

Appendix 1: Screening station

The trash removed by the screens will affect the particulate parameters, with the exception of particulate phosphorus and nitrogen that is set equal to the measured values. Unlike the other processes in the treatment plant, the calculation on the screening station has been done backwards. Meaning the concentration leaving the screening station has been set equal to the concentrations measured and calculated based on influent data from IVAR SNJ. This is done due to the sampling technique performed at IVAR SNJ. The reject flow from the screw compressor is return to the treatment plant at IVAR SNJ, in the calculations the contribution from the screw compressor reject flow has been neglected due to very low concentrations.

Flow entering screw compressor is calculated based on the following equation:

$$Q_{SC} = \frac{M_{\text{Trash}} * (1 - f_{TS,SS})}{1000 \frac{1}{m^3}}$$

It is assumed that 1 kg wastewater = 1 liter wastewater.

Flow and concentration entering screening station:

$$Q_{in,SS} = Q_{eff,SS} + Q_{SC}$$

$$C_{in,SS} = \frac{(Q_{eff,SS} * C_{eff,SS}) + (Q_{SC} * C_{SC})}{Q_{in,SS}}$$

(SC = Screw compressor, SS= Screening station)

CONCENTRATION ENTERING SCREW COMPRESSOR (SC)		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD _{in,SC}	rbCOD _{eff,SS} + ssbCOD _{eff,SS} + snbCOD _{eff,SS}
	rbCOD _{in,SC}	rbCOD _{eff,SS}
	VFA _{in,SC}	VFA _{eff,SS}
	ssbCOD _{in,SC}	ssbCOD _{eff,SS}
	snbCOD _{in,SC}	snbCOD _{eff,SS}

Particulate COD	tpCOD_{in,SC}	$\frac{\text{tpCOD}_{r,SS}}{Q_{SC}}$ Where: $\text{tpCOD}_{r,SS} = \text{VSS}_{r,SS} * f_{cv}$
	psbCOD_{in,SC}	$\frac{\text{psbCOD}_{r,SS}}{Q_{SC}}$ Where: $\text{psbCOD}_{r,s} = \text{tpCOD}_{r,s} * \left(\frac{\text{psbCOD}_{\text{eff},SS}}{\text{tpCOD}_{\text{eff},SS}} \right)$
	pnbCOD_{in,SC}	$\frac{\text{pnbCOD}_{r,SS}}{Q_{SC}}$ Where: $\text{pnbCOD}_{r,s} = \text{tpCOD}_{r,SS} * \left(\frac{\text{pnbCOD}_{\text{eff},SS}}{\text{tpCOD}_{\text{eff},SS}} \right)$
Suspended solids	TSS_{in,SC}	$\frac{\text{TSS}_{r,SS}}{Q_{SC}}$ Where: $\text{TSS}_{r,SS} = M_{\text{trash}} * f_{TS,SS}$
	VSS_{in,SC}	$\frac{\text{VSS}_{r,SS}}{Q_{SC}}$ Where: $\text{VSS}_{r,SS} = 0,74 * \text{TSS}_{r,SS}$
Phosphorus	Tot-P_{in,SC}	TotP _{eff,SS}
	PO4_{in,SC}	PO4 _{eff,SS}
Nitrogen	Tot-N_{in,SC}	TotN _{eff,SS}
	NH4_{in,SC}	NH4 _{eff,SS}
	NO3_{in,SC}	NO3 _{eff,SS}
Oxygen	DO_{in,SC}	DO _{eff,SS}

Appendix 2: Sand and grease removal

Input concentration entering sand and grease trap:

The capacity of the sand and grease trap is 2,8 m³/s, if the flow from the screening station (Q_{eff,S}) summarized with the reject flow (Q_{rj}) exceeds 2,8 m³/s, the residue flow will go in bypass. This needs to be included in the mass balance model, se the equation for Q_{in,SG}. The concentrations entering the sand and grease trap will be dependent on the masses leaving the screening station, the masses in the reject and the masses going in bypass. See the general equation for C_{in,SG}.

$$C_{in,SG} = \frac{(Q_{eff,SS} * C_{eff,SS}) + (Q_{rj} * C_{rj}) - (Q_{by,SS} * C_{by,SS})}{Q_{in,SG}}$$

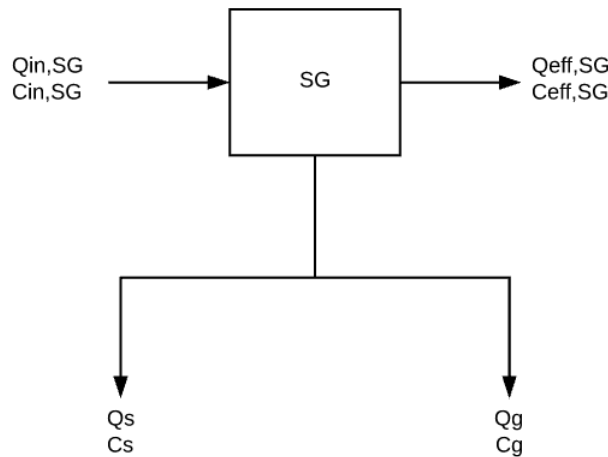
Where:

SG= Sand/grease trap

rj = reject

by,SS = bypass after screening station

The removed substances from the sand and grease trap have two different path, the total system is shown in the figure below:



Calculation of flows:

$$Q_{in,SG} = [if (Q_{eff,SS} + Q_{rj}) \geq 2,8; 2,8; (Q_{eff,SS} + Q_{rj})]$$

$$Q_s = \frac{M_s * (1 - f_{TS,S})}{1000 \frac{1}{m^3}}$$

$$Q_G = \frac{M_G * (1 - f_{TS,G})}{1000 \frac{1}{m^3}}$$

$$Q_{eff,SG} = Q_{in,SG} - Q_S - Q_G$$

CONCENTRATION REMOVED BY SAND AND GREASE TRAP (C _s and C _G)		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD _{r,SG}	tsCOD _{in,SG}
	rbCOD _{r,SG}	rbCOD _{in,SG}
	VFA _{r,SG}	VFA _{in,SG}
	ssbCOD _{r,SG}	ssbCOD _{in,SG}
	snbCOD _{r,SG}	snbCOD _{in,SG}
Particulate COD	tpCOD _{r,SG}	$tpCOD_S = tpCOD_{in,SG}$ $tpCOD_G = \frac{tpCOD_{r,S}}{Q_G}$ Where: $tpCOD_{r,G} = VSS_{r,G} * f_{cv}$
	psbCOD _{r,SG}	$psbCOD_S = psbCOD_{in,SG}$ $psbCOD_G = \frac{psbCOD_{r,G}}{Q_G}$ Where: $psbCOD_{r,G} = tpCOD_{r,G} * \left(\frac{psbCOD_{in,SG}}{tpCOD_{in,SG}} \right)$
	pnbCOD _{r,SG}	$pnbCOD_G = \frac{pnbCOD_{r,G}}{Q_G}$ Where: $pnbCOD_{r,G} = tpCOD_{r,G} * \left(\frac{pnbCOD_{in,SG}}{tpCOD_{in,SG}} \right)$
	TSS _{r,SG}	$TSS_S = \frac{TSS_{r,S}}{Q_S}$

Suspended solids		$\text{TSS}_G = \frac{\text{TSS}_{r,G}}{Q_G}$ <p>Where:</p> $\text{TSS}_{r,S} = M_S * f_{TS,S}$ $\text{TSS}_{r,G} = M_G * f_{TS,G}$
	VSS_{r,SG}	$\text{VSS}_S = \text{VSS}_{in,SG}$ $\text{VSS}_G = \frac{\text{VSS}_{r,G}}{Q_G}$ <p>Where:</p> $\text{VSS}_{r,G} = f_{VSS,G} * \text{TSS}_{r,G}$
Phosphorus	TotP_{r,SG}	TotP _{in,SG}
	PO₄_{r,SG}	OrthoP _{in,SG}
Nitrogen	TotN_{r,SG}	TotN _{in,SG}
	NH₄_{r,SG}	NH ₄ _{in,SG}
	NO₃_{r,SG}	NO ₃ _{in,SG}
Oxygen	DO_{r,SG}	DO _{in,SG}

Effluent concentration ($C_{eff,SG}$):

$$C_{eff,SG} = \frac{(Q_{in,SG} * C_{in,SG}) - (Q_G * C_G) - (Q_S * C_S)}{Q_{eff,SG}}$$

Appendix 3: Mechanical drum filter

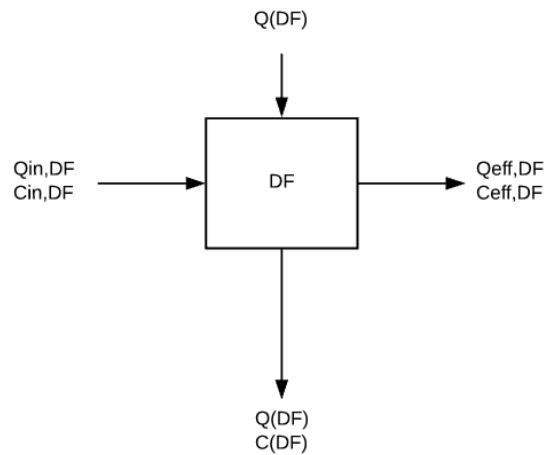
The capacity of the drum filter have been set to 2,5 m³/s, because this is the maximum flow the biological treatment step can handle. If the flow from the sand and grease trap (Q_{eff,SG}) exceeds 2,5 m³/s, the residue flow will go in bypass. The flow entering the drum filter (Q_{in,DF}) is given by the following equation.

$$Q_{in,DF} = [if\ Q_{eff,SG} \geq 2,5 \frac{m^3}{s}; 2,5 \frac{m^3}{s}; Q_{eff,SG}]$$

$$C_{in,DF} = \frac{(Q_{eff,SG} * C_{ff,SG}) - (Q_{By,SG} * C_{By,SG})}{Q_{in,DF}}$$

The drum filter is frequently backwashed with treated wastewater. The concentrations transported with the treated wastewater is assumed to be negligible, and it is assumed that the flow entering the drum filter (Q_{in,DF}) is equal to the flow exiting the drum filter (Q_{eff,DF}). The flow sent to sludge treatment (Q_{DF}) is set equal to 0,014 m³/s, based on data from IVAR SNJ. The concentration leaving the drum filter is calculated based on this general equation:

$$C_{DF} = \frac{(Q_{in,DF} + Q_{DF}) * C_{in,DF} - (Q_{eff,DF} * C_{eff,DF})}{Q_{DF}}$$



EFFLUENT CONCENTRATION FROM DRUM FILTER		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD_{eff,DF}	tsCOD _{in,DF}
	rbCOD_{eff,DF}	rbCOD _{in,DF}
	VFA_{eff,DF}	VFA _{in,DF}
	ssbCOD_{eff,DF}	ssbCOD _{in,DF}
	snbCOD_{eff,DF}	snbCOD _{in,DF}
Particulate COD	tpCOD_{eff,DF}	psbCOD _{eff,DF} + pnbCOD _{eff,DF}
	psbCOD_{eff,DF}	psbCOD _{in,DF} - psbCOD _{r,DF} Where: $\text{psbCOD}_{r,DF} = f_{cv} * VSS_{r,DF} * \left(\frac{\text{psbCOD}_{in,DF}}{\text{tpCOD}_{in,DF}} \right)$
	pnbCOD_{eff,DF}	pnbCOD _{in,DF} - pnbCOD _{r,DF} Where: $\text{pnbCOD}_{r,DF} = f_{cv} * VSS_{r,DF} * \left(\frac{\text{pnbCOD}_{in,DF}}{\text{tpCOD}_{in,DF}} \right)$
Suspended solids	TSS_{eff,DF}	TSS _{in,DF} - TSS _{r,DF} Where: $\text{TSS}_{r,DF} = 0,5 * \text{TSS}_{in,DF}$
	VSS_{eff,DF}	VSS _{in,DF} - VSS _{r,DF} Where: $\text{VSS}_{r,DF} = 0,773 * \text{TSS}_{r,DF}$
Phosphorus	TotP_{eff,DF}	TotP _{in,DF} - TotP _{r,DF} Where: $\text{TotP}_{r,DF} = (\text{TotP}_{in,DF} - \text{PO4}_{in,DF}) * 0,5$
	PO4_{eff,DF}	PO4 _{in,DF}
Nitrogen	TotN_{eff,DF}	TotN _{in,DF} - TotN _{r,DF} Where: $\text{TotN}_{r,DF} = (\text{TotN}_{in,DF} - \text{NH}_{4,in,DF} - \text{NO}_{3,in,DF}) * 0,5$
	NH4_{eff,DF}	NH4 _{in,DF}
	NO3_{eff,DF}	NO3 _{in,DF}
Oxygen	DO_{eff,DF}	DO _{in,DF}

Appendix 4: All Calculation for AN1

1. Hydrolysis

The formulas used to find the different COD fractions produced during hydrolysis, and the biomass reduction during hydrolysis are given in the table below.

HYDROLYSIS IN AN1		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{hyd,AN1}$	$\left(\frac{k_{hyd} V_{tot,AN1} psbCOD_{in}}{Q_R} \right) f_s$
	$rbCOD_{hyd,AN1}$	$tsCOD_{hyd,AN1} * f_{rbCOD}$
	$ssbCOD_{hyd,AN1}$	$tsCOD_{hyd,AN1} * f_{ssbCOD}$
	$snbCOD_{hyd,AN1}$	$tsCOD_{hyd,AN1} * f_{snbCOD}$
Particulate COD	$tpCOD_{hyd,AN1}$	$\left(\frac{k_{hyd} V_{tot,AN1} psbCOD_{in,AN1}}{Q_R} \right) f_p$
	$psbCOD_{hyd,AN1}$	$tpCOD_{hyd,AN1} * f_{psnbCOD})$
	$pnbCOD_{hyd,AN1}$	$tpCOD_{hyd,AN1} * f_{pnbCOD}$
Suspended solids	$TSS_{hyd,AN1}$	
	$VSS_{hyd,AN1}$	$\frac{psbCOD_{hyd,AN1}}{f_{cv}}$

2. Acidogenesis fermentation

The biodegradable soluble COD available for fermentation in AN1 is the particulate COD solubilized through hydrolysis, and is given by the equation below:

$$bsCOD_{in,AN1} = tsCOD_{hyd,AN1} * (f_{rbCOD} + f_{ssbCOD})$$

The biodegradable soluble COD converted to VFA during fermentation are given by the following equation:

$$bsCOD_{fer,AN1} = \frac{r_{fer,AN1} * V_{tot,AN1}}{Q_R}$$

It is not possible convert more bsCOD than what is available in the reactor. The VFA produced after fermentation are dependent on bsCOD_{in,AN1}, see table below.

If	Then
$bsCOD_{fer,AN1} > bsCOD_{in,AN1}$	$bsCOD_{fer,AN1} = bsCOD_{in,AN1}$
$bsCOD_{fer,AN1} < bsCOD_{in,AN1}$	$bsCOD_{fer,AN1} = bsCOD_{fer,AN1}$

Where the fermentable conversion rate, r_{fer} , are given by the following equation:

$$r_{fer,AN1} = k_{fer,T} * bsCOD_{in,AN1} * X_{OHO,active,AN1}$$

$$X_{OHO,active,AN1} = VSS_R * f_{A,OHO}$$

ACIDOGENESIS FERMENTATION IN AN1		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD_{fer,AN1}	$rbCOD_{fer,AN1} + ssbCOD_{fer,AN1}$
	rbCOD_{fer,AN1}	$if [bsCOD_{fer,AN1} < rbCOD_{hyd,AN1}; rbCOD_{hyd,AN1}; bsCOD_{fer,AN1}]$
	VFA_{fer,AN1}	$bsCOD_{fer,AN1}$
	ssbCOD_{fer,AN1}	$if [bsCOD_{fer,AN1}$ $= bsCOD_{in,AN1}; 0; (ssbCOD_{ava,fer,AN1} - (bsCOD_{fer,AN1}$ $- rbCOD_{ava,fer,AN1}))]$ Where: $ssbCOD_{ava,fer,AN1} = ssbCOD_{in,AN1} + ssbCOD_{hyd,AN1}$ $rbCOD_{ava,fer,AN1} = rbCOD_{in,AN1} + rbCOD_{hyd,AN1}$
Particulate COD	tsCOD_{fer,AN1}	$psbCOD_{fer,AN1} + pnbCOD_{fer,AN1}$
	psbCOD_{fer,AN1}	$VSS_{fer,AN1} * F_{psbCOD}$
	pnbCOD_{fer,AN1}	$VSS_{AN1} * F_{pnbCOD}$
	VSS_{fer,AN1}	$Y_{OBS,fer} * bsCOD_{fer,AN1}$ $Y_{OBS,fer} = \frac{Y_{fer}}{1 + k_{d,fer} * SRT}$

How much of the new biomass is formed to particulate COD:

$$F_{psbCOD} = 1,48 \text{ mg} \frac{\text{pCOD}}{\text{g VSS}} * 0,75 = 1,11 \frac{\text{g psbCOD}}{\text{g VSS}}$$

$$F_{pnbCOD} = 1,48 \text{ mg} \frac{\text{pCOD}}{\text{g VSS}} * 0,25 = 0,37 \frac{\text{g pnbCOD}}{\text{g VSS}}$$

3. COD removal due to dissolved oxygen

Dissolved oxygen in AN1		
Main parameters	Under parameters	Formulas
Soluble COD	$\text{rbCOD}_{\text{DO,AN1}}$	<p>If $\text{rbCOD}_{\text{pot,DO,AN1}} \geq \text{rbCOD}_{\text{ava,DO,AN1}}; \text{rbCOD}_{\text{ava,DO,AN1}}; \text{rbCOD}_{\text{pot,DO,AN1}}$</p> <p>Where:</p> <p>$\text{rbCOD}_{\text{pot,DO,AN1}} = F_{\text{DO}} * \text{DO}_{\text{in,AN1}}$</p> <p>$\text{rbCOD}_{\text{ava,DO,AN1}} = \text{rbCOD}_{\text{fer,AN1}}$</p>
	$\text{VFA}_{\text{DO,AN1}}$	<p>if $\text{rbCOD}_{\text{DO,AN1}} < \text{VFA}_{\text{ava,DO,AN1}}; \text{rbCOD}_{\text{DO,AN1}}; \text{VFA}_{\text{ava,DO,AN1}}$</p> <p>Where:</p> <p>$\text{VFA}_{\text{ava,DO,AN1}} = \text{VFA}_{\text{fer,AN1}}$</p>
Particulate COD	$\text{psbCOD}_{\text{DO,AN1}}$	$\text{VSS}_{\text{DO,AN1}} * F_{\text{psbCOD}}$
	$\text{pnbCOD}_{\text{DO,AN1}}$	$\text{VSS}_{\text{DO,AN1}} * F_{\text{pnbCOD}}$
Suspended solids	$\text{VSS}_{\text{DO,AN1}}$	<p>$Y_{\text{OBS,DO}} * \text{rbCOD}_{\text{r,DO,AN1}}$</p> <p>$Y_{\text{OBS,DO}} = \frac{Y_{\text{OHO}}}{1 + k_{\text{d,OHO,15}} * \text{SRT}}$</p>
	DO_{AN1}	$\frac{1}{F_{\text{DO}}} * \text{rbCOD}_{\text{DO,AN1}}$

4. Denitrification

The denitrification process only affects the readily biodegradable COD in the solution. The potential nitrate concentration removed are given by the following formula:

$$(\text{NO}_3 - \text{N})_{\text{pot,AN1}} = \left(\frac{1}{F_{\text{DN}}} * \text{rbCOD}_{\text{ava,DN,AN1}} \right)$$

Where the rbCOD available for DN ($\text{rbCOD}_{\text{ava,DN,AN1}}$) in AN1 is the rbCOD present in the reactor after fermentation, minus the rbCOD utilized due to dissolved oxygen.

$$\text{rbCOD}_{\text{ava,DN,AN1}} = \text{rbCOD}_{\text{fer,AN1}} - \text{rbCOD}_{\text{DO,AN1}}$$

The VFA available for DN in AN1 ($\text{VFA}_{\text{ava,DN,AN1}}$) is the amount of biodegradable soluble COD converted to VFA in fermentation, minus the VFA utilized due to dissolved oxygen.

$$\text{VFA}_{\text{ava,DN,AN1}} = \text{bsCOD}_{\text{fer,AN1}} - \text{VFA}_{\text{r,DO,AN1}}$$

DENITRIFICATION IN AN1		
Main parameters	Under parameters	Formulas
Soluble COD	$\text{rbCOD}_{\text{DN,AN1}}$	$F_{\text{DN}} * (\text{NO}_3)_{\text{DN,AN1}}$
	$\text{VFA}_{\text{DN,AN1}}$	If $[\text{rbCOD}_{\text{DN,AN1}} \geq \text{VFA}_{\text{ava,DN,AN1}}; \text{VFA}_{\text{ava,DN,AN1}}; (\text{VFA}_{\text{ava,DN,AN1}} - \text{rbCOD}_{\text{DN,AN1}})]$
Particulate COD	$\text{psbCOD}_{\text{DN,AN1}}$	$\text{VSS}_{\text{DN,AN1}} * F_{\text{psbCOD}}$
	$\text{pnbCOD}_{\text{DN,AN1}}$	$\text{VSS}_{\text{DN,AN1}} * F_{\text{pnbCOD}}$
Suspended solids	$\text{VSS}_{\text{DN,AN1}}$	$Y_{\text{OBS,DN}} * \text{rbCOD}_{\text{DN,AN1}}$ $Y_{\text{OBS,DN}} = \frac{Y_{\text{DN}}}{1 + k_{\text{d,OH},15} * \text{SRT}}$
Nitrogen	$\text{Tot-N}_{\text{DN,AN1}}$	$(\text{TotN})_{\text{in,AN1}} - \text{NO}_3_{\text{DN,AN1}}$
	$\text{NO}_3_{\text{DN,AN1}}$	If $[\text{NO}_3_{\text{pot,AN1}} \geq \text{NO}_3_{\text{in,AN1}}; \text{NO}_3_{\text{in,AN1}}; \text{NO}_3_{\text{pot,AN1}}]$

5. Effluent concentration AN1

EFFLUENT CONCENTRATION FROM AN1		
Main parameters	Under parameters	Formulas
Soluble COD	$\text{tsCOD}_{\text{eff,AN1}}$	$\text{rbCOD}_{\text{eff,AN1}} + \text{ssbCOD}_{\text{eff,AN1}} + \text{snbCOD}_{\text{eff,AN1}}$
	$\text{rbCOD}_{\text{eff,AN1}}$	$\text{rbCOD}_{\text{fer,AN1}} - \text{rbCOD}_{\text{DO,AN1}} - \text{rbCOD}_{\text{DN,AN1}}$
	$\text{VFA}_{\text{eff,AN1}}$	$\text{VFA}_{\text{fer,AN1}} - \text{VFA}_{\text{DO,AN1}} - \text{VFA}_{\text{DN,AN1}}$
	$\text{ssbCOD}_{\text{eff,AN1}}$	$\text{ssbCOD}_{\text{fer,AN1}}$
	$\text{snbCOD}_{\text{eff,AN1}}$	$\text{snbCOD}_{\text{in,AN1}} + \text{snbCOD}_{\text{hyd,AN1}}$
Particulate COD	$\text{tpCOD}_{\text{eff,AN1}}$	$\text{psbCOD}_{\text{eff,AN1}} + \text{pnbCOD}_{\text{eff,AN1}}$
	$\text{psbCOD}_{\text{eff,AN1}}$	$\text{psbCOD}_{\text{in,AN1}} + \text{tsCOD}_{\text{hyd,AN1}} * (f_{\text{psnbCOD}} - 1)$ $+ \text{psbCOD}_{\text{DO,AN1}} + \text{psbCOD}_{\text{DN,AN1}}$ $+ \text{psbCOD}_{\text{fer,AN1}}$
	$\text{pnbCOD}_{\text{eff,AN1}}$	$\text{pnbCOD}_{\text{in,AN1}} + \text{pnbCOD}_{\text{hyd,AN1}} + \text{pnbCOD}_{\text{DO,AN1}}$ $+ \text{pnbCOD}_{\text{DN,AN1}} + \text{pnbCOD}_{\text{fer,AN1}}$
Suspended solids	$\text{TSS}_{\text{eff,AN1}}$	$(\text{TSS}_{\text{in,AN1}} - \text{VSS}_{\text{in,AN1}}) + \text{VSS}_{\text{eff,AN1}}$
	$\text{VSS}_{\text{eff,AN1}}$	$\text{VSS}_{\text{in,AN1}} + (\text{VSS}_{\text{DO,AN1}} + \text{VSS}_{\text{DN,AN1}} + \text{VSS}_{\text{fer,AN1}}$ $- \text{VSS}_{\text{hyd,AN1}})$
Phosphate	$\text{Tot-P}_{\text{eff,AN1}}$	$\text{TotP}_{\text{in,AN1}}$
	$\text{PO4}_{\text{eff,AN1}}$	$\text{PO4}_{\text{in,AN1}}$
Nitrogen	$\text{Tot-N}_{\text{eff,AN1}}$	$\text{TotN}_{\text{in,AN1}} - \text{NO3}_{\text{DN,AN1}}$
	$\text{NH4}_{\text{eff,AN1}}$	$\text{NH4}_{\text{in,AN1}}$
	$\text{NO3}_{\text{eff,AN1}}$	$\text{NO3}_{\text{in,AN1}} - \text{NO3}_{\text{DN,AN1}}$
Oxygen	$\text{DO}_{\text{eff,AN1}}$	$\text{DO}_{\text{in,AN1}} - \text{DO}_{\text{AN1}}$

Appendix 5: All calculation for AN2 and AN3

1. COD removal due to presents of dissolved oxygen

In AN2 COD removal due to DO concentration can occur in two different time steps:

1. COD removal happens immediately

How much rbCOD and DO is removed due to the influent rbCOD concentration

$$\text{rbCOD}_{\text{pot1,AN2}} = F_{\text{DO}} * \text{DO}_{\text{in,AN2}}$$

$$\text{DO}_{1,\text{AN2}} = \frac{1}{F_{\text{DO}}} * \text{rbCOD}_{\text{DO1,AN2}}$$

- Still dissolved oxygen in the solution?
 - **Yes:** $\text{DO}_{\text{res,AN2}} > 0$
 - COD removal will occur when rbCOD are formed through hydrolysis and fermentation. Follow step 2.
 - **No:** $\text{DO}_{\text{res,AN2}} = 0$
 - Effluent dissolved oxygen concentration equals to zero.

$$\text{DO}_{\text{res,AN2}} = \text{DO}_{\text{in,AN2}} - \text{DO}_{1,\text{AN2}}$$

2. COD removal occurs when rbCOD are formed through hydrolysis and fermentation

How much rbCOD and DO can be removed by the rbCOD available after hydrolysis and fermentation are given by the following equation.

$$\text{rbCOD}_{\text{pot2,AN2}} = F_{\text{DO}} * \text{DO}_{\text{res,AN2}}$$

$$\text{DO}_{2,\text{AN2}} = \frac{1}{F_{\text{DO}}} * \text{rbCOD}_{\text{DO2,AN2}}$$

(i represent step one and step two)

Dissolved oxygen in AN2		
Main parameters	Under parameters	Formulas
Soluble COD	$rbCOD_{DO(i)}$	If $rbCOD_{pot(i),AN2} \geq rbCOD_{ava,DO(i),AN2}; rbCOD_{ava,DO(i),AN2}; rbCOD_{pot,DO(i),AN2}$ 1. $rbCOD_{ava,DO1,AN2} = rbCOD_{in,AN2}$ 2. $rbCOD_{ava,DO2,AN2} = rbCOD_{fer,AN2}$
	$VFA_{DO(i),AN2}$	if $rbCOD_{DO(i),AN2} < VFA_{ava,DO(i),AN2}; rbCOD_{DO(i),AN2}; VFA_{ava,DO(i),AN2}$ 1. $VFA_{ava,DO1,AN2} = VFA_{in,AN2}$ 2. $VFA_{ava,DO2,AN2} = VFA_{fer,AN2}$
Particulate COD	$psbCOD_{DO,AN2}$	$VSS_{DO,AN2} * F_{psbCOD}$
	$pnbCOD_{DO,AN2}$	$VSS_{DO,AN2} * F_{pnbCOD}$
Suspended solids	$VSS_{DO,AN2}$	$Y_{OBS,DO} * rbCOD_{DO,tot,AN2}$ $Y_{OBS,DO} = \frac{Y_{OHO}}{1 + k_{d,OHO,15} * SRT}$
Oxygen	DO_{AN2}	$\frac{1}{F_{DO}} * rbCOD_{DO,tot,AN2}$

If there this still is dissolved oxygen left when the wastewater reach the third anaerobic reactor, the rbCOD concentration entering AN3 is zero, due to presents of dissolved oxygen in the previous anaerobic reactors. Reactor AN3 will thereby act similar as AN1.

Dissolved oxygen in AN3		
Main parameters	Under parameters	Formulas
Soluble COD	$\text{rbCOD}_{\text{DO},\text{AN3}}$	$\text{If } \text{rbCOD}_{\text{pot},\text{AN3}} \geq \text{rbCOD}_{\text{ava},\text{DO},\text{AN3}}; \text{rbCOD}_{\text{ava},\text{DO},\text{AN3}}; \text{rbCOD}_{\text{pot},\text{DO},\text{AN3}}$ $\text{rbCOD}_{\text{ava},\text{DO},\text{AN3}} = \text{rbCOD}_{\text{fer},\text{AN3}}$
	$\text{VFA}_{\text{DO},\text{AN3}}$	$\text{if } \text{rbCOD}_{\text{DO},\text{AN3}} < \text{VFA}_{\text{fer},\text{AN3}}; \text{rbCOD}_{\text{DO},\text{AN3}}; \text{VFA}_{\text{fer},\text{AN3}}$
Particulate COD	$\text{psbCOD}_{\text{DO},\text{AN3}}$	$\text{VSS}_{\text{DO},\text{AN3}} * F_{\text{psbCOD}}$
	$\text{pnbCOD}_{\text{DO},\text{AN3}}$	$\text{VSS}_{\text{DO},\text{AN3}} * F_{\text{pnbCOD}}$
Suspended solids	$\text{VSS}_{\text{DO},\text{AN3}}$	$\text{Y}_{\text{OBS},\text{DO}} * \text{rbCOD}_{\text{DO},\text{AN3}}$ $\text{Y}_{\text{OBS},\text{DO}} = \frac{\text{Y}_{\text{OHO}}}{1 + k_{\text{d},\text{OHO},15} * \text{SRT}}$
Oxygen	DO_{AN3}	$\frac{1}{F_{\text{DO}}} * \text{rbCOD}_{\text{DO},\text{AN3}}$

2. Denitrification

In AN2 denitrification can occur at two different time steps:

1. Denitrification happens immediately

How much nitrate can be removed by the inlet rbCOD concentration are given by the following equation:

$$\text{NO3}_{\text{pot1},\text{AN2}} = \left(\frac{1}{F_{\text{DN}}} * \text{rbCOD}_{\text{ava},\text{DN1},\text{AN2}} \right)$$

$$\text{rbCOD}_{\text{ava},\text{DN1},\text{AN2}} = \text{rbCOD}_{\text{in},\text{AN2}} - \text{rbCOD}_{\text{DO1},\text{AN2}}$$

- Still nitrate in the solution?
 - **Yes:** $\text{NO3}_{\text{res},\text{AN2}} > 0$
 - Denitrification will occur when rbCOD are formed through hydrolysis and fermentation. Follow step 2.
 - **No:** $\text{NO3}_{\text{res},\text{AN2}} = 0$
 - Effluent nitrate concentration equals to zero.

$$\text{NO3}_{\text{res},\text{AN2}} = \text{NO3}_{\text{in},\text{AN2}} - \text{NO3}_{\text{DN1},\text{AN2}}$$

3. Denitrification occurs when rbCOD are formed through hydrolysis and fermentation

How much nitrate can be removed by the rbCOD available after hydrolysis and fermentation are given by the following equation.

$$\text{NO3}_{\text{pot2,AN2}} = \left(\frac{1}{F_{\text{DN}}} * \text{rbCOD}_{\text{ava,DN2,AN2}} \right)$$

Where:

$$\text{rbCOD}_{\text{ava,DN2,AN2}} = \text{rbCOD}_{\text{fer,AN2}} - \text{rbCOD}_{\text{DO2,AN2}}$$

(i = step 1 and step 2)

DENITRIFICATION in AN2		
Main parameters	Sub parameters	Formulas
Soluble COD	$\text{rbCOD}_{\text{DN(i),AN2}}$	<ol style="list-style-type: none"> $\text{rbCOD}_{\text{DN1,AN2}} = F_{\text{DN}} * [(\text{NO}_3)_{\text{DN1,AN2}}]$ $\text{rbCOD}_{\text{DN2,AN2}} = F_{\text{DN}} * [(\text{NO}_3)_{\text{DN2,AN2}}]$
	$\text{VFA}_{\text{DN(i),AN2}}$	<p>If $[\text{rbCOD}_{\text{DN(i),AN2}} \geq \text{VFA}_{\text{ava,DN(i),AN2}}; \text{VFA}_{\text{ava,DN(i),AN2}}; (\text{VFA}_{\text{ava,DN(i),AN2}} - \text{rbCOD}_{\text{DN(i),AN2}})]$</p> <ol style="list-style-type: none"> $\text{VFA}_{\text{ava,DN1,AN2}} = \text{VFA}_{\text{in,AN2}} - \text{VFA}_{\text{DO1,AN2}}$ $\text{VFA}_{\text{ava,DN2,AN2}} = \text{bsCOD}_{\text{fer,AN2}} - \text{VFA}_{\text{DO2,AN2}}$
Particulate COD	$\text{tsCOD}_{\text{DN,AN2}}$	$\text{psbCOD}_{\text{DN,AN2}} + \text{pnbCOD}_{\text{DN,AN2}}$
	$\text{psbCOD}_{\text{DN,AN2}}$	$\text{VSS}_{\text{DN,AN2}} * F_{\text{psbCOD}}$
	$\text{pnbCOD}_{\text{DN,AN2}}$	$\text{VSS}_{\text{DN,AN2}} * F_{\text{pnbCOD}}$
Suspended solids	$\text{VSS}_{\text{DN,AN2}}$	<p>$\text{Y}_{\text{OBS,DN}} * \text{rbCOD}_{\text{DN,tot,AN2}}$</p> <p>Where:</p> $\text{Y}_{\text{OBS,DN}} = \frac{\text{Y}_{\text{DN}}}{1 + k_{\text{d,OH0,15}} * \text{SRT}}$ <p>$\text{rbCOD}_{\text{DN,tot,AN2}} = \text{rbCOD}_{\text{DN1,AN2}} + \text{rbCOD}_{\text{DN2,AN2}}$</p>
Nitrogen	$\text{TotN}_{\text{DN,AN2}}$	$\text{TotN}_{\text{in,AN2}} - \text{NO3}_{\text{DN,tot,AN2}}$
	$\text{NO3}_{\text{DN(i),AN2}}$	<ol style="list-style-type: none"> $\text{NO3}_{\text{DN1,AN2}} =$ If $[\text{NO3}_{\text{pot1,AN2}} \geq \text{NO3}_{\text{in,AN2}}; \text{NO3}_{\text{in,AN2}}; \text{NO3}_{\text{pot1,AN2}}]$ $\text{NO3}_{\text{DN2,AN2}} =$ If $[\text{NO3}_{\text{pot2,AN2}} \geq \text{NO3}_{\text{res,AN2}}; \text{NO3}_{\text{res,AN2}}; \text{NO3}_{\text{pot2,AN2}}]$ <p>Where:</p> <p>$\text{NO3}_{\text{DN,tot,AN2}} = \text{NO3}_{\text{DN1,AN2}} + \text{NO3}_{\text{DN2,AN2}}$</p>

Denitrification will occur in AN3 if there is nitrate in the effluent of AN2. Then denitrification are limited by hydrolysis such as in AN1, and will only happen after rbCOD are formed through hydrolysis and fermentation.

$$\text{NO3}_{\text{pot,AN3}} = \left(\frac{1}{F_{\text{DN}}} * \text{rbCOD}_{\text{ava,DN,AN3}} \right)$$

$$\text{rbCOD}_{\text{ava,DN,AN3}} = \text{rbCOD}_{\text{fer,AN2}} - \text{rbCOD}_{\text{DO,AN3}}$$

DENITRIFICATION IN AN3		
Main parameters	Under parameters	Formulas
Soluble COD	$\text{rbCOD}_{\text{DN,AN3}}$	$F_{\text{DN}} * (\text{NO}_3)_{\text{DN,AN3}}$
	$\text{VFA}_{\text{DN,AN3}}$	If $[\text{rbCOD}_{\text{DN,AN3}} \geq \text{VFA}_{\text{fer,AN3}}; \text{VFA}_{\text{fer,AN3}}; (\text{VFA}_{\text{fer,AN3}} - \text{rbCOD}_{\text{DN,AN3}})]$
Particulate COD	$\text{psbCOD}_{\text{DN,AN3}}$	$\text{VSS}_{\text{DN,AN3}} * F_{\text{psbCOD}}$
	$\text{pnbCOD}_{\text{DN,AN3}}$	$\text{VSS}_{\text{DN,AN3}} * F_{\text{pnbCOD}}$
Suspended solids	$\text{VSS}_{\text{DN,AN3}}$	$Y_{\text{OBS,DN}} * \text{rbCOD}_{\text{DN,AN3}}$ $Y_{\text{OBS,DN}} = \frac{Y_{\text{DN}}}{1 + k_{\text{d,OH0,15}} * \text{SRT}}$
Nitrogen	TotN_{AN3}	$\text{TotN}_{\text{in,AN3}} - \text{NO3}_{\text{DN,AN3}}$
	$\text{NO3}_{\text{DN,AN3}}$	If $[\text{NO3}_{\text{pot,AN3}} \geq \text{NO3}_{\text{in,AN3}}; \text{NO3}_{\text{in,AN3}}; \text{NO3}_{\text{pot,AN3}}]$

2. Hydrolysis

(ANn = AN1 or AN2)

HYDROLYSIS IN AN2/AN3		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{hyd,ANn}$	$\left(\frac{k_{hyd} V_{tot,ANn} psbCOD_{in,ANn}}{Q_{in,ANn}} \right) f_s$
	$rbCOD_{hyd,ANn}$	$tsCOD_{hyd,ANn} * f_{rbCOD}$
	$ssbCOD_{hyd,ANn}$	$tsCOD_{hyd,ANn} * f_{ssbCOD}$
	$snbCOD_{hyd,ANn}$	$tsCOD_{hyd,ANn} * f_{snbCOD}$
Particulate COD	$tpCOD_{hyd,ANn}$	$\left(\frac{k_{hyd} V_{tot,ANn} psbCOD_{in,ANn}}{Q_{in,ANn}} \right) f_p$
	$psbCOD_{hyd,ANn}$	$tpCOD_{hyd,ANn} * f_{psnbCOD}$
	$pnbCOD_{hyd,ANn}$	$tpCOD_{hyd,ANn} * f_{pnbCOD}$
Suspended solids	$VSS_{hyd,ANn}$	$\frac{psbCOD_{hyd,ANn}}{f_{cv}}$

3. Acidogenesis fermentation

In AN2 and AN3 the biodegradable soluble COD available for fermentation are given by the following formulas:

$$bsCOD_{in,AN2} = (rbCOD_{in,AN2} + ssbCOD_{in,AN2} - rbCOD_{DN1,AN2} - rbCOD_{DO1,AN2}) + tsCOD_{hyd,AN2} * (f_{rbCOD} + f_{ssbCOD})$$

$$bsCOD_{in,AN3} = (rbCOD_{in,AN3} + ssbCOD_{in,AN3}) + tsCOD_{hyd,AN3} * (f_{rbCOD} + f_{ssbCOD})$$

The VFA formed through fermentation ($bsCOD_{fer,ANn}$) is given by the equation below, and the final value are selected based on the dependency shown in the table.

$$bsCOD_{fer,ANn} = \frac{k_{fer} * bsCOD_{in} * X_{OHO,active} * V_{tot,ANn}}{Q_{in,ANn}}$$

If	Then
$bsCOD_{fer,ANn} > bsCOD_{in,ANn}$	$bsCOD_{fer,ANn} = bsCOD_{in,ANn}$
$bsCOD_{fer,ANn} < bsCOD_{in,ANn}$	$bsCOD_{fer,ANn} = bsCOD_{fer,ANn}$

Here $rbCOD_{fer}$ and VFA_{fer} represent the $rbCOD$ and VFA concentration available in the solution after fermentation.

ACIDOGENESIS FERMENTATION IN AN2/AN3		
Main parameters	Sub parameters	Formulas
Soluble COD	$rbCOD_{fer,ANn}$	<p>if $[bsCOD_{fer,ANn} < (rbCOD_{ava,ANn}); rbCOD_{ava,ANn}; bsCOD_{fer,ANn}]$</p> <p>Where:</p> <p>$rbCOD_{ava,AN2} = rbCOD_{hyd,AN2} + (rbCOD_{in,AN2} - rbCOD_{DN1,AN2} - rbCOD_{DO1,AN2})$</p> <p>$rbCOD_{ava,AN3} = rbCOD_{hyd,AN3} + rbCOD_{in,AN3}$</p>
	$VFA_{fer,ANn}$	$bsCOD_{fer,ANn}$
	$ssbCOD_{fer,ANn}$	<p>if $[bsCOD_{fer,ANn} = bsCOD_{in,ANn}; 0; (ssbCOD_{ava,fer,ANn} - (bsCOD_{fer,ANn} - rbCOD_{ava,fer,ANn}))]$</p> <p>Where:</p> <p>$ssbCOD_{ava,fer,AN2} = ssbCOD_{in,AN2} + ssbCOD_{hyd,AN2}$</p> <p>$rbCOD_{ava,fer,AN2} = rbCOD_{in,AN2} + rbCOD_{hyd,AN2} - rbCOD_{DO1,AN2} - rbCOD_{DN1,AN2}$</p> <p>$ssbCOD_{ava,fer,AN3} = ssbCOD_{in,AN3} + ssbCOD_{hyd,AN3}$</p> <p>$rbCOD_{ava,fer,AN3} = rbCOD_{in,AN3} + rbCOD_{hyd,AN3}$</p>
Particulate COD	$psbCOD_{fer,ANn}$	$VSS_{fer,ANn} * F_{psbCOD}$
	$pnbCOD_{fer,ANn}$	$VSS_{fer,ANn} * F_{pnbCOD}$
Suspended solids	$VSS_{fer,ANn}$	<p>$Y_{OBS,fer} * bsCOD_{fer,ANn}$</p> <p>$Y_{OBS,fer} = \frac{Y_{fer}}{1 + k_{d,fer} * SRT}$</p>

4. P-release in AN2 and AN3

In AN2:

The maximum P-release in AN2:

$$P_{rel,MAX,AN2} = M_{A,PAO} * f_{luxP}$$

The active PAO mass available in AN2:

$$M_{A,PAO,AN2} = X_{PAO,active} = 0,15 * VSS_R * Q_R$$

How much P can potentially be released based on the available VFA concentration in AN2:

$$P_{rel,pot,AN2} = f_{PO4} * VFA_{ava,PAO,AN2}$$

In AN3:

The maximum P-release in AN3:

$$P_{rel,MAX,AN3} = P_{rel,MAX,AN2} - P_{rel,ac,AN2}$$

P-release in AN2/AN3		
Main parameters	Sub parameters	Formulas
Soluble COD	rbCOD_{PAO,ANn}	$VFA_{PAO,ANn}$
	VFA_{PAO,ANn}	$\min(VFA_{max,PAO,ANn}; VFA_{ava,PAO,ANn})$ Where: <u>In AN2:</u> $VFA_{max,PAO,AN2} = \frac{P_{rel,max,AN2}}{f_{PO4} * Q_{in,AN2}}$ $VFA_{ava,PAO,AN2} = VFA_{fer,AN2} - VFA_{DO2,AN2} - VFA_{DN2,AN2}$ <u>In AN3:</u> $VFA_{max,PAO,AN3} = \frac{P_{rel,max,AN3}}{f_{PO4} * Q_{in,AN3}}$ $VFA_{ava,PAO,AN3} = VFA_{fer,AN3} - VFA_{DO,AN3} - VFA_{DN,AN3}$
Phosphate	TotP_{rel,ANn}	$TotP_{in,ANn}$
	PO4_{PAO,ANn}	$P_{rel,ac} = \min (P_{rel,MAX,ANn}; P_{rel,pot,ANn})$

5. Effluent concentration in AN2 and AN3 (n= AN1, AN2)

EFFLUENT CALCULATIONS IN AN2/AN3		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{eff,ANn}$	$rbCOD_{eff,ANn} + ssbCOD_{eff,ANn} + snbCOD_{eff,ANn}$
	$rbCOD_{eff,ANn}$	<p>AN2: $rbCOD_{fer,AN2} - rbCOD_{DO2,AN2} - rbCOD_{DN2,N2} - rbCOD_{rel,AN2}$</p> <p>AN3: $rbCOD_{fer,AN3} - rbCOD_{DO,AN3} - rbCOD_{DN,AN3} - rbCOD_{rel,AN3}$</p>
	$VFA_{eff,ANn}$	<p>AN2: $VFA_{fer,AN2} - VFA_{DO2,AN2} - VFA_{DN2,AN2} - VFA_{rel,AN2}$</p> <p>AN3: $VFA_{fer,AN3} - VFA_{DO,AN3} - VFA_{DN,AN3} - VFA_{rel,AN3}$</p>
	$ssbCOD_{eff,ANn}$	$ssbCOD_{fer,ANn}$
	$snbCOD_{eff,ANn}$	$snbCOD_{in,ANn} + snbCOD_{hyd,ANn}$
Particulate COD	$tpCOD_{eff,ANn}$	$psbCOD_{eff,ANn} + pnbCOD_{eff,ANn}$
	$psbCOD_{eff,ANn}$	$psbCOD_{in,ANn} + tpCOD_{hyd,ANn}(f_{psbCOD} - 1)$ $+ (psbCOD_{DO,ANn} + psbCOD_{DN,ANn} + psbCOD_{fer,ANn})$
	$pnbCOD_{eff,ANn}$	$pnbCOD_{in,ANn} + pnbCOD_{hyd,ANn}$ $+ (pnbCOD_{DO,ANn} + pnbCOD_{DN,ANn} + pnbCOD_{fer,ANn})$
Suspended solids	$TSS_{eff,ANn}$	$(TSS_{in,AN2} - VSS_{in,AN2}) + VSS_{eff,ANn}$
	$VSS_{eff,ANn}$	$VSS_{in,ANn} + (VSS_{DO,ANn} + VSS_{DN,ANn} + VSS_{fer,ANn})$ $- VSS_{hyd,ANn}$
Phosphate	$Tot-P_{eff,ANn}$	$TotP_{in,AN2}$
	$PO4_{eff,ANn}$	$PO4_{in,ANn} + PO4_{PAO,ANn}$
Nitrogen	$Tot-N_{eff,ANn}$	$TotN_{in,ANn} - NO3_{DN,tot,ANn}$
	$NH4_{eff,ANn}$	$NH4_{in,ANn}$
	$NO3_{eff,ANn}$	$NO3_{in,ANn} - NO3_{DN,tot,ANn}$

Appendix 6: All calculation done in aeration tank

1. COD removal

Assumptions:

- COD removal in aeration tank will only affect the soluble biodegradable COD concentration (rbCOD and ssbCOD).
 - o Meaning the effluent snbCOD, psbCOD, pnbCOD concentrations will be equal to the influent concentrations.
- The effluent rbCOD and VFA concentration is assumed to be equal to zero.

$$bsCOD_{eff,aer} = \frac{K_s[1 + k_d SRT]}{SRT(\mu_{max} - k_d) - 1}$$

COD REMOVAL IN AERATION TANK		
Main parameters	Sub parameters	Formulas
Soluble COD	rbCOD _{COD}	0
	VFA _{COD}	0
	ssbCOD _{COD}	If $[bsCOD_{eff,aer} > bsCOD_{in,aer}; ssbCOD_{in,aer} - rbCOD_{in,aer}; bsCOD_{eff,aer}]$ Where: $bsCOD_{in,aer} = rbCOD_{in,aer} + ssbCOD_{in,aer}$
Particulate COD	psbCOD _{COD}	$VSS_{COD} * F_{psbCOD}$
	pnbCOD _{COD}	$VSS_{COD} * F_{pnbCOD}$
Suspended solids	VSS _{COD}	$Y_{OHO,OBS} * (bsCOD_{in,aer} - bsCOD_{eff,aer})$

2. P-removal in aeration tank

P-REMOVAL IN AERATION TANK		
Main parameters	Sub parameters	Formula
Particulate COD	psbCOD _P	$VSS_P * F_{psbCOD}$
	pnbCOD _P	$VSS_P * F_{pnbCOD}$
Phosphorus	TotP _P	$TotP_{in,aer}$
	PO ₄ _P	$[\min (P_{r,tot}; PO_{4,in,aer})]$
Suspended solids	VSS _P	$Y_{PAO,OBS} * (VFA_{PAO,AN2} + VFA_{PAO,AN3})$

The four different processes that remove phosphorus from the solution is further explained in the thesis.

3. Nitrification in aeration tank

Nitrification will not occur if $SRT \leq SRT_{min}$, where SRT_{min} is calculated based on the following equation:

$$SRT_{min} = \frac{1}{\left(1 + \frac{K_{S,NIT}}{NH_{4,in,aer}}\right) \mu_{Max,NIT} - k_{d,NIT}}$$

The nitrogen incorporated in new biomass is calculated as following:

$$N_{sludge} = \frac{f_n * (M_{OHO,new} + M_{PAO,new})}{Q_{in,aer}}$$

If	Then
$N_{sludge} \geq NH_{4,in,aer}$	$N_{sludge} = NH_{4,in,aer}$

NITRIFICATION IN AERATION TANK		
Main parameters	Under parameters	Formulas

Particulate COD	tpCOD_{NIT}	psbCOD _{NIT} + pnbCOD _{NIT}
	psbCOD_{NIT}	VSS _{NIT} * F _{psbCOD}
	pnbCOD_{NIT}	VSS _{NIT} * F _{pnbCOD}
Suspended solids	VSS_{NIT}	Y _{NIT,OBS} * NH _{4,ava,NIT}
Nitrogen	NH₄_{NIT}	NH ₄ _{eff,aer} = if [SRT = SRT _{min} ; NH ₄ _{in,aer} - N _{sludge} ; (NH ₄ _{in,aer} - N _{sludge}) * 0,3]
	NO₃_{NIT}	NO ₃ _{in,aer} + NH ₄ _{ava,NIT} Where: NH₄_{ava,NIT} = NH₄_{in,aer} - N_{sludge} - NH₄_{eff,aer}

4. Effluent Concentration from aeration tank

EFFLUENT CALCULATIONS FOR AERATION TANK		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD_{eff,aer}	rbCOD _{eff,aer} + ssbCOD _{eff,aer} + snbCOD _{eff,aer}
	rbCOD_{eff,aer}	0
	VFA_{eff,aer}	0
	ssbCOD_{eff,aer}	ssbCOD _{COD}
	snbCOD_{eff,aer}	snbCOD _{in,aer}
Particulate COD	tpCOD_{eff,aer}	psbCOD _{eff,aer} + pnbCOD _{eff,aer}
	psbCOD_{eff,aer}	psbCOD _{in,aer} + psbCOD _{COD} + psbCOD _P + psbCOD _{NIT}
	pnbCOD_{eff,aer}	pnbCOD _{in,aer} + pnbCOD _{COD} + pnbCOD _P + pnbCOD _{NIT}
Suspended solids	TSS_{eff,aer}	(TSS _{in,AN2} - VSS _{in,AN2}) + VSS _{eff,aer}
	VSS_{eff,aer}	VSS _{in,aer} + VSS _{COD} + VSS _P + VSS _{NIT}
Phosphate	TotP_{eff,aer}	TotP _{in,aer}
	PO₄_{eff,aer}	PO ₄ _{in,aer} - PO ₄ _P
Nitrogen	TotN_{eff,aer}	TotN _{in,aer}
	NH₄_{eff,aer}	NH ₄ _{NIT}
	NO₃_{eff,aer}	NO ₃ _{NIT}

Appendix 7: All calculation for sedimentation basin

Needed relationship between flowrates, and VSS masses in the different flowrates are given by the following formulas:

$$Q_{\text{eff}} = Q_{\text{in}} - Q_w$$

$$Q_w = \frac{M_{\text{VSS},w}}{VSS_R}$$

$$Q_{R,\text{Out}} = Q_{\text{in},\text{sed}} - Q_{\text{eff},\text{sed}}$$

$$M_{\text{VSS},\text{eff}} = M_{\text{VSS},\text{in},\text{sed}} * (1 - f_{\text{sc},\text{sed}})$$

$$SP_{\text{net}} = (M_{\text{VSS},\text{in},\text{sed}} - M_{\text{VSS},\text{in},\text{AN}2}) + M_{\text{VSS},\text{in}} - M_{\text{hyd},\text{AN}1} = M_{\text{VSS},\text{eff}} + M_{\text{VSS},w}$$

$$M_{\text{VSS},w} = SP_{\text{net}} - M_{\text{VSS},\text{eff}}$$

$$M_{\text{hyd},\text{AN}1} = M_{\text{VSS},\text{in},\text{AN}1} - M_{\text{VSS},\text{eff},\text{AN}1}$$

Concentration in return sludge line/waste sludge line:

$$C_R = \frac{(Q_{\text{eff},\text{aer}} * C_{\text{eff},\text{aer}}) - (Q_{\text{eff},\text{sed}} * C_{\text{eff},\text{sed}})}{(Q_R + Q_w)}$$

The effluent concentration leaving the treatment plant is depended on the total bypass flow and concentration, and the flow and concentration leaving the settling tank.

$$Q_{\text{eff}} = Q_{\text{eff},\text{sed}} + Q_{\text{by,tot}}$$

$$C_{\text{eff}} = \frac{(Q_{\text{eff},\text{sed}} * C_{\text{eff},\text{sed}}) + (Q_{\text{By,tot}} * C_{\text{By,tot}})}{Q_{\text{eff}}}$$

EFFLUENT CONCENTRATIONS FROM SETTLING TANK		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{eff, sed}$	$rbCOD_{eff, sed} + ssbCOD_{eff, sed} + snbCOD_{eff, sed}$
	$rbCOD_{eff, sed}$	0
	$VFA_{eff, sed}$	0
	$ssbCOD_{eff, sed}$	$ssbCOD_{eff, aer}$
	$snbCOD_{eff, sed}$	$snbCOD_{eff, aer}$
Particulate COD	$tpCOD_{eff, sed}$	$psbCOD_{eff, sed} + pnbCOD_{eff, sed}$
	$psbCOD_{eff, sed}$	$\frac{(psbCOD_{eff, aer} * Q_{eff, aer}) * (1 - f_{SC, sed})}{Q_{eff, sed}}$
	$pnbCOD_{eff, sed}$	$\frac{(pnbCOD_{eff, aer} * Q_{eff, aer}) * (1 - f_{SC, sed})}{Q_{eff, sed}}$
Suspended solids	$TSS_{eff, sed}$	$\frac{(TSS_{eff, aer} * Q_{eff, aer}) * (1 - f_{SC, sed})}{Q_{eff, sed}}$
	$VSS_{eff, sed}$	$\frac{(VSS_{eff, aer} * Q_{eff, aer}) * (1 - f_{SC, sed})}{Q_{eff, sed}}$
Phosphate	$TotP_{eff, sed}$	$PO4_{eff, aer} + VSS * [(f_{A, PAO} * f_{PAO}) + (f_{A, OHO} * f_{OHO})]$
	$PO4_{eff, sed}$	$PO4_{eff, aer}$
Nitrogen	$TotN_{eff, sed}$	$TotN_{eff, aer} - \frac{N_{par} * Q_{eff, aer} * (1 - f_{SC, sed})}{Q_{eff, sed}}$ <p>Where:</p> $N_{par} = TotN_{eff, aer} - NO_{3, eff, aer} - NH_{4, eff, aer}$
	$NH4_{eff, sed}$	$NH4_{eff, aer}$
	$NO3_{eff, sed}$	$NO3_{eff, aer}$

Appendix 8: All calculations for thickener 1 and thickener 2

The calculations have been performed for the two thickener always in operation, one thickenes primary sludge the other thickens biological sludge.

Thickener 1 (TH1): Primary sludge

Polymer dosage

For the first thickener there is added 1 kg polymer/ ton TS.

The daily polymer dosage in TH1 (PD_{TH1}) [kg/d]:

$$PD_{TH1} = \left(\frac{Q_{in,TH1} * TSS_{DF}}{10^6 \frac{g}{ton}} \right) * 1 \frac{kg \text{ Polymer}}{ton \text{ TSS}}$$

The polymer added is an organic polymer that will slightly increase the influent TSS, VSS, psbCOD and tpCOD concentrations.

$$TSS_{in, TH1}: \quad TSS_{DF} + \left(\frac{PD_{TH1} * 1000 \frac{g}{kg}}{Q_{in,TH1}} \right)$$

$$VSS_{in,TH1}: \quad VSS_{DF} + \left(\frac{PD_{TH1} * 1000 \frac{g}{kg}}{Q_{in,TH1}} \right)$$

$$tpCOD_{in,TH1}: \quad TpCOD_{DF} + \left(\frac{PD_{TH1} * 1000 \frac{g}{kg}}{Q_{in,TH1}} \right) * f_{cv}$$

$$psbCOD_{in,TH1}: \quad psbCOD_{DF} + \left(\frac{PD_{TH1} * 1000 \frac{g}{kg}}{Q_{in,TH1}} \right) * f_{cv}$$

Thickener 2 (TH2): Biological sludge

Polymer dosage

For the second thickener there is added 3 kg polymer/ ton TS.

The daily polymer dosage in TH2 (PD_{TH2}) [kg/d]:

$$PD_{TH2} = \left(\frac{Q_{in,TH2} * TSS_w}{10^6 \frac{g}{ton}} \right) * 3 \frac{kg \text{ Polymer}}{ton \text{ TSS}}$$

The polymer added is an organic polymer that will slightly increase the influent TSS, VSS, psbCOD and tpCOD concentrations.

$$TSS_{in, TH2}: \quad TSS_w + \left(\frac{PD_{TH2} * 1000 \frac{g}{kg}}{Q_{in,TH2}} \right)$$

$$VSS_{in,TH2}: \quad VSS_w + \left(\frac{PD_{TH2} * 1000 \frac{g}{kg}}{Q_{in,TH2}} \right)$$

$$tpCOD_{in,TH2}: \quad TpCOD_w + \left(\frac{PD_{TH2} * 1000 \frac{g}{kg}}{Q_{in,TH2}} \right) * f_{cv}$$

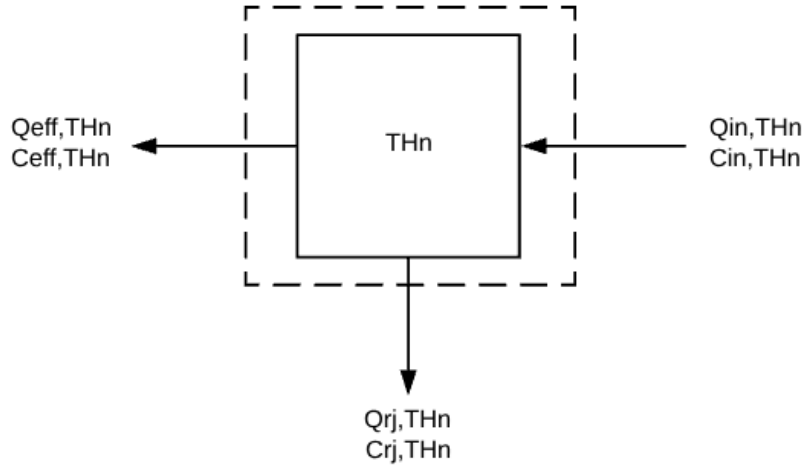
$$psbCOD_{in,TH2}: \quad psbCOD_w + \left(\frac{PD_{TH2} * 1000 \frac{g}{kg}}{Q_{in,TH2}} \right) * f_{cv}$$

The sludge volume leaving thickener and continues to the next sludge treatment process are given by the following equation.

$$Q_{eff,THn} = \frac{M_{cake,THn}}{S_{SL,THn} * \rho_w * P_{s,THn}} = \left[\frac{m^3}{d} \right]$$

$$M_{cake,THn} = \frac{f_{SC,THn} * Q_{in,THn}}{1000 \text{ g/kg}} = \left[\frac{kg}{d} \right]$$

Calculations for thickener 1 and thickener 2



The specific gravity of solids (S_s) is calculated based on the influent FSS and VSS fractions, and will remain the same before and after the sludge had been thickened.

$$S_{S,THn} = \frac{1}{\left(\frac{\left(\frac{FSS}{TSS} \right)}{S_f} \right) + \left(\frac{\left(\frac{VSS}{TSS} \right)}{S_v} \right)}$$

The specific gravity of sludge (S_{SL}) for thickened sludge can then be calculated based on the following formula.

$$S_{SL,THn} = \frac{1}{\left(\left(\frac{P_{s,THn}}{S_s} \right) + \left(\frac{P_{w,THn}}{\rho_w} \right) \right)}$$

Where:

$$P_{w,THn} = 1 - P_{s,THn}$$

EFFLUENT CONCENTRATIONS FROM THICKENER 1 AND THICKENER 2		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{eff,THn}$	$rbCOD_{eff,THn} + ssbCOD_{eff,THn} + snbCOD_{eff,THn}$
	$rbCOD_{eff,THn}$	$rbCOD_{in,THn}$
	$VFA_{eff,THn}$	$VFA_{in,THn}$
	$ssbCOD_{eff,THn}$	$ssbCOD_{in,THn}$
	$snbCOD_{eff,THn}$	$snbCOD_{in,THn}$
Particulate COD	$tpCOD_{eff,THn}$	$psbCOD_{eff,THn} + pnbCOD_{eff,THn}$
	$psbCOD_{eff,THn}$	$\frac{(psbCOD_{in,TH} * Q_{in,TH}) * f_{SC,THn}}{Q_{eff,TH}}$
	$pnbCOD_{eff,THn}$	$\frac{(pnbCOD_{in,THn} * Q_{in,THn}) * f_{SC,THn}}{Q_{eff,THn}}$
Suspended solids	$TSS_{eff,THn}$	$\frac{(TSS_{in,THn} * Q_{in,THn}) * f_{SC,THn}}{Q_{eff,THn}}$
	$VSS_{eff,THn}$	$\frac{(VSS_{in,THn} * Q_{in,THn}) * f_{SC,THn}}{Q_{eff,THn}}$
Phosphate	$TotP_{eff,THn}$	$PO4_{eff,THn} + \left(\frac{P_{par} * Q_{in,THn} * f_{SC,THn}}{Q_{eff,THn}} \right)$ Where: $P_{par} = TotP_{in,THn} - PO4_{in,THn}$
	$PO4_{eff,THn}$	$PO4_{in,THn}$
Nitrogen	$TotN_{eff,THn}$	$NO3_{eff,THn} + NH4_{eff,THn} + \left(\frac{N_{par} * Q_{in,THn} * f_{SC,THn}}{Q_{eff,THn}} \right)$ Where: $N_{par} = TotN_{in,THn} - NO3_{in,THn} - NH4_{in,THn}$
	$NH4_{eff,THn}$	$NH4_{in,THn}$
	$NO3_{eff,THn}$	$NO3_{in,THn}$
Oxygen	$DO_{eff, THn}$	$DO_{in,THn}$

The reject flow and concentration from TH1 and TH2:

$$Q_{rj,THn} = Q_{in,THn} - Q_{eff,THn}$$

$$C_{rj,THn} = \frac{(Q_{in,THn} * C_{in,THn}) - (Q_{eff,THn} * C_{in,THn})}{Q_{rj,THn}}$$

The total reject flow and concentration sent back to treatment plant:

$$Q_{rj} = Q_{rj,TH1} + Q_{rj,TH2}$$

$$C_{rj} = \frac{(Q_{rj,TH1} * C_{rj,TH1}) + (Q_{rj,TH2} * C_{rj,TH2})}{Q_{rj}}$$

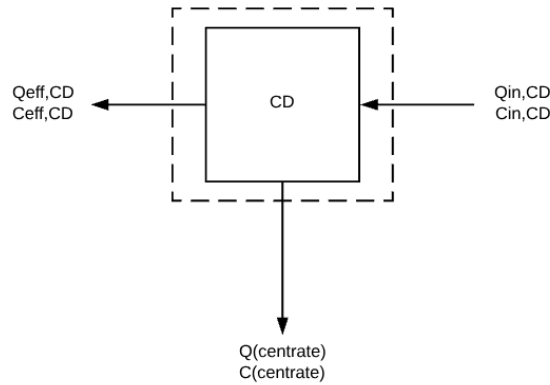
Appendix 9: All calculations for anaerobic digestion

EFFLUENT CONCENTRATIONS FROM ANAEROBIC DIGESTION (AD)		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{eff,AD}$	$rbCOD_{eff,THn} + ssbCOD_{eff,THn} + snbCOD_{eff,THn}$
	$rbCOD_{eff,AD}$	$VFA_{eff,AD}$
	$VFA_{eff,AD}$	$if[NH4_{eff,AD} > 3000; (VSS_{in,AD} * f_{biogas} * f_{cv}); 0]$
	$ssbCOD_{eff,AD}$	0
	$snbCOD_{eff,AD}$	$snbCOD_{in,AD}$
Particulate COD	$tpCOD_{eff,AD}$	$psbCOD_{eff,AD} + pnbCOD_{eff,AD}$
	$psbCOD_{eff,AD}$	$psbCOD_{in,AD} - (VSS_{des} * F_{psbCOD})$
	$pnbCOD_{eff,AD}$	$pnbCOD_{in,AD} - (VSS_{des} * F_{pnbCOD})$ Where: $VSS_{des} = VSS_{in,AD} * f_{biogas}$
Suspended solids	$TSS_{eff,AD}$	$(TSS_{in,AD} - VSS_{in,AD}) + VSS_{eff,AD}$
	$VSS_{eff,AD}$	$VSS_{in,AD} - VSS_{des}$
Phosphorus	$TotP_{eff,AD}$	$TotP_{in,AD}$
	$PO4_{eff,AD}$	$if [PO4_{rel,AD} > TotP_{in,AD}; TotP_{in,AD}; (PO4_{rel,AD} + PO4_{in,AD})]$ Where: $PO4_{rel,AD} = PO4_{rel,PAO,AD} + PO4_{rel,ass,AD}$
Nitrogen	$TotN_{eff,AD}$	$TotN_{in,AD} - NO3_{in,AD}$
	$NH4_{eff,AD}$	$NH4_{in,AD} + NH4_{rel,AD}$
	$NO3_{eff,AD}$	0
Oxygen	DO	0

Biogas production:

Methane (CH₄) [m³/d]	If [NH ₄ _{eff,AD} ≥ 3000; 0; CH ₄ _{AD}] Where: $\text{CH}_{4\text{AD}} = (\text{COD}_{\text{CH}_4} * Q_{\text{in,AD}}) * f_{\text{CH}_4}$ $\text{COD}_{\text{CH}_4} = \text{VSS}_{\text{des}} * f_{\text{cv}}$
Carbon dioxide (CO₂) [m³/d]	$\text{CO}_{2\text{AD}} = \text{Biogas}_{\text{AD}} * 0,35$
Total biogas [m³/d]	$\text{Biogas}_{\text{AD}} = \frac{\text{CH}_{4,\text{AD}}}{0,65}$

Appendix 10: All calculation for centrifugal dewatering



Polymer dosage

For the centrifugal dewatering there is added approximately 6 kg polymer/ ton TS.

The daily polymer dosage in CD (PD_{CD}) [kg/d]:

$$PD_{CD} = \left(\frac{Q_{in,CD} * TSS_{eff,AD}}{10^6 \frac{g}{ton}} \right) * 6 \frac{kg \text{ Polymer}}{ton \text{ TSS}}$$

The polymer added is an organic polymer that will slightly increase the influent TSS, VSS, psbCOD and tpCOD concentrations.

$$TSS_{in,CD}: \quad TSS_{eff,AD} + \left(\frac{PD_{CD} * 1000 \frac{g}{kg}}{Q_{in,CD}} \right)$$

$$VSS_{in,CD}: \quad VSS_{eff,AD} + \left(\frac{PD_{CD} * 1000 \frac{g}{kg}}{Q_{in,CD}} \right)$$

$$tpCOD_{in,CD}: \quad TpCOD_{eff,AD} + \left(\frac{PD_{Cd} * 1000 \frac{g}{kg}}{Q_{in,CD}} \right) * f_{cv}$$

$$\text{psbCOD}_{\text{in,CD}}: \text{psbCOD}_{\text{eff,AD}} + \left(\frac{\text{PD}_{\text{CD}} * 1000 \frac{\text{g}}{\text{kg}}}{Q_{\text{in,CD}}} \right) * f_{\text{cv}}$$

The sludge volume leaving the centrifugal dewatering and entering thermal drying ($Q_{\text{eff,CD}}$) are calculated based on the equation below:

$$Q_{\text{eff,CD}} = \frac{M_{\text{cake,CD}}}{S_{\text{SL,CD}} * \rho_w * P_{\text{s,CD}}} = \left[\frac{\text{m}^3}{\text{d}} \right]$$

$$M_{\text{cake,CD}} = \frac{f_{\text{SC}} * Q_{\text{in,CD}}}{1000 \text{ g/kg}} = \left[\frac{\text{kg}}{\text{d}} \right]$$

The specific gravity of solids (S_s) is calculated based on the influent FSS and VSS fractions, and will remain the same before and after the sludge had been centrifuged.

$$S_{\text{s,CD}} = \frac{1}{\left(\frac{\left(\frac{\text{FSS}}{\text{TSS}} \right)}{S_f} \right) + \left(\frac{\left(\frac{\text{VSS}}{\text{TSS}} \right)}{S_v} \right)}$$

The specific gravity of sludge (S_{SL}) for thickened sludge can then be calculated based on the following formula.

$$S_{\text{SL,CD}} = \frac{1}{\left(\left(\frac{P_{\text{s,CD}}}{S_s} \right) + \left(\frac{P_{\text{w,CD}}}{\rho_w} \right) \right)}$$

Where:

$$P_{\text{w,CD}} = 1 - P_{\text{s,CD}}$$

The centrate flow and concentration from the centrifugal dewatering process:

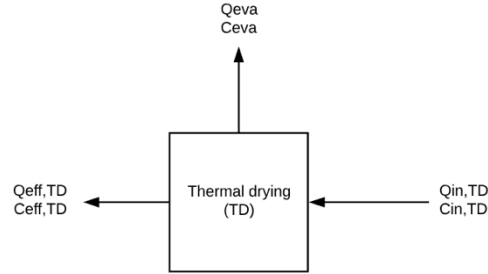
$$Q_{\text{centrate}} = Q_{\text{in,CD}} - Q_{\text{eff,CD}}$$

$$C_{\text{centrate}} = \frac{(Q_{\text{in,CD}} * C_{\text{in,CD}}) - (Q_{\text{eff,CD}} * C_{\text{in,CD}})}{Q_{\text{rj,CD}}}$$

EFFLUENT CONCENTRATIONS FROM CENTRIFUGAL DEWATERING (CD)		
Main parameters	Under parameters	Formulas
Soluble COD	$tsCOD_{eff,CD}$	$rbCOD_{eff,CD} + ssbCOD_{eff,CD} + snbCOD_{eff,CD}$
	$rbCOD_{eff,CD}$	$rbCOD_{in,CD}$
	$VFA_{eff,CD}$	$VFA_{in,CD}$
	$ssbCOD_{eff,CD}$	$ssbCOD_{in,CD}$
	$snbCOD_{eff,CD}$	$snbCOD_{in,CD}$
Particulate COD	$tpCOD_{eff,Cd}$	$psbCOD_{eff,CD} + pnbCOD_{eff,CD}$
	$psbCOD_{eff,CD}$	$\frac{(psbCOD_{in,CD} * Q_{in,CD}) * f_{SC,CD}}{Q_{eff,CD}}$
	$pnbCOD_{eff,CD}$	$\frac{(pnbCOD_{in,CD} * Q_{in,CD}) * f_{SC,CD}}{Q_{eff,CD}}$
Suspended solids	$TSS_{eff,CD}$	$\frac{(TSS_{in,CD} * Q_{in,CD}) * f_{SC,CD}}{Q_{eff,CD}}$
	$VSS_{eff,CD}$	$\frac{(VSS_{in,CD} * Q_{in,CD}) * f_{SC,CD}}{Q_{eff,CD}}$
Phosphate	$TotP_{eff,CD}$	$PO4_{eff,CD} + \left(\frac{P_{par} * Q_{in,CD} * f_{SC,CD}}{Q_{eff,CD}} \right)$ <p>Where: $P_{par} = TotP_{in,CD} - PO4_{in,CD}$</p>
	$PO4_{eff,CD}$	$PO4_{in,CD}$
Nitrogen	$TotN_{eff,CD}$	$NO3_{eff,CD} + NH4_{eff,CD} + \left(\frac{N_{par} * Q_{in,CD} * f_{SC,CD}}{Q_{eff,CD}} \right)$ <p>Where: $N_{par} = TotN_{in,CD} - NO3_{in,CD} - NH4_{in,CD}$</p>
	$NH4_{eff,CD}$	$NH4_{in,CD}$
	$NO3_{eff,CD}$	$NO3_{in,CD}$

Appendix 11: All calculations for thermal drying

The thermal drying is a dewatering process, but it differs from thickening and the centrifugal dewatering, it is assumed that only NH₃ follows the evaporated vapor.



The sludge volume leaving the thermal dryer and later produced into pellets ($Q_{\text{eff,TD}}$) is calculated based on the same principal as for thickener and centrifugal dewatering.

$$Q_{\text{eff,TD}} = \frac{M_{\text{cake,TD}}}{S_{\text{SL,TD}} * \rho_w * P_{\text{s,TD}}} = \left[\frac{\text{m}^3}{\text{d}} \right]$$

$$M_{\text{cake,TD}} = \frac{f_{\text{sc,TD}} * Q_{\text{in,TD}}}{1000 \text{ g/kg}} = \left[\frac{\text{kg}}{\text{d}} \right]$$

The specific gravity of solids (S_s) is calculated based on the influent FSS and VSS fractions, and will remain the same before and after the sludge had been centrifuged.

$$S_{\text{s,TD}} = \frac{1}{\left(\frac{\left(\frac{\text{FSS}}{\text{TSS}} \right)}{S_f} \right) + \left(\frac{\left(\frac{\text{VSS}}{\text{TSS}} \right)}{S_v} \right)}$$

The specific gravity of sludge (S_{SL}) leaving the thermal dryer can then be calculated based on the following formula.

$$S_{\text{SL,TD}} = \frac{1}{\left(\frac{P_{\text{s,TD}}}{S_{\text{s,TD}}} \right) + \left(\frac{P_{\text{w,TD}}}{\rho_w} \right)}$$

Where:

$$P_{w,TD} = 1 - P_{s,TD}$$

The evaporated flow and concentration is calculated as showed below:

$$Q_{eva} = Q_{in,TD} - Q_{eff,TD}$$

$$C_{eva} = \frac{(Q_{in,TD} * C_{in,TD}) - (Q_{eff,TD} * C_{eff,TD})}{Q_{eva}}$$

EFFLUENT CONCENTRATIONS FROM THERMAL DRYER (TD)		
Main parameters	Under parameters	Formulas
Soluble COD	tsCOD _{eff,TD}	rbCOD _{eff,TD} + ssbCOD _{eff,TD} + snbCOD _{eff,TD}
	rbCOD _{eff,TD}	$\frac{(rbCOD_{in,TD} * Q_{in,TD})}{Q_{eff,TD}}$
	VFA _{eff,TD}	$\frac{(VFA_{in,TD} * Q_{in,TD})}{Q_{eff,TD}}$
	ssbCOD _{eff,TD}	$\frac{(ssbCOD_{in,TD} * Q_{in,TD})}{Q_{eff,TD}}$
	snbCOD _{eff,TD}	$\frac{(snbCOD_{in,TD} * Q_{in,TD})}{Q_{eff,TD}}$
Particulate COD	tpCOD _{eff,TD}	psbCOD _{eff,TD} + pnbCOD _{eff,TD}
	psbCOD _{eff,TD}	$\frac{(psbCOD_{in,TD} * Q_{in,TD}) * f_{sc,TD}}{Q_{eff,TD}}$
	pnbCOD _{eff,TD}	$\frac{(pnbCOD_{in,TD} * Q_{in,TD}) * f_{sc,TD}}{Q_{eff,TD}}$
Suspended solids	TSS _{eff,TD}	$\frac{(TSS_{in,TD} * Q_{in,TD}) * f_{sc,CD}}{Q_{eff,TD}}$
	VSS _{eff,TD}	$\frac{(VSS_{in,TD} * Q_{in,TD}) * f_{sc,TD}}{Q_{eff,TD}}$
Phosphate	TotP _{eff,TD}	$PO4_{eff,TD} + \left(\frac{P_{par} * Q_{in,TD} * f_{sc,TD}}{Q_{eff,TD}} \right)$

		Where: $P_{par} = TotP_{in,TD} - PO4_{in,TD}$
	PO4_{eff,TD}	$\frac{PO4_{in,TD} * Q_{in,TD}}{Q_{eff,TD}}$
Nitrogen	TotN_{eff,TD}	$NH4_{eff,TD} + NO3_{eff,TD} + \left(\frac{N_{par} * Q_{in,TD} * f_{sc,TD}}{Q_{eff,TD}} \right)$ <p>Where: $N_{par} = TotN_{in,TD} - NO3_{in,TD} - NH4_{in,TD}$</p>
	NH4_{eff,TD}	$\frac{(NH4_{in,TD} * Q_{in,TD}) - (NH4_{eva} * Q_{eva})}{Q_{eff,TD}}$ <p>Where: $NH4_{eva} = \frac{P_{NH4,eva} * NH4_{in,TD} * Q_{in,TD}}{Q_{eva}}$</p>
	NO3_{eff,TD}	$\frac{NO3_{in,TD} * Q_{in,TD}}{Q_{eff,TD}}$

VALUES USED

Parameter	Values	Reference
F_{DN}	5,43 mg rbCOD/mg NO_3 -N	(Tchobanoglous <i>et al.</i> , 2014)
F_{DO}	2,99 g rbCOD/g O_2	(Tchobanoglous <i>et al.</i> , 2014)
F_{pnbCOD}	0,37 g pnbCOD/ g VSS	Calculated
F_{psbCOD}	1,1 g psbCOD/g VSS	Calculated
f_{biogas}	0,55	IVAR SNJ
$f_{A,OHO}$	0,214	Assumed
$f_{A,PAO}$	0,15 or varies	(Amy <i>et al.</i> , 2008)
f_{CH4}	0,4 l CH_4 /g COD	(Tchobanoglous <i>et al.</i> , 2014)
f_{cv}	1,48 g COD/g VSS	(Gori <i>et al.</i> , 2011)
$f_{end,OHO}$	0,25	(Amy <i>et al.</i> , 2008)
$f_{end,PAO}$	0,2	(Amy <i>et al.</i> , 2008)
f_{luxP}	0,365 g P/g VSS	Calculated
f_N	0,1 g N/g VSS	(Amy <i>et al.</i> , 2008)
f_{OHO}	0,015 g P/g VSS	(Amy <i>et al.</i> , 2008)
f_{PAO}	0,38 g P/g VSS	(Amy <i>et al.</i> , 2008)
$f_{P,end}$	0,03g P/g VSS	(Amy <i>et al.</i> , 2008)
$f_{P,inert}$	0,03g P/g VSS	(Amy <i>et al.</i> , 2008)
f_{PO4}	0,5 g P/g VFA	(Amy <i>et al.</i> , 2008)
f_p	0,15	(Gori <i>et al.</i> , 2011)
$f_{P,ass}$	0,015 g P/g VSS	(Amy <i>et al.</i> , 2008)
f_{psbCOD}	0,59	(Souza <i>et al.</i> , 2013)
f_s	0,85	(Gori <i>et al.</i> , 2011)
f_{rbCOD}	0,5015	(Souza <i>et al.</i> , 2013)
$f_{sc,CD}$	0,97	Assumed based on Table 14
$f_{sc,TD}$	0,99	Assumed
$f_{sc,THn}$	0,94	(Turoviskiy and Mathai, 2006)
$f_{sc,sed}$	0,99	Assumed
f_{snbCOD}	0,41	(Souza <i>et al.</i> , 2013)
f_{snb-N}	0,034	(Amy <i>et al.</i> , 2008)
f_{ssbCOD}	0,0885	(Souza <i>et al.</i> , 2013)

$f_{TS,SS}$	0,4	IVAR SNJ
$f_{TS,G}$	0,6	Assumed
$f_{TS,s}$	0,75	IVAR SNJ
$f_{VSS,R}$	0,83	(Amy <i>et al.</i> , 2008)
$f_{VSS,G}$	0,95	Assumed
$k_{d,fer,15}$ $k_{d,fer,35} = 0,02 \text{ d}^{-1}$ $\theta = 1,04$	0,009 d^{-1}	(Tchobanoglous <i>et al.</i> , 2014)
k_{fer}	0,06 $\text{m}^3/\text{g VSS} \cdot \text{d}$	(Amy <i>et al.</i> , 2008)
$k_{hyd,15}$ $\theta = 1,14$	0,03 d^{-1}	(Zhang <i>et al.</i> , 2016)
$k_{d,NIT,15}$ $k_{d,NIT,20} = 0,04 \text{ d}^{-1}$ $\theta = 1,029$	0,035 d^{-1}	(Amy <i>et al.</i> , 2008)
$k_{d,OHO,15}$ $k_{d,OHO,20} = 0,12$ $\theta = 1,04$	0,098 d^{-1}	(Tchobanoglous <i>et al.</i> , 2014)
$K_{S,COD,15}$ $K_{S,NIT,20} = 8$ $\theta = 1$	8 g COD/ m^3	(Tchobanoglous <i>et al.</i> , 2014)
$K_{S,NIT,15}$ $K_{S,NIT,20} = 1$ $\theta = 1,123$	0,56 g NH ₃ / m^3	(Amy <i>et al.</i> , 2008)
M_G	100 kg grease/d	Assumed
M_S	500 kg sand/d	IVAR SNJ
M_{trash}	500 kg trash/d	IVAR SNJ
$P_{NH4,eva}$	0,92	See chapter 3.2.5 Thermal drying
$P_{s,CD}$	0,25	Assumed
$P_{s,TD}$	0,85	Assumed
$P_{s,TH1}$	0,06	Assumed
$P_{s,TH2}$	0,04	Assumed
S_f	2,5	(Tchobanoglous <i>et al.</i> , 2014)
S_v	1	(Tchobanoglous <i>et al.</i> , 2014)
$V_{tot,aer}$	16740 m^3	IVAR SNJ

$V_{\text{tot, AN1}}$	1500 m ³	IVAR SNJ
$V_{\text{tot, AN2}}$	2820 m ³	IVAR SNJ
$V_{\text{tot, AN3}}$	2820 m ³	IVAR SNJ
$X_{\text{OHO,active}}$	$(VSS_R * f_{A,\text{OHO}})$ g/m ³	
$X_{\text{PAO,active}}$	$(VSS_R * f_{A,\text{PAO}})$ g/m ³	
$Y_{\text{OHO,DN}}$	0,32 gVSS/gCOD _r	(Tchobanoglous <i>et al.</i> , 2014)
Y_{fer}	0,06 VSS/g COD	(Tchobanoglous <i>et al.</i> , 2014)
Y_{NIT}	0,1 g VSS/g NH ₄	(Amy <i>et al.</i> , 2008)
Y_{OHO}	0,45 gVSS/gCOD _r	(Tchobanoglous <i>et al.</i> , 2014)
$\mu_{\text{max,NIT},15}$ $\theta = 1,072$ $\mu_{\text{max,NIT},20} = 0,7 \text{ d}^{-1}$	0,5 d ⁻¹	(Tchobanoglous <i>et al.</i> , 2014)
ρ_w	1000 kg/m ³	