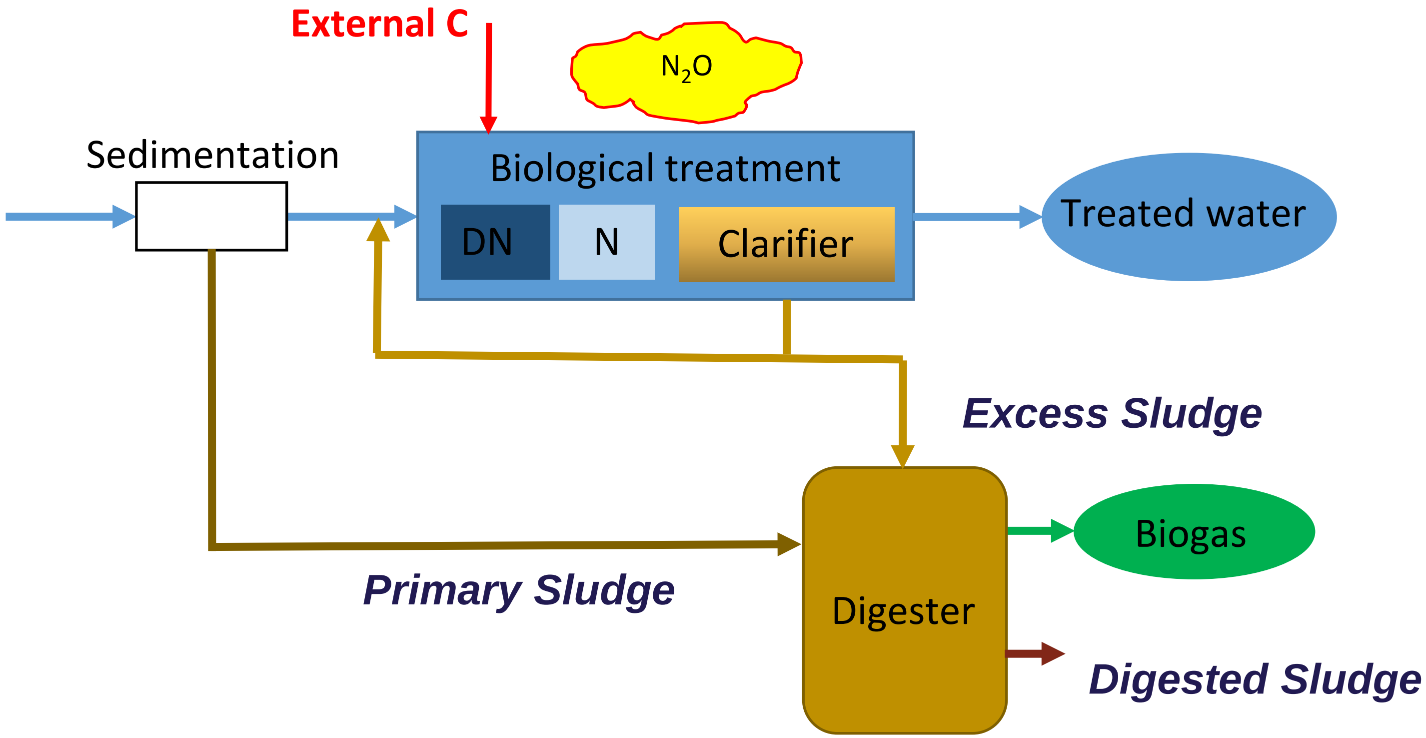
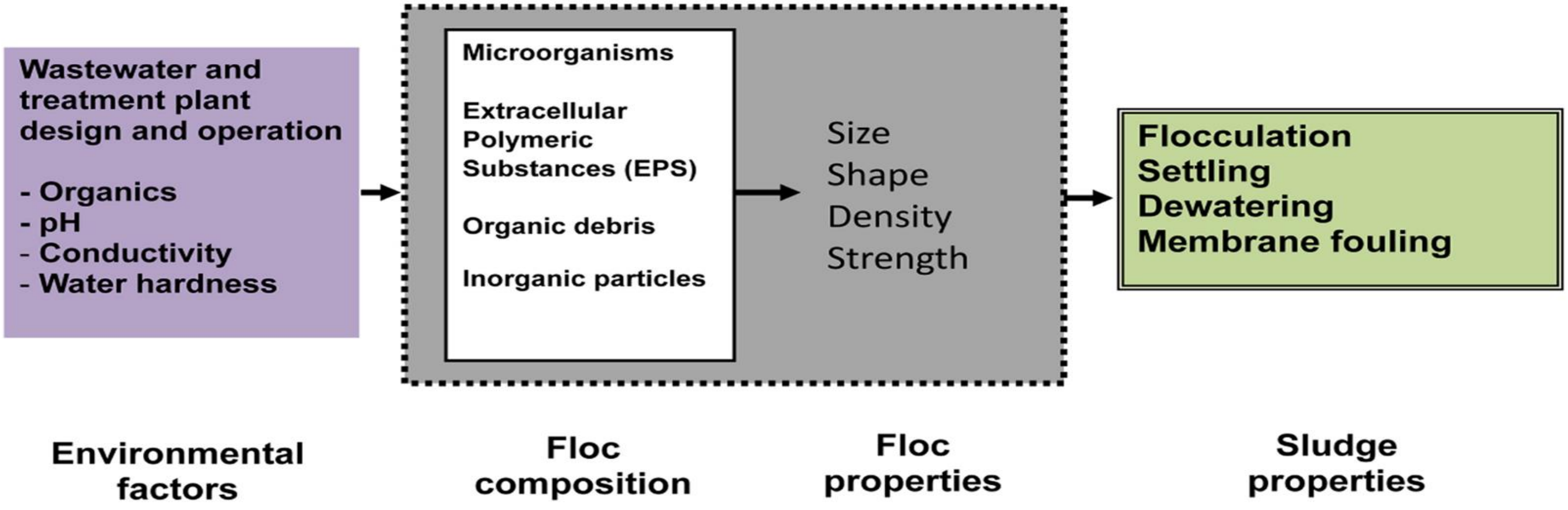
Background

- PhD. Dewatering of excess sludge / model compounds
- Membrane bioreactor / fouling control
- Sludge handling
- Phosphorus recovery /struvite, acidification, ash
- Refining carbon from wastewater





WATER RESEARCH 82 (2015) 14–24

Reed bed facility in Esbjerg

	Dimensioning	WWTP East	WWTP West
Sludge	Excess / digested	Excess sludge	Excess sludge
Load		400-500 m^3/portion	375-400 m^3/portion
Drainage time		20-25 hours	30-36 hours
Capacity	52 kg SS/m^2/year	38-42 kg SS/m^2/year	27-32 kg SS/m^2/year

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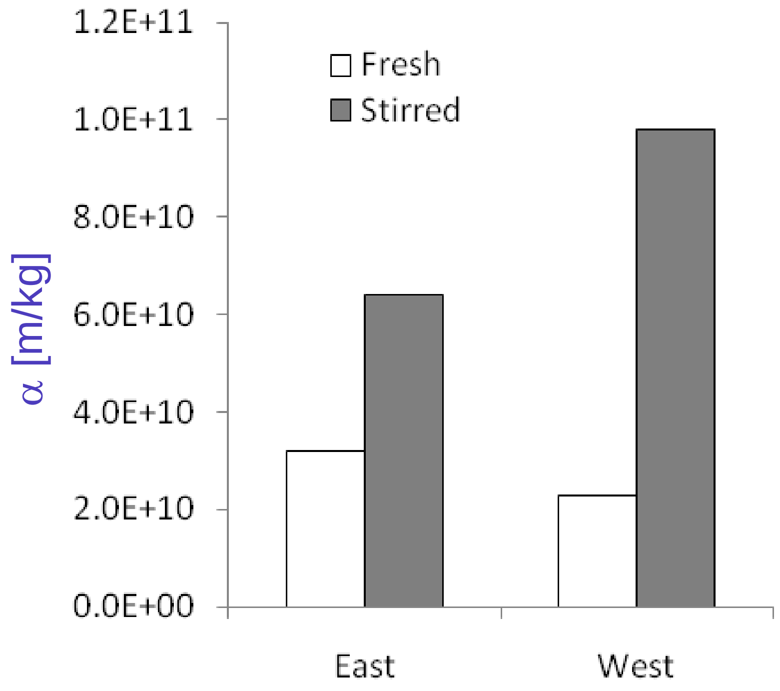
Sludge is a dynamic system



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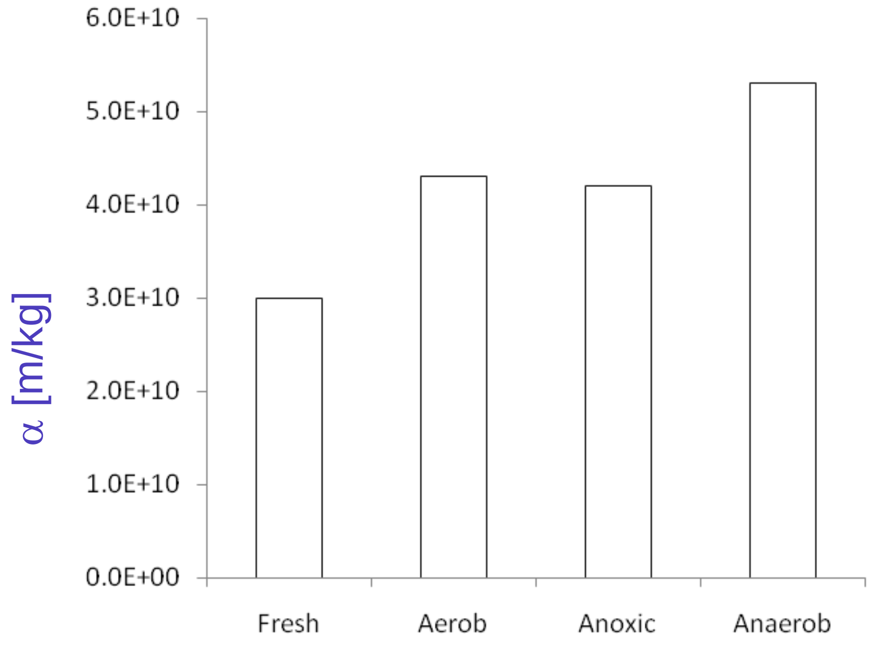

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Wastewater treatment plant

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Pipeline

-Anoxic condition (calciumnitrate)

-Gentle pumping

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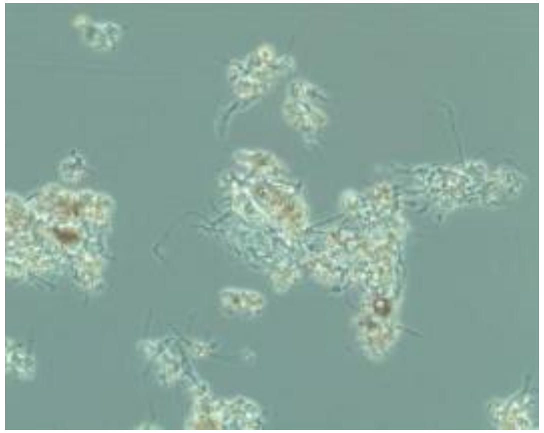
Storage tank

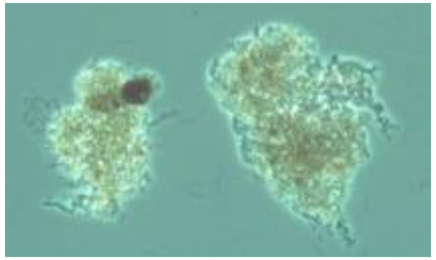
- Reestablish sludge flocs / aeration / calcium

↓

Red bed

- Load
- Rest period





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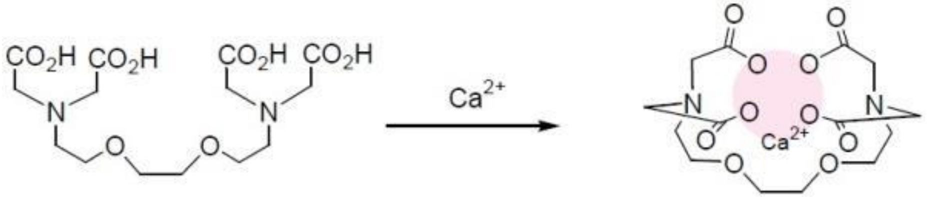
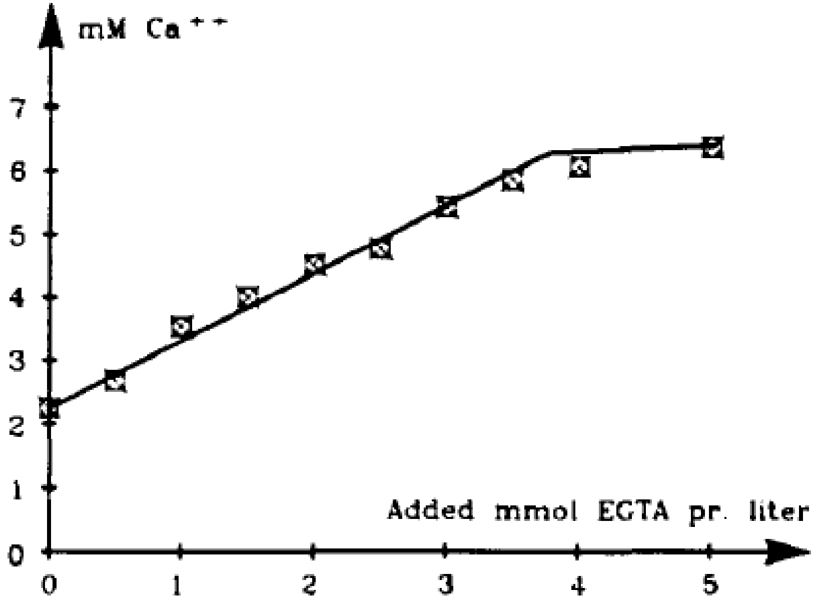
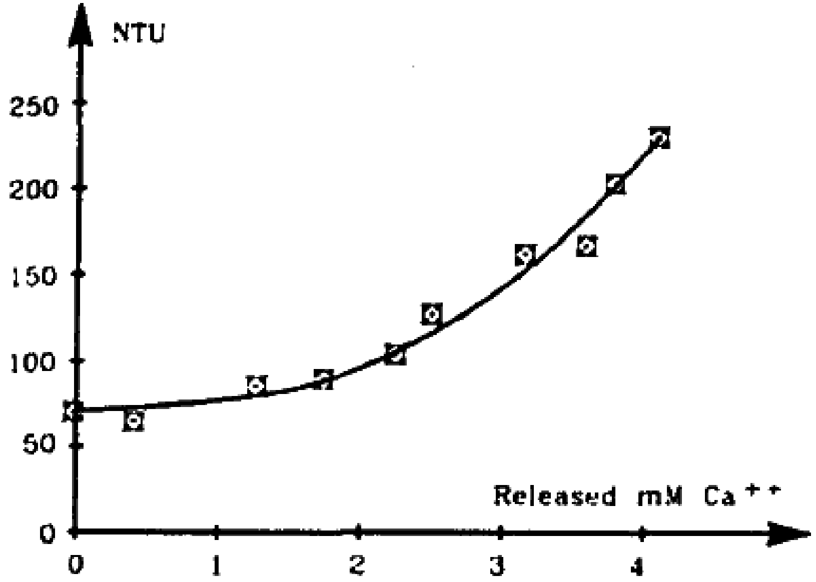
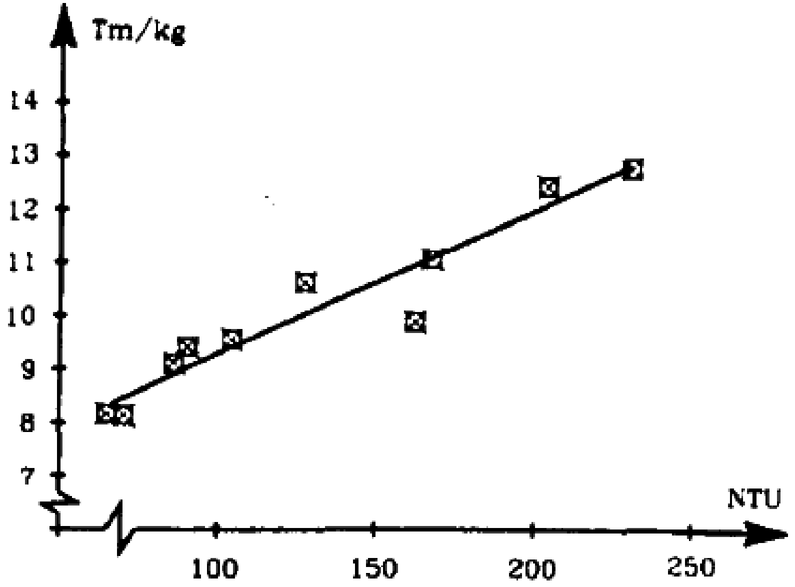
Calcium flocs

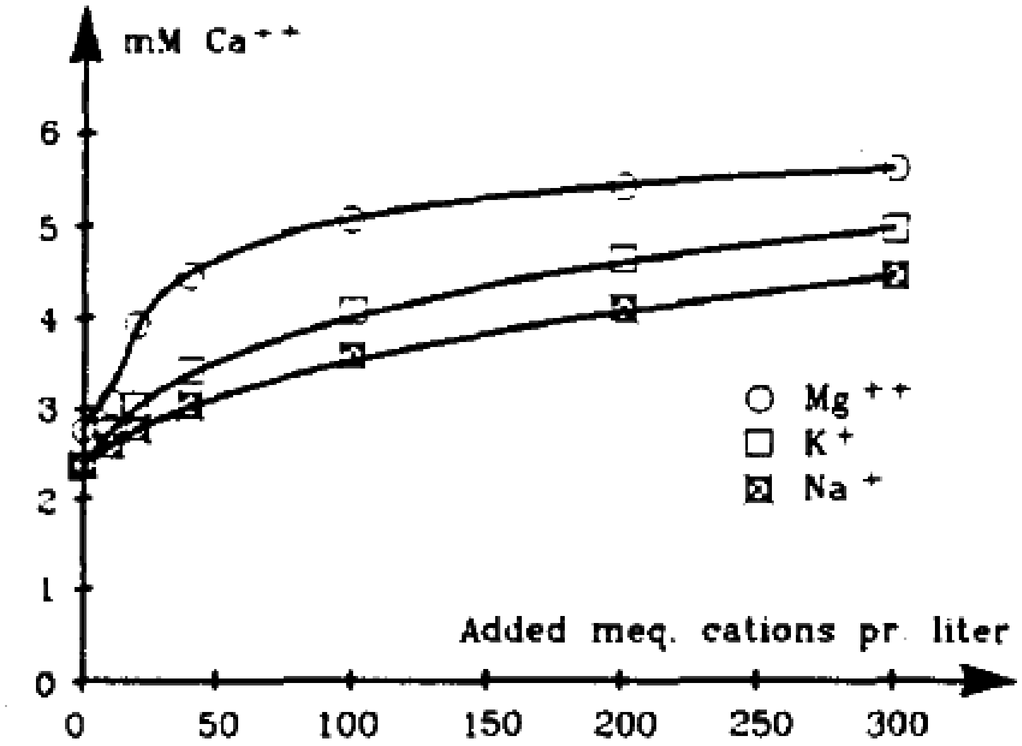




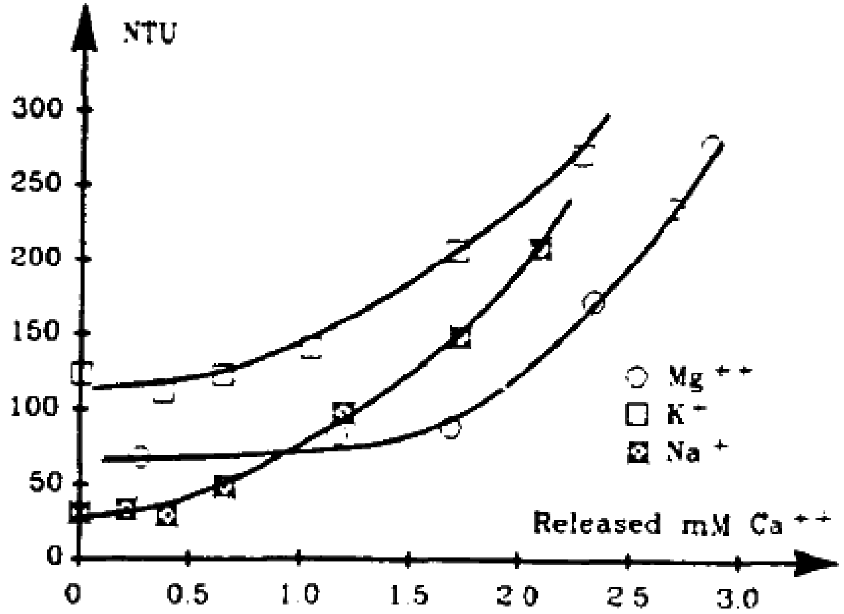


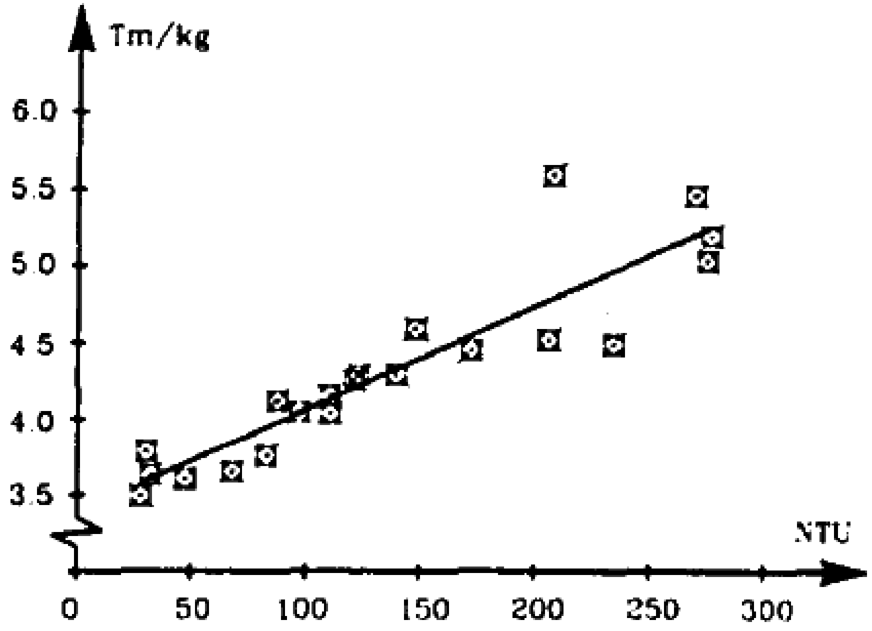


Other cations



	Unit	Median	Minimum	Maximum
pH	-	7.07	6.42	7.53
Conductivity	µS/cm	750	407	4350





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Anaerobic storage / digestion

Table 3 – Physical-chemical characteristics of primary, activated, digester (mesophilic, thermophilic) feed with surplus activated sludge and MBR sludge.

	Activated sludge[a]	MBR sludge[b]	Mesophilic sludge[a]	Thermophilic sludge[a]
Total protein (mg/gSS)	346 ± 111	185 ± 45	248 ± 12	155 ± 62
Total humics (mg/gSS)	58 ± 35	22 ± 8	112 ± 108	188 ± 92
Total polysaccharides (mg/gSS)	101 ± 35	111 ± 13	70 ± 5	78 ± 10
EPS (mg/gSS)	130 ± 65	89 ± 11	78 ± 49	41 ± 9
Mean floc size (μm)	125 ± 109	65 ± 23	51 ± 21	57 ± 11
Shear sensitivity, k_{SS}	0.062 ± 0.049	0.102 ± 0.066	0.244 ± 0.016	0.418 ± 0.337
SFF (kg/(m·s))	$83.3 \cdot 10^{-7}$	$72.9 \cdot 10^{-7}$	$9.7 \cdot 10^{-7}$	$0.78 \cdot 10^{-7}$

[a] Data from Mikkelsen and Keiding (2002).
[b] Data from Bugge et al. (2013).

Environmental factors

Table 4 – Link between sludge treatment and dewaterability.

Parameter	Effect
Conductivity	Changes in conductivity (high conductivity or dilution) lower specific flow rate This can be a problem due to road salting, intrusion of sea water and some industries
Water hardness	High water hardness improves specific flow rate Calcium carbonate can be added to improved dewaterability
pH	High pH leads to floc disintegration, which lowers the specific flow rate The water content in the formed filter cake may be lower if the pH value is lowered.
Storage	Anaerobic storage lowers specific flow rate Tanks/pipes with anaerobic pockets are problematic Addition of nitrate during storage or aeration can improve the filterability
Pumping	Vigorous pumping lowers specific flow rate Gentle pumping and mixing is recommended. Avoid sharp bends on pipes
Treatment system	Conventional plant usually gives better sludge than membrane bioreactors (MBR). Sludge from digesters is difficult to dewater.

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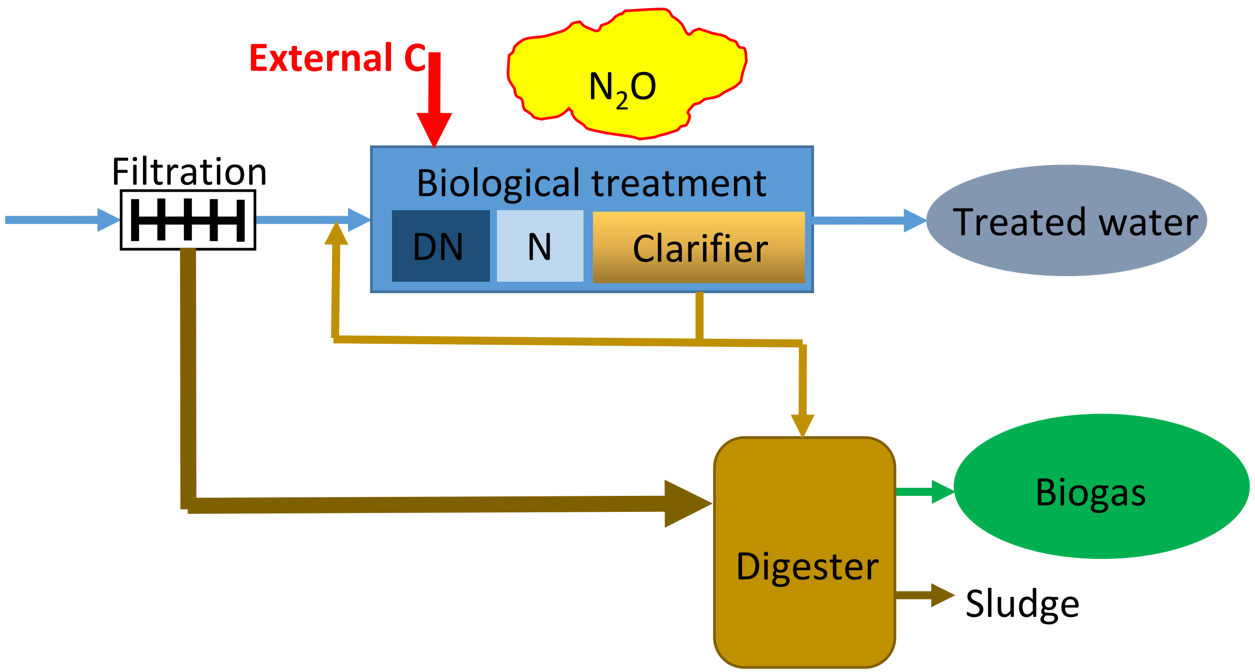
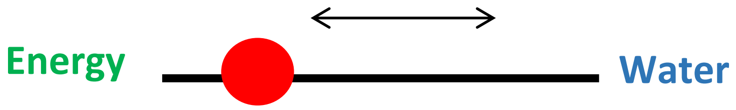
Carbon as a resource

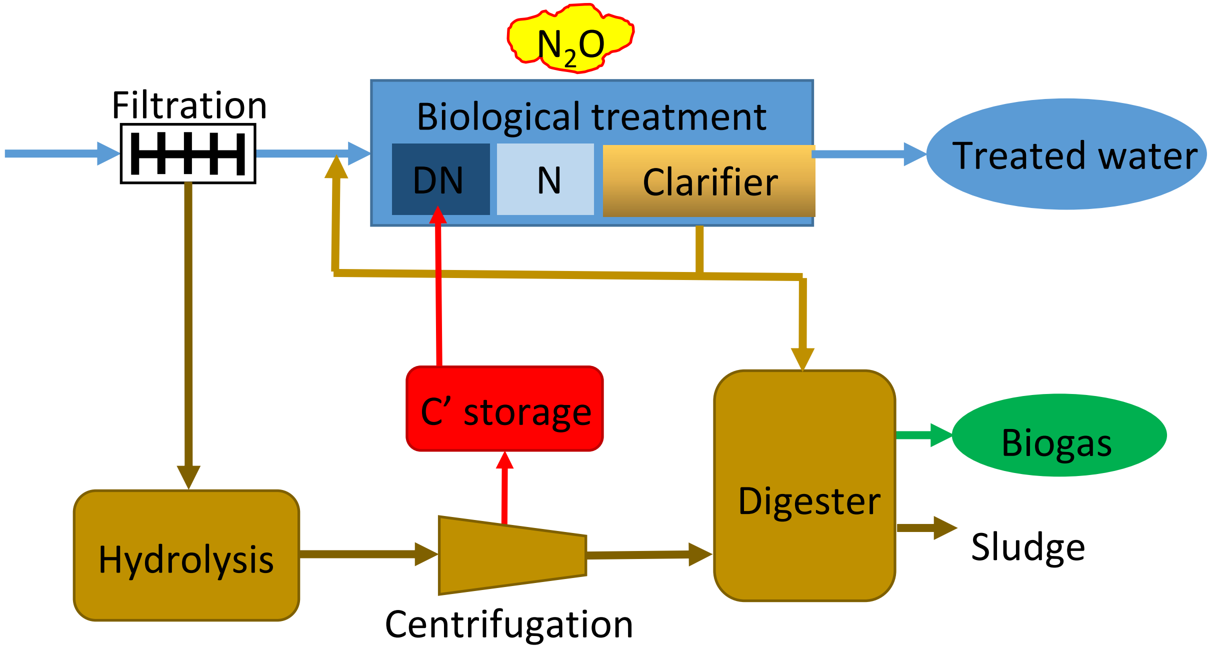


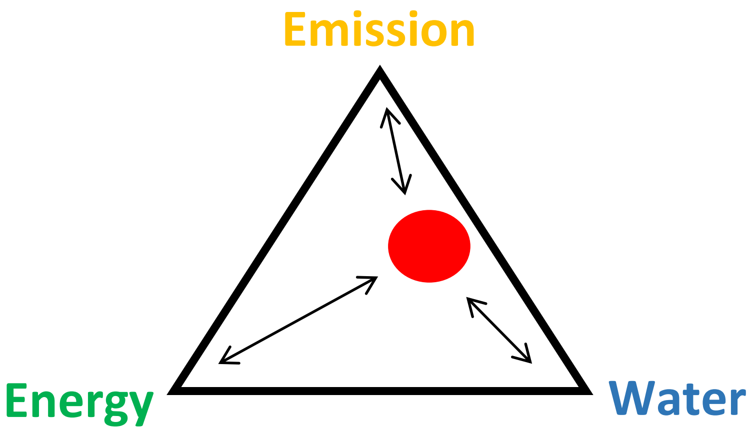


N_2O Nitrous oxide is a strong greenhouse gas, app. 300 as strong as carbon dioxide.

External C Extra cost

Refining carbon





Hydrolysis tank used for production of soluble COD / volatile fatty acids (VFA)

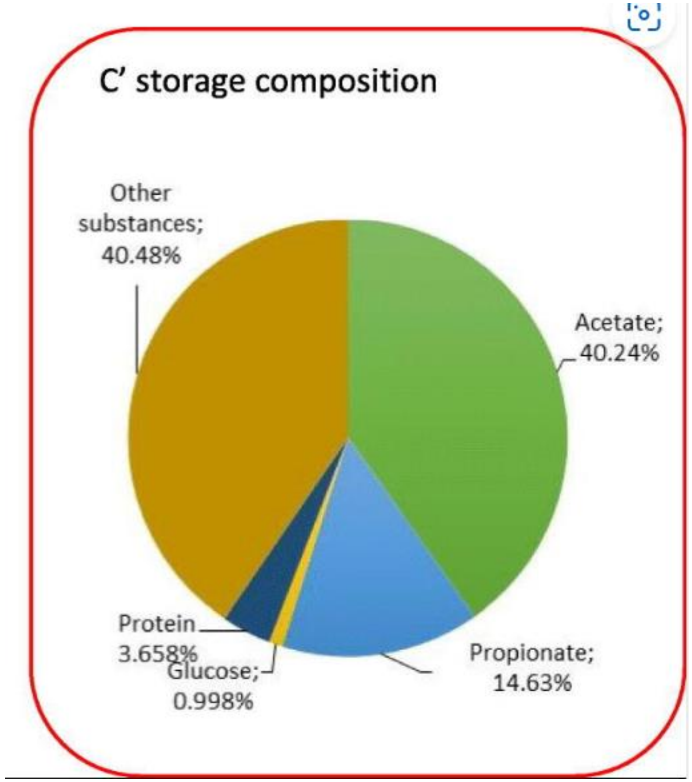
Storage tank with VFA either for the biological treatment (**Water** quality and low **Emission**) or the digester (**Energy**)

Hydrolysis

Table 1
Sludge characteristics before and after hydrolysis.

	Bruunshåb WWTP		Mariagerfjord WWTP	
	Raw	Hydrolyzed	Raw	Hydrolyzed
sCOD/tCOD (%)	4.4 ± 0.3	14.4 ± 4.1	9.8 ± 7.5	17.4 ± 8.8
VFA/VS (mg/g)	0.4 ± 0.2	30.1 ± 12.6	0.3 ± 0.5	14.3 ± 4.4
P-PO_4^{3-}/VS (mg/g)	1.5 ± 0.3	3.3 ± 0.7	0.9 ± 0.6	2.3 ± 0.6
NH_4^+/VS (mg/g)	2.5 ± 0.3	5.2 ± 2.1	1.5 ± 0.8	2.3 ± 1.0

Notice: tCOD and sCOD is the total and soluble chemical oxygen demand, VFA is volatile fatty acids, and VS volatile solid. Average value and standard deviation is given in the table based on triplicates.



Hydrolysis
VFA production 1000-2000 mg/l
Yield: 30-35 g/kg
Soluble COD: 2000 – 3500 mg/L
High temperature + pH => best result

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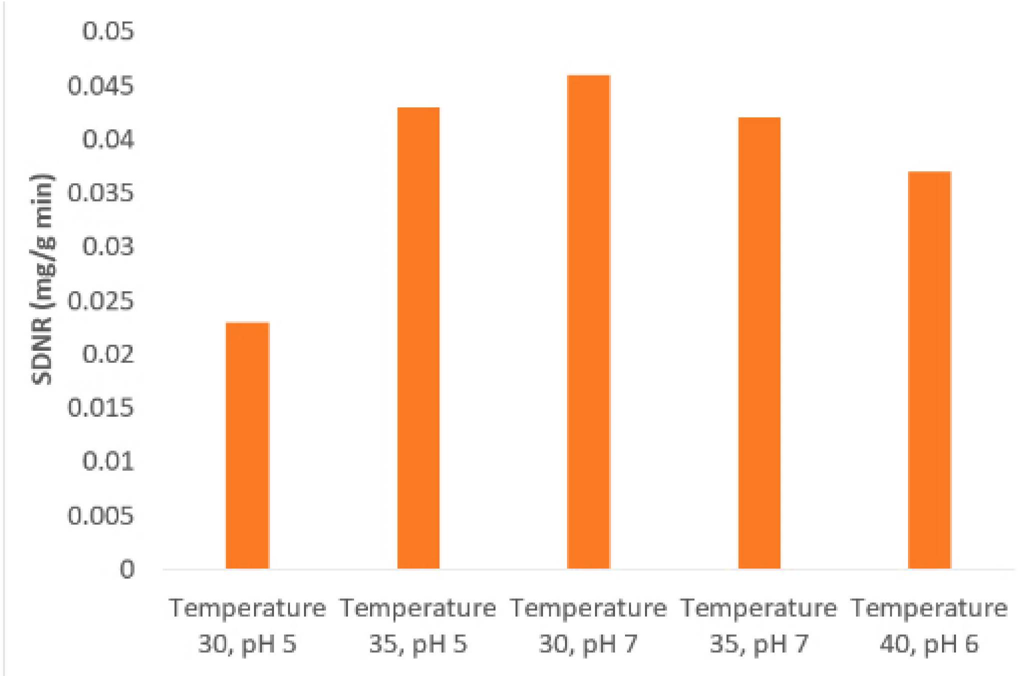
Science of the Total Environment 846 (2022) 157532

Denitrification rate



Separation and specific denitrification rate

Solid-liquid separation - App. 85% of dry matter removed

Specific denitrification rate: **0.02 – 0.04 mg/g min**
Acetate: 0.031 mg/g min

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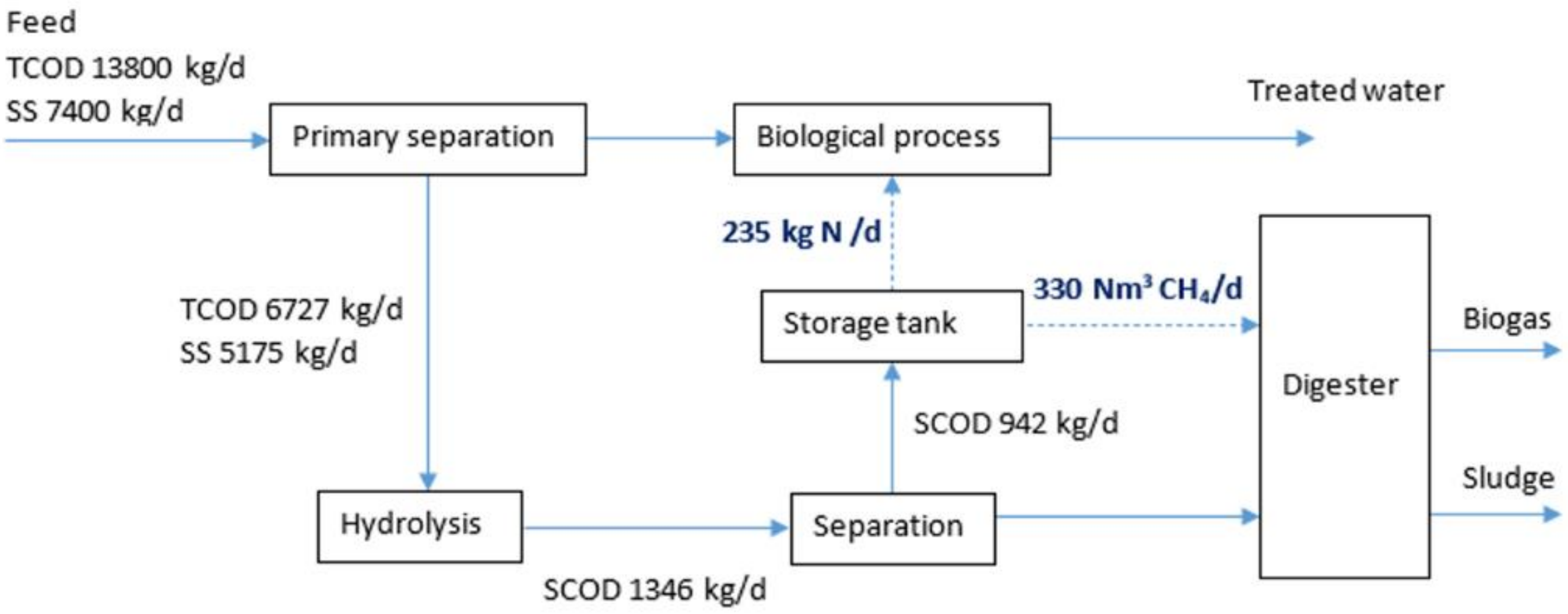
Mass balance for 100,000 PE plant



Cost for ethanol	3,938	DKK/d

Methane production	1,320	DKK/d

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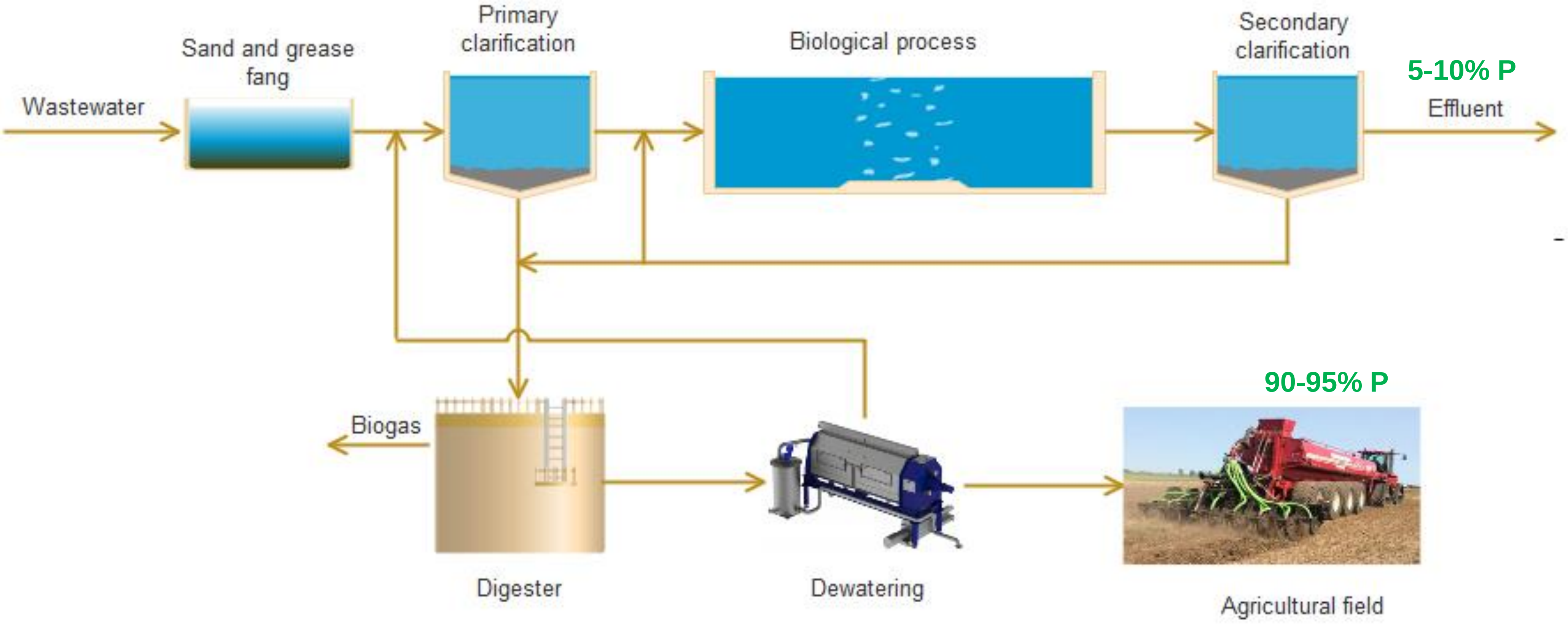
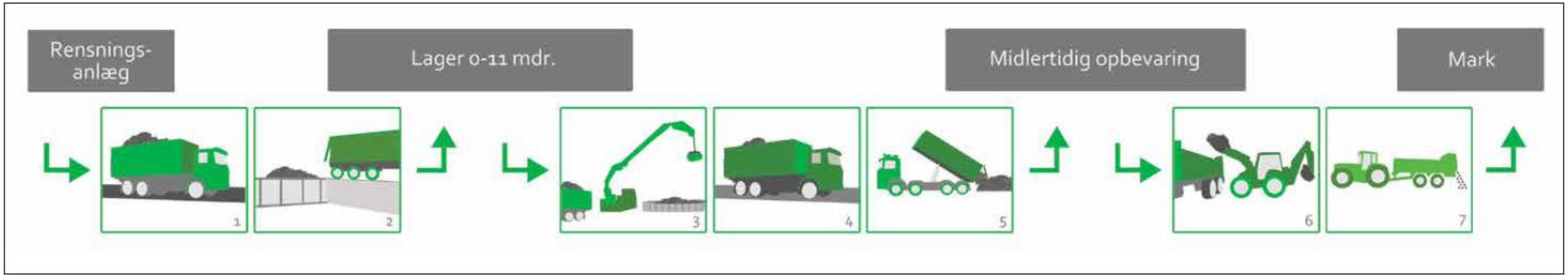
Phosphorus reuse

- Denmark goal: 80% phosphorus from wastewater recycled



Sludge handling



Figur 1. Containeren med biogødning hentes på renseanlægget og transporteres til lager, hvor det læses af. Når det er tid til spredning, skal biogødningen igen læsses på en lastbil, transporteres og læses af i et midlertidigt opbevaringsdepot, hvorefter det igen omlæsses til den spreder, der skal sprede det på marken.

Øget tørstof →

VÆSKE	PLASTISK MATERIALE	FAST STOF

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Sludge handling

Renseanlæg	Belastning (PE)	Rådnetank	Biogødningens hånd-terbarhed
1	200.000	+	God
2	40.000	-	God
3	200.000	+	God
4	200.000	+	God
5	15.000	-	God
6	20.000	+	God
7	170.000	+	God
A	75.000	-	Dårlig
B	30.000	-	Dårlig
C	15.000	-	Dårlig
D	7.500	-	Dårlig
E	75.000	+	Dårlig
F	25.000	-	Dårlig
G	10.000	-	Dårlig

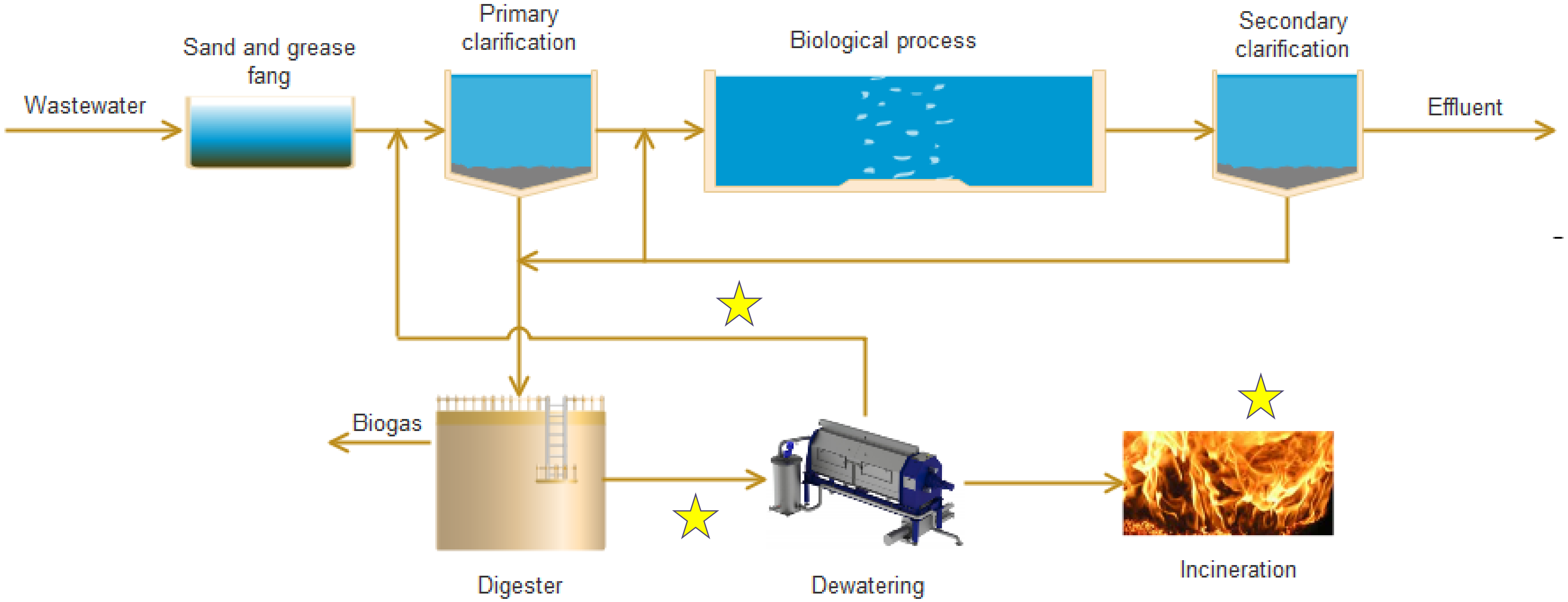
Figur 2: Liste over renseanlæg, der indgik i undersøgelsen. Listen er anonymiseret af hensyn til det enkelte anlæg.

	Dårlig håndterbarhed	God håndterbarhed
Beskrivelse	Biogødning, der skiller ad	Biogødning, der ikke ændrer karakter
pH	< 7	> 7
TS	< 20 %	> 20 %
Glødetab	> 65 %	< 65 %
Ledningsevne	Stigende ledningsevne ved lagring	Konstant ledningsevne ved lagring

Figur 8: Resultater over de målte parametre, der beskriver biogødning, som har henholdsvis dårlig og god håndterbarhed.

Alternative phosphorus recovery

Unwanted compounds (heavy metals, pathogens, micropollutants, microplast …)



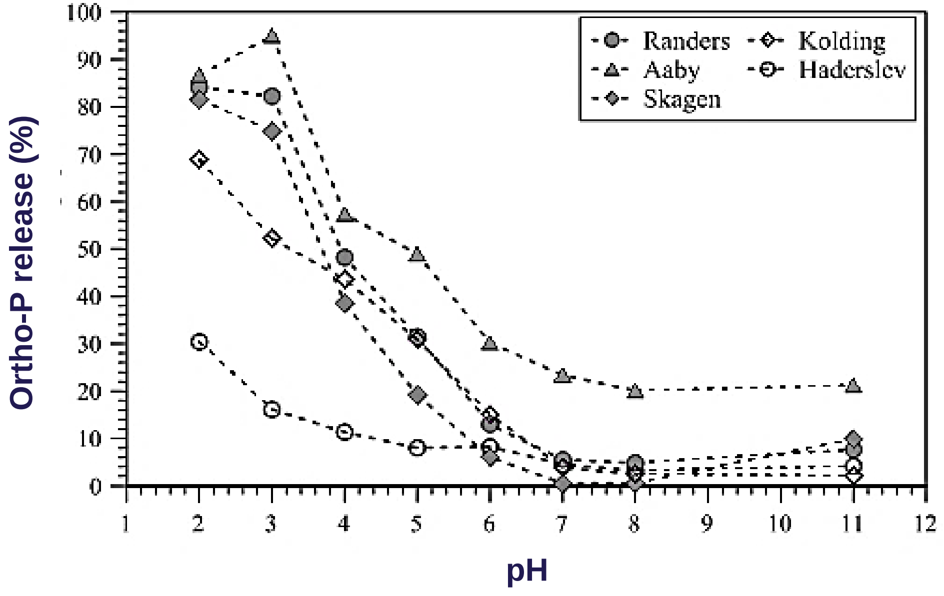
Sludge liquor

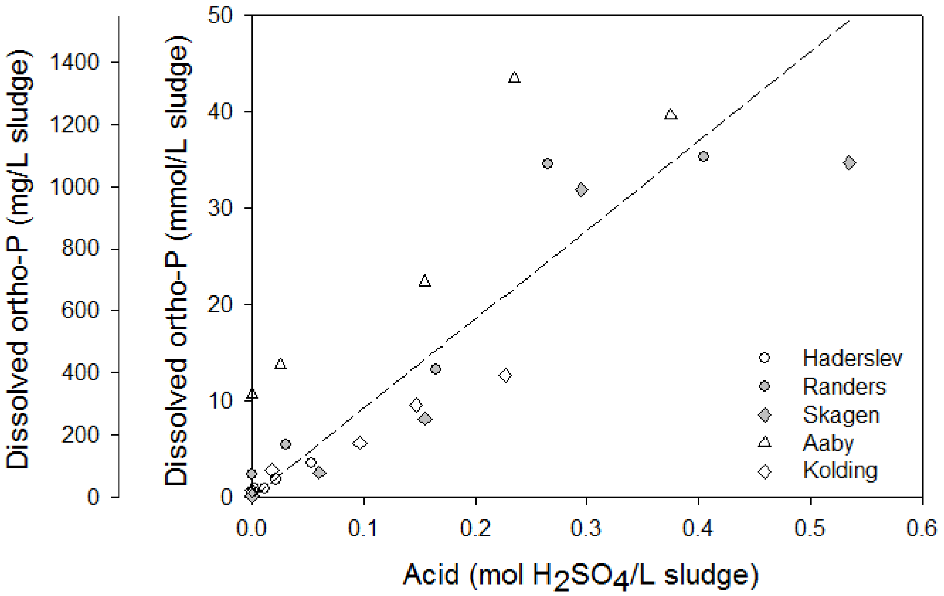
Digested sludge extraction

Sludge ash

Acidification

	Sludge type	Inlet flow [m³/d]	P Inlet [mg/L]	P outlet [mg/L]
Randers	Digested (pri/sec)	23,150	6.78	0.42
Aaby	Digested (pri/sec)	16,874	6.70	0.34
Skagen	Digested (pri/sec)	8,736	20	0.47
Kolding	Digested (primary)	28,449	6.20	1.03
Haderslev	Non-digested (Pri/ sec)	10,953	7.75	0.45





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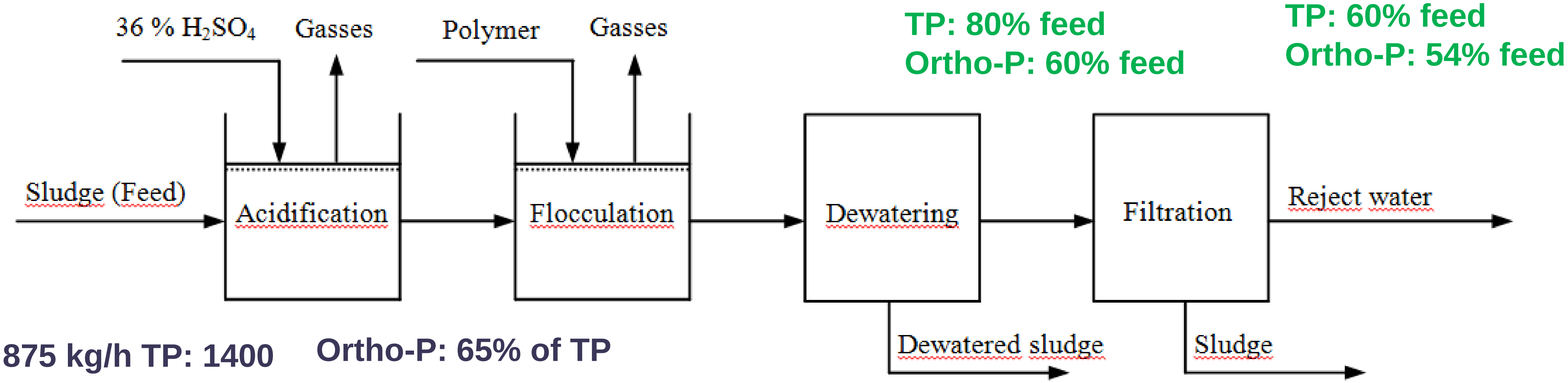
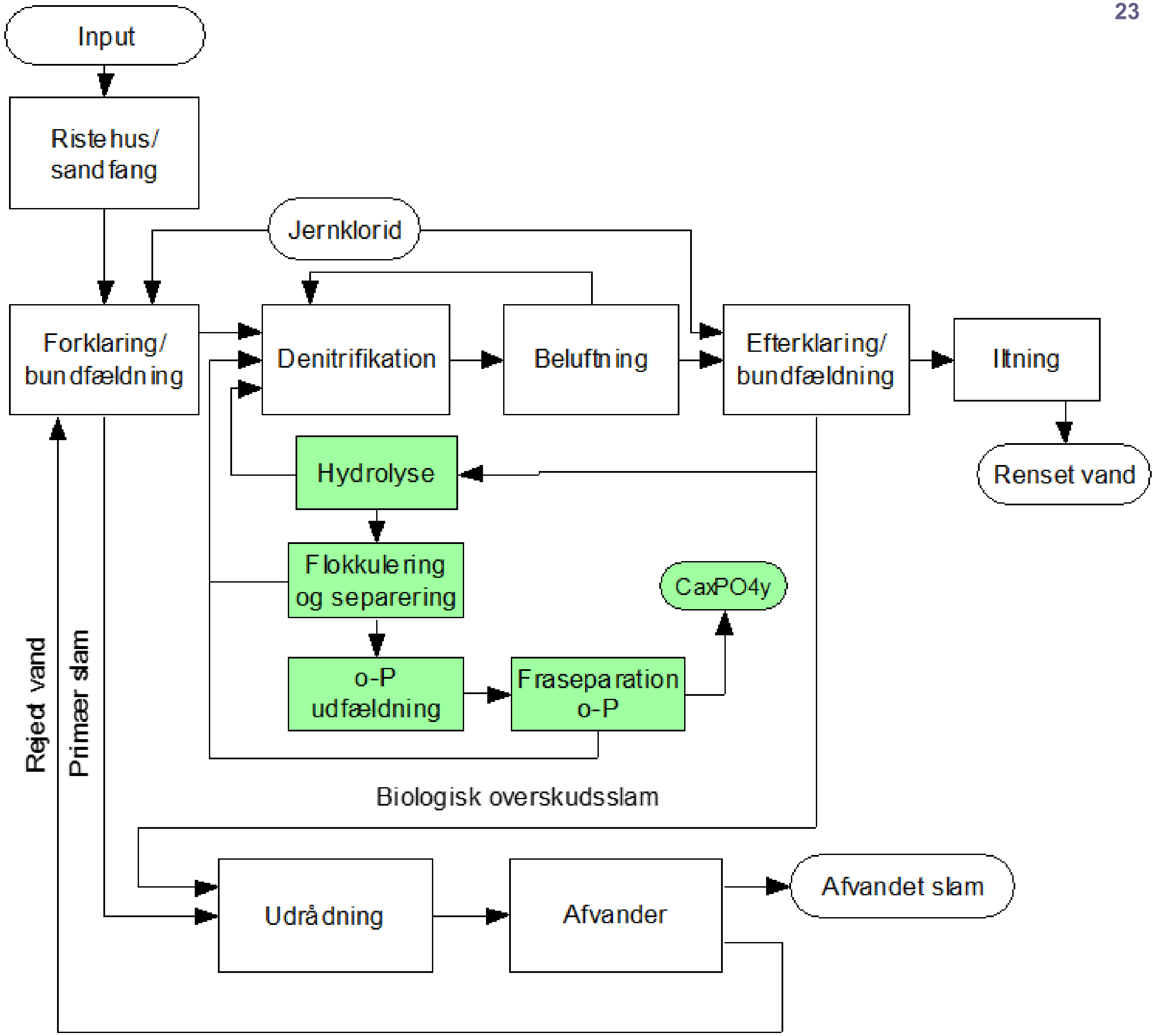
Phosphorus recovery



Flow: 875 kg/h TP: 1400 mg/kg
Ortho-P: 5.8% of TP

Phosphorus recovery after hydrolysis

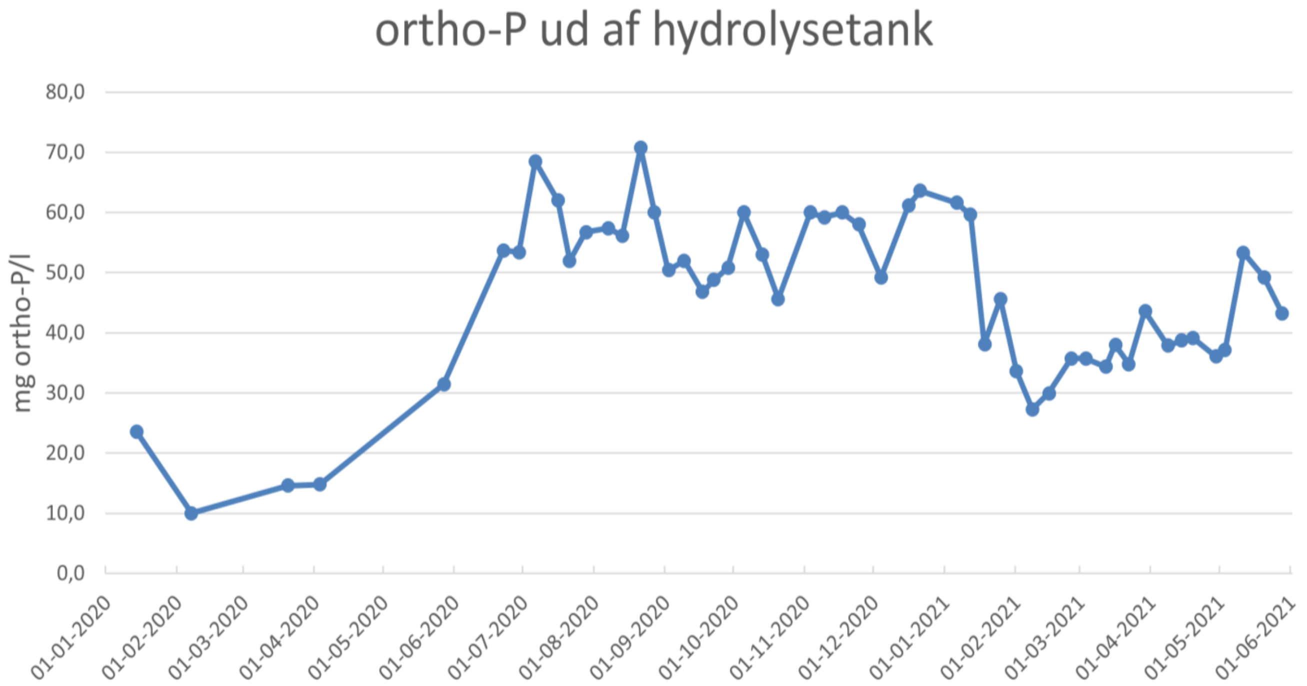
1. Dissolved phosphorus relatively high (35-50 mg/L)
2. Remove dry material
3. Precipitation
   - Calcium salt
     - Cheaper than magnesium salt
     - Low ammonium content
4. Separation

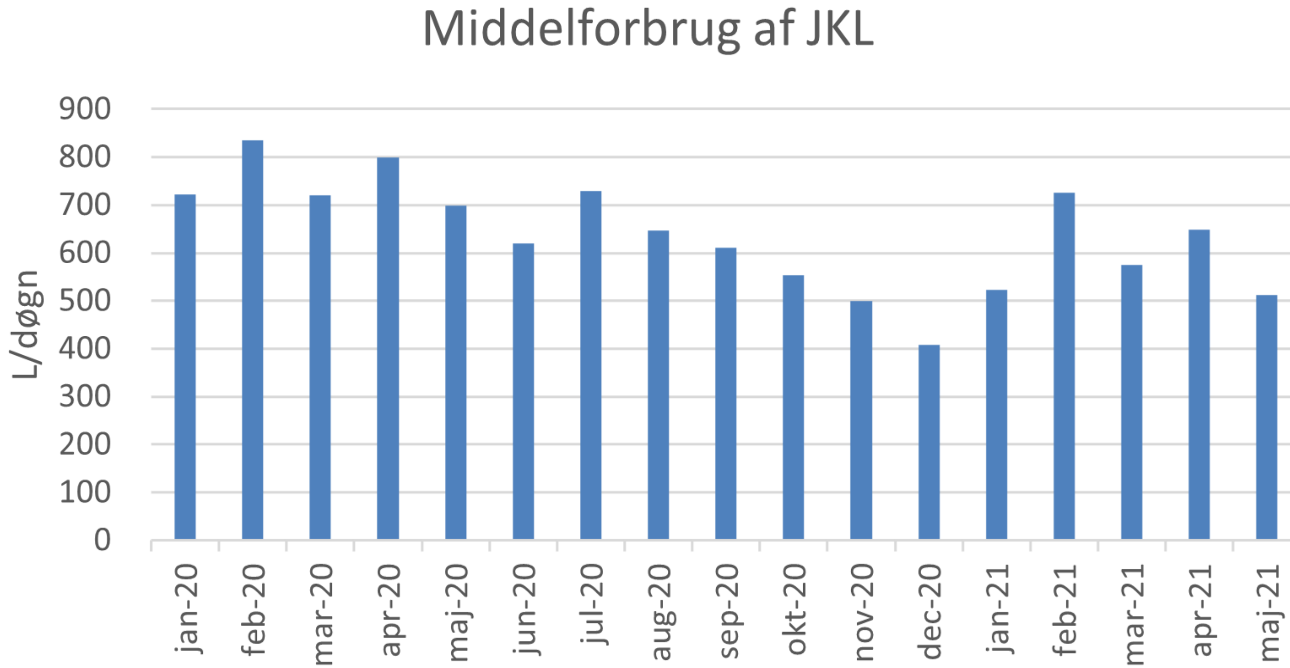


Optimisation of bio-P process

Increased concentration ortho-phosphate in hydrolysis

Forår 2020: Reduction of ironchloride (JKL)





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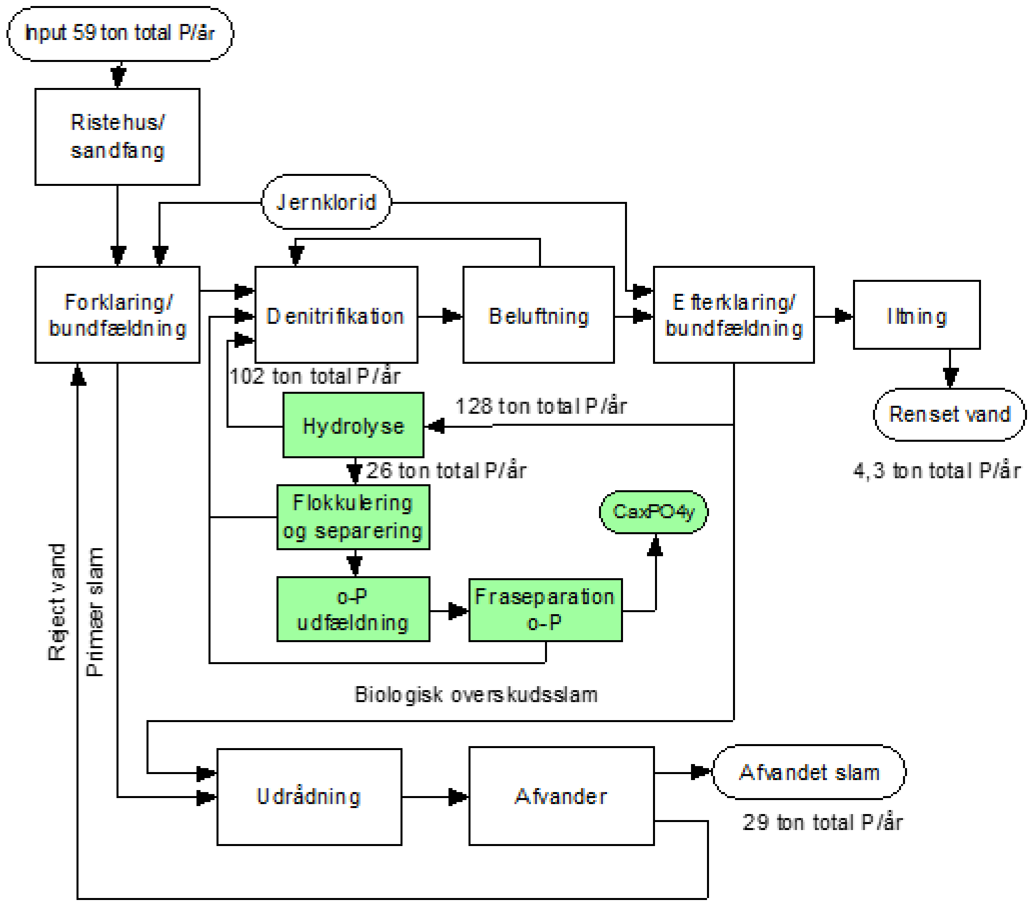
Businesscase for recovery

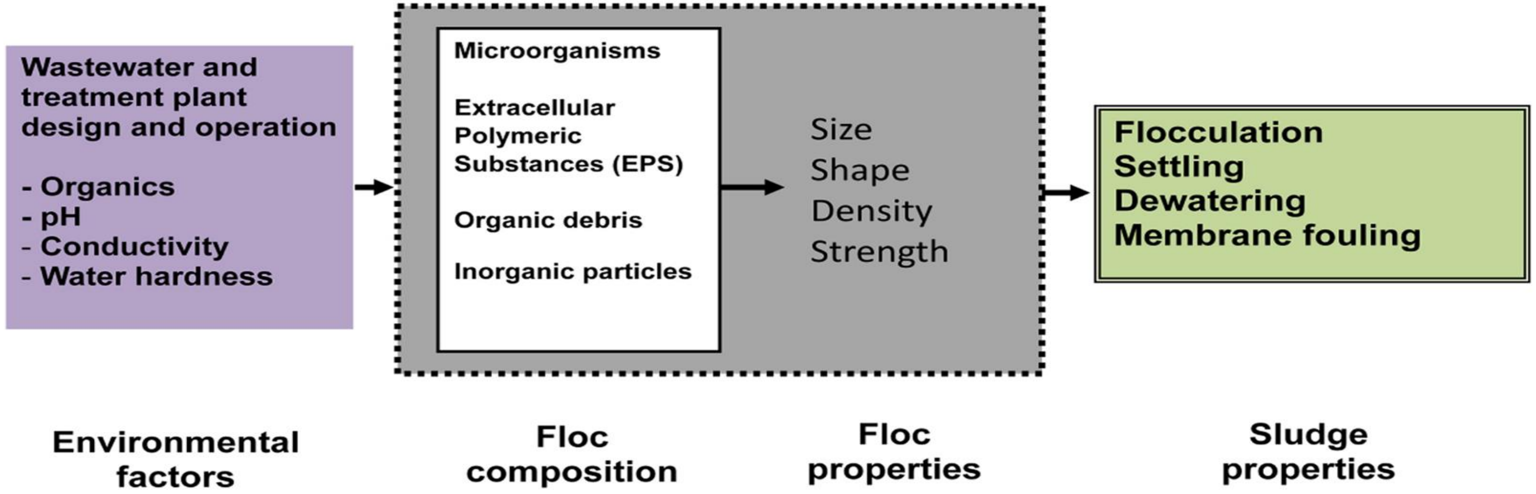
- Potential yield at Randers Centralrenseanlæg:

Ortho-P in hydrolyse tank	Yield	Yield compared inlet concentration
40 mgP/l	20,0 tonP/år	34%
50 mgP/l	25,6 tonP/år	43%
80 mgP/l	40,9 tonP/år	69%

- Proces cost estimate (incl salts) 47-144 kr./kgP depending on orthoP concentration in hydrolysis tank and chemicals (ca. 70 kr./kgP at 50 mgP/l og $CaOH_2$)



Conclusion



Sludge properties

Wastewater as a ressource

Carbon ressource: biogas, VFA, bioplastic, EPS, carbon capture (pyrolyse, HTC), biofuel (HTL)

Phosphorus ressource: Recovery from wastewater or ash

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