overflow: in this way the turbulence flow assured by the overflow will provide the proper mixing for efficient reaction of Fe^{3+} with dissolved phosphate. The generated non-dissolved $FePO_4$ is removed in the downstream sedimentation tank.

Sedimentation occurs in a rectangular tank with a horizontal flow pattern. The effluent of the nitrification/denitrification tanks mixed with iron chloride enters the tank on one side. During the flow to the opposite side the suspended solids as well as the biomass settle to the bottom of the tank. The collection pipe, perforated at the lower side, collects the purified water. The effluent flows to the Pump receiving tank by gravity and from here is pumped to the Surplus Water Tank.

The settled sludge is collected at the bottom of the tank. A chain scraper system pushes the settled sludge into a sludge hopper at the bottom of tank. This hopper is located at that side of the tank where the effluent of the nitrification/denitrification tanks enters the settling tank. Sludge Backcharge Pumps recycle settled sludge to the nitrification/denitrification tanks to maintain sufficient biomass content in these tanks. The Sludge Discharge Pump 1 feeds the excess sludge into the Suspension Buffer.

The chain scraper system pushes floating sludge and foam into a skimming channel. Collected floating sludge and foam flows into the Sludge Pump Sump by gravity and from here is pumped by means of the Sludge discharge Pump 2 into the Suspension Buffer.

Compared to a conventional SBR-process, having the sedimentation in a separate tank provides more efficient control of the settling characteristic of the sludge as well as precipitation of dissolved phosphorous. In fact, a separated sedimentation step helps to separate the foam and the floating sludge (with bad sedimentation characteristics) from the sludge with good sedimentation characteristics that have to be recirculate into the reaction tanks. This is also a big advantage compare to the conventional SBR system.

5. Plant Dimensioning

5.1 Process Water 2 Buffer

Wastewater is not produced during the time period from Saturday 12 am to Monday morning 8 am. To be able to feed the WWTP continuously at design flow rate all over the week, the wastewater has to be stored during this period of 44 hours. This requires a buffer volume of 317 m³ upstream to WWTP.

The Process Water 2 Buffer is designed to store a water volume of 400 m³. The dimensions (LxWxH) are 2.4 m x 30.25 m x 5.5 m.

5.2 Consumption of Carbon Source (Acetic Acid) for Denitrification

To calculate the required amount of carbon source the following worst case is assumed:

- The waste water does not contain any easily degradable BOD_5.
- The whole TKN-load fed into WWTP has to be nitrified and denitrified.

The theoretical COD demand for biological nitrification and subsequent denitrification is 2.86 kg COD per kg TKN. Based on operation results of full scale WWTP treating wastewater from AD Plants for biological denitrification a ratio of 4 kg COD per kg TKN is required. That means a COD demand of 2,970 kg COD to remove 742 kg TKN by denitrification. That generates a daily acetic acid feed to WWTP of 2.6 m³ per day.

The Acetic Acid Dosing Buffer has a volume of about 30 m³ to be able to store at least one truck load. This storage tank is equipped with two pumps for separate dosing in each nitrification/denitrification tank. The consumption of acetic acid is calculated on theoretical and operational results from operating plant: it is related to the bacteria metabolism and so to the biological process chooses (in this case nitrification and denitrification process); in other words it is independent from the operational mode of the plant itself (SBR or the proposed solution).

5.3 Consumption of Precipitation Agent (FeCl3) for Phosphorous Removal

The following table shows the determination of the FeCl3 consumption as well as the excess sludge production according to the German guideline ATV-DWVK-A 131.

P-Removal rate		kg/d	86.3
COD degradation	Biomass generation	kg TS / kg BOD	0.52
		kg TS / d	1,680
	P in excess sludge	g P / kg TS	15
		kg/d	25.2
P-Precipitation	P-load to be removed	kg/d	61.1
	Fe(III)-consumption	kg Fe / kg P	2.7
	P-removal sludge	kg TS/d	413
Total excess sludge	Total	kg TS / d	2,093

To get a proper removal of the 61.1 kg P / d by precipitation 480 kg FeCl3 have to be dosed per day. Adding a ferric chloride solution with a concentration of 40% about 35 l/h have to be pumped to the nitrification/denitrification tanks.

The Iron Chloride Dosing Buffer has a volume of about 30 m³ to be able to store at least one truck load. This storage tank is equipped with two dosing pumps for separate $FeCl_3$-dosing in each nitrification/denitrification tank.

Also in this case the consumption of Iron Chloride is equal to the conventional SBR. The main difference consists in process optimization that is higher in the solution here proposed. In the SBR the phosphorus precipitation takes place at the same time of the phosphorus uptake for the bacterial growth. In this proposal those two reactions are separate in time and then optimized: the Bacteria have an high phosphorus amount available for growth (faster growth speed), and the remains amount is removed by precipitation in the sedimentation tank.

5.4 Nitrification/Denitrification Tanks

To establish a stable nitrification in the activated sludge system, the sludge age as well as the specific TKN-load of the biomass has to be carefully defined.

According to the German guideline ATV-DWVK-A 131 the required minimum aerobic sludge age is about 4.6 days for an assumed minimum temperature of 18°C in the Nitrification/Denitrification Tank. The following table shows that a total volume of 4,550 m³ meets the limits:

Nitrification/denitrification volume	m³	4,550
Total Solids in tank	kg/m3	5
	kg TS	22,750
Total excess sludge	kg TS / d	2.093
Aeration time	% of total	50%
Sludge age aerated	d	5.4
Total TKN-load	kg N / d	742
specific TKN-load	kg N / kg TS / d	0.03

The calculated specific TKN-load of the biomass of 0.03 kg per kg TS and per day is practice proven on WWTP of BTA AD Plants and is in accordance to the German guideline DWA-M 710.

Reactors number		2
Length	m	27.6
Width	m	15
Water level	m	5.6
Surface	m^2	414
Volume /tank	m^3	2,300
Total surface	m^2	828
Total volume	m^3	4,600

To check the potential increase of TKN-concentration in the effluent during the feeding sequence a worst case scenario shows that in case of no denitrification activity and complete mixing of a one hour TKN-load of 31 kg into the tank volume of 2,300 m³ the TKN-level in the effluent would increase about 13 mg/l. Regarding the target value of 182 mg TKN/l for the effluent such an increase of the TKN-level is acceptable.

5.5 Mixing of Nitrification/Denitrification Tanks

During aeration the aeration system provides proper mixing of the Nitrification/Denitrification Tanks. Two submerged stirrers in each tank located in opposite position provide efficient mixing during the periods of non-aeration.

The mixers are equipped with variable frequency drives (VFD) to provide smooth start of the mixer and to reduce the load during ramp-up.

Example for stirrers: 4 x Flygt submerged mixer with Banana propeller; 2.3 kW; VFD.

5.6 Aeration System for Nitrification/Denitrification Tanks

The determination of the performance of the aeration system is based on water temperature of 30°C in the aerated tanks (see table below).

Oxygen consumption according to ATV-DVWK A131:			
Oxygen consumption carbon compounents	OV_{dC}	kg/d	2,085
Oxygen consumption denitrification	OV_{dD}	kg/d	-1,989
Oxygen consumption nitrification	OV_{dN}	kg/d	2,949
Oxygen consumption total	OV_{d}	kg/d	3,045
	$OV_{h,avg}$	kg/h	126.9
Load factor carbon removal	f_C	-	1
Load factor nitrification	f_N	-	1
Factor for intermitted DN	f_{int}	-	1.0
Maximal oxygen consuption	$OV_{h,max}$	kg/h	127
Pressure aeration according to DWA M 229-1 :			
Water depth of aeration units	h_d	m	5.30
Interface factor	α	-	0.60
Depth factor pressurized air aeration	f_d	-	1.26
Salt factor	b	-	1.0
Temperature factor	θ	-	1.000
Atmosphere pressure	p_{atm}	mbar	1,013.3
Standard air pressure	p_N	mbar	1,013.3
Max. dissolved oxygen content at 20°C	$C_{S,30}$	mg/l	9.1
Dissolved oxygen saturation concentration at 30°C	$C_{S,T}$	mg/l	7.6
Required oxygen concentration in N/DN-tank	C_x	mg/l	2.00
Ratio oxygen supply water/OV	SOTR/OV	-	2.542
Oxygen supply water	SOTR	kg/h	**322.6**
Oxygen supply waste water	α·SOTR	kg/h	193.5
Spezific standard oxygen supply aeration unit	SSOTR	$g/(Nm^3 \cdot m)$	17.0
Required air supply for each N/DN-tank	$\mathbf{Q_{L,max}}$	$\mathbf{Nm^3/h}$	**3,600**

$$SOTR = \frac{f_d \cdot \beta \cdot C_{S,20}}{\alpha \cdot (f_d \cdot \beta \cdot C_{S,T} \cdot \frac{p_{atm}}{1.013} - C_x) \cdot \theta^{(T_W - 20)}} \cdot OV_h \quad (kg/h\ O_2)$$

To optimize the usage of the air injected, both tanks are equipped with high efficiency air diffuser systems. The diffusers are mounted on liftable frames. The diffuser consists of a perforated EPDM membrane plate which is mounting on a body plate and frame made of polypropylene. Efficient membranes form very fine bubbles which provide excellent oxygen transfer rates.

In each tank 532 membrane plate diffuser discs OXYFLEX –MF 1100 Type B "Efficient" are going to be installed covering about 26% of the 414 m² floor area of each tank. The membranes are used in different media: municipal waste water, industrial waste water and pond aeration are the field of application. They have proven to be very reliable.

The recommended air feed per diffuser ranges from 5 to 11 Nm³/h. That means that the air blowers have to provide an air flow from 2,700 to 5,900 Nm³/h for each tank. This meets the required air supply of 3,600 Nm³/h for each nitrification/denitrification tank.

For maintenance requirement the air flow per diffuser has to be increased to 14 Nm³/h on a regular base. That means that a maximum air flow of 7,500 Nm³/h is required for each tank.

The two parallel operated tanks are being fed alternatingly and during feeding no aeration occurs. Therefore, the two tanks are always aerated alternatingly. That means that a total blower capacity of 8,000 Nm³/h is sufficient.

Three blowers are going to be installed with a capacity of 4,000 Nm³/h each. During aeration two blowers provide 2,700 to 5,900 Nm³/h for each tank. The third blower is operated in stand-by mode. All blowers are equipped with variable frequency drives (VFD) in order to achieve a smooth change of the air load.

Example for blowers: 3 x Aerzen positive displacement blower GM 90 S; 160 kW; 1,300 – 4,000 Nm³/h.

5.7 Sedimentation Tank

Once the water has been treated in the nitrification/denitrification tanks and before to discharge it, it is necessary to separate the liquid phase from the biomass and suspended solids still present in the Nitrification/denitrification effluent. For this reason a sedimentation tank has been foreseen. In the table below are listed the dimensions:

Length	m	18
Width	m	4
Water level	m	4
Surface	m2	72
Volume /tank	m3	288

The Sedimentation Tank has been designed as a longitudinal square sedimentation tank. The Nitrification/denitrification effluent is fed (by overflow) into the short side. Just below the inflow, in an area with low turbulence, most part of the sludge is already separated and collects in a funnel. From here the sludge is pumped back to the Nitrification/denitrification tanks or discharge as surplus sludge in the Suspension Buffer. The sludge that sediments along the tank is conveyed into the funnel by means of an Bottom Scraper. The Sedimentation Tank is also provided with a Floating sludge/Foam removal system: it collects the floating material and sent it direct to the Suspension Buffer.

The sedimentation tank is designed for a return sludge flow rate equal to the design feed flow according to the German guideline ATV-DWVK-A 131. The tank surface of 72 m^2 guarantees that the maximum surface overflow rate does not exceed 0.2 m/h. This rate meets the requirements of the German guideline.

The clarified water will then be discharged by overflow in a Pump Receiving tank and then pumped and stored in the Surplus Water Tank.

6. References

6.1 WWTP of MBT Facility in Suldouro (Portugal)

The MBT facility in Suldouro, Portugal treats municipal solid wastes. The WWTP of this facility purifies the liquid effluent of the anaerobic digestion unit.

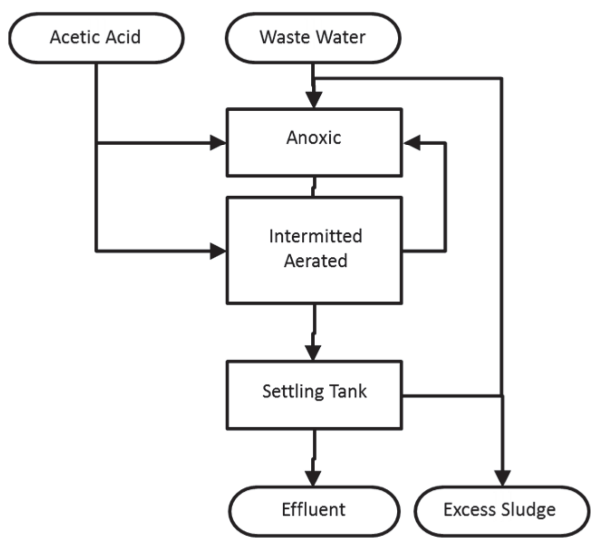
Process Description:

The WWTP is designed as an activated sludge system and consists of an upstream anoxic completely mixed tank (230 m³) for partial denitrification followed by an intermitted aerated completely mixed tank (330 m³) for nitrification / denitrification. A downstream located settling tank removes the sludge from the effluent.

The waste water is continuously or periodically fed into the denitrification zone. To accelerate denitrification acetic acid is fed into the denitrification zone as well. Nitrate rich mixed liquor is recycled from the aerated tank into the upstream anaerobic tank. Nitrification occurs during intermitted aeration in the second tank. To improve denitrification during non-aeration acetic acid is added for carbon source.

Downstream located settling tank separates the solids from the effluent. The segregated solids are either recycled into the denitrification tank or discharged.

Block diagram:



Operation Data:

Feed	Volume	[m³/d]	58
	COD	[kg/d]	157
	NH_4-N	[kg/d]	64
Effluent	COD	[g/m³]	955
	NH_4-N	[g/m³]	8
	NO_2-N	[g/m³]	6
	NO_3-N	[g/m³]	36
NH_4-N-load		[kgN/kgTS/d]	0.03