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Evaluering av renseanlegg med sekundærrensing uten nitrogen fjerning

Fremtidens RA

Norsk Vann

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02	03.10.2024	Issue for Review (IFR)	KS	SW	
01	20.09.2024	Issue for Review (IFR)	RRA	SW	Click to input
Rev.	*Date*	*Reason of issue*	*Prep*	*Checked*	*Accepted*

BIOWATER TECHNOLOGY	*Title* WP 1: Evaluering av renseanlegg med sekundærrensing uten nitrogen fjerning Fremtidens RA – Norsk Vann	*Responsible party* Biowater Technology *No. of sheets* 13

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1 Case presentation

The selected sewage treatment plant plays a decisive role in handling municipal wastewater from the town, at North of Buskerud (Fig 1). The facility has undergone extensive renovations to meet the requirements for secondary cleaning and ensure the highest environmental standards. By reusing existing building stock and choosing CO_2 emission-saving materials, the selected treatment plant will probably be one of the most energy-smart in the country. With a designed capacity of 9,300 person equivalents (PE), the facility treats and cleans wastewater efficiently. The plant has a new levelling reservoir and pre-treatment, as well as a biological cleaning step in the existing empty sludge basin.

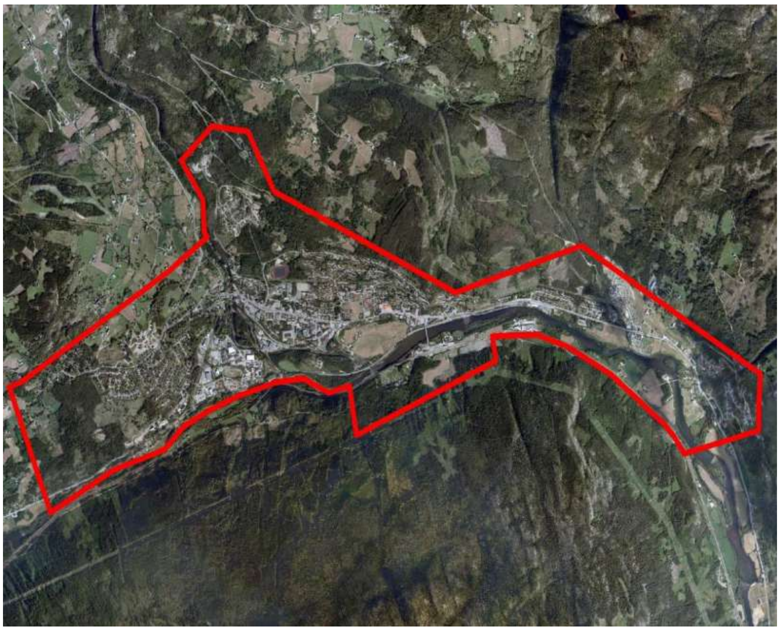

Figure 1 the area which the selected wastewater treatment is covering.

In 2017, The selected wastewater treatment plant had approx. 2 790 permanent residents associated with and average organic burden corresponding to approx. 4 600 person equivalents (PE). Much of the discrepancy is because a local food processing industry has a discharge agreement for contaminated wastewater from its slaughterhouse and processing operations for cattle and small cattle.

The load on the treatment facilities in the municipality varies throughout the year, with peaks during the Easter and winter holiday periods.

The plant was upgraded to meet the secondary treatment requirement and included the installation of a biological treatment step for the removal of organic matter by Biowater Technology.

1.1 Dimension basis to 2040

Dimensioning data for current treatment plant inlet to the selected RA, inlet biological treatment step and cleaning requirements in 2040 are given in Table 1.

Tabel 1: Dimensioning parameters for the plant given for the year 2040, 9300 PE:*

Parameter	**m^3/h, mg/L**	**m3/d, kg/d**	**Comments**
Flow Design ($Q_{maks,dim}$)	149		Two lines. Max to biological stage,
Flow Max (Q_{maks})	300		Only for pretreatment design
BOD_5 (1)	156	558	
COD	369	1317	
SS	203	725	
SS/BOD_5 (3)	1,3		
TP	4.3	15.3	
Dry matter amount (2)	390		Tonnes TS/year
Dry matter amount (2)	1336		Kg TS/d
Temperature ^{O}C	6/16		Min/max

** The information in table is given in tender phase by the consultant.*

1) Dimensioning organic load (and other loads) applies to wastewater supplied to the facility. Reject water load, including return flows from septic tanks and septic sludge management, is not included in the stated quantities.

2) Annual sludge production is calculated based on added organic load (PE and an expected specific sludge production 115 g TS/ PE x d). Daily sludge production is calculated from a daily factor of 1,25. It is assumed that the general contractor calculates dimensioning sludge production based on load data above and selected process solution.

3) There are no SS measurements for existing facilities. It is in the numerical material above that what has been done is a conservative assumption for the SS content in incoming water.

The current treatment plant consisted of two parallel lines and includes inlet screens, sand and fat removal, biological reactors (Biowater Technology Patented CFIC®) step, chemical precipitation, flocculation and sludge separation (decanting centrifuge) with sedimentation (Fig 2 and 3). Sludge containers, polymer processors and chemical tanks are in the existing building.

The biological stage has a total volume of 120 m3 (155 FWC m3 volume), distributed over two lines with one reactor in each line. Each reactor has a wet volume of 78 m3. 108 m3 of BWTX biomedia which has a protected surface of 650 m2/m3 in bulk was filled in the two CFIC® reactors. The degree of filling in the CMFF® process is 70% and 90% in CFIC®.

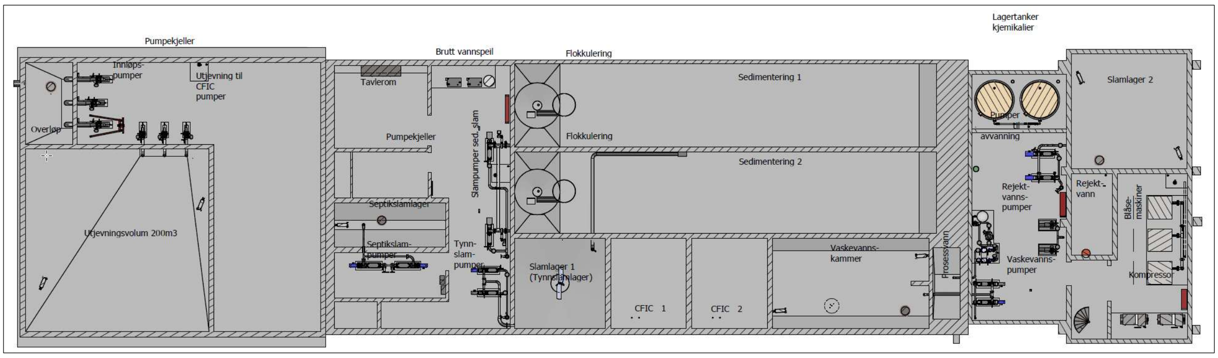

Figure 2: Layout of current treatment plant

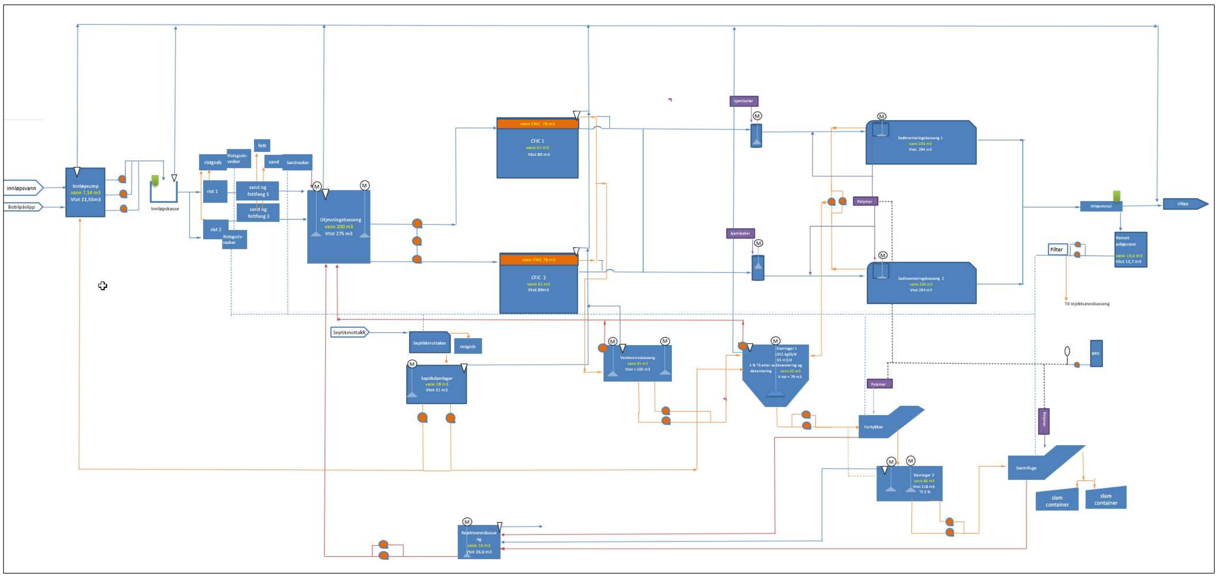

Figure 3: The selected Flow Diagram

1.2 Current flow and loading

Currently, the plant is running at a much lower organic loads than it was designed for (Fig 5) and a higher flow (Fig 4):

Flow: **Average: 52 m^3/h, Max: 102 m^3/h, Min: 26 m^3/h**

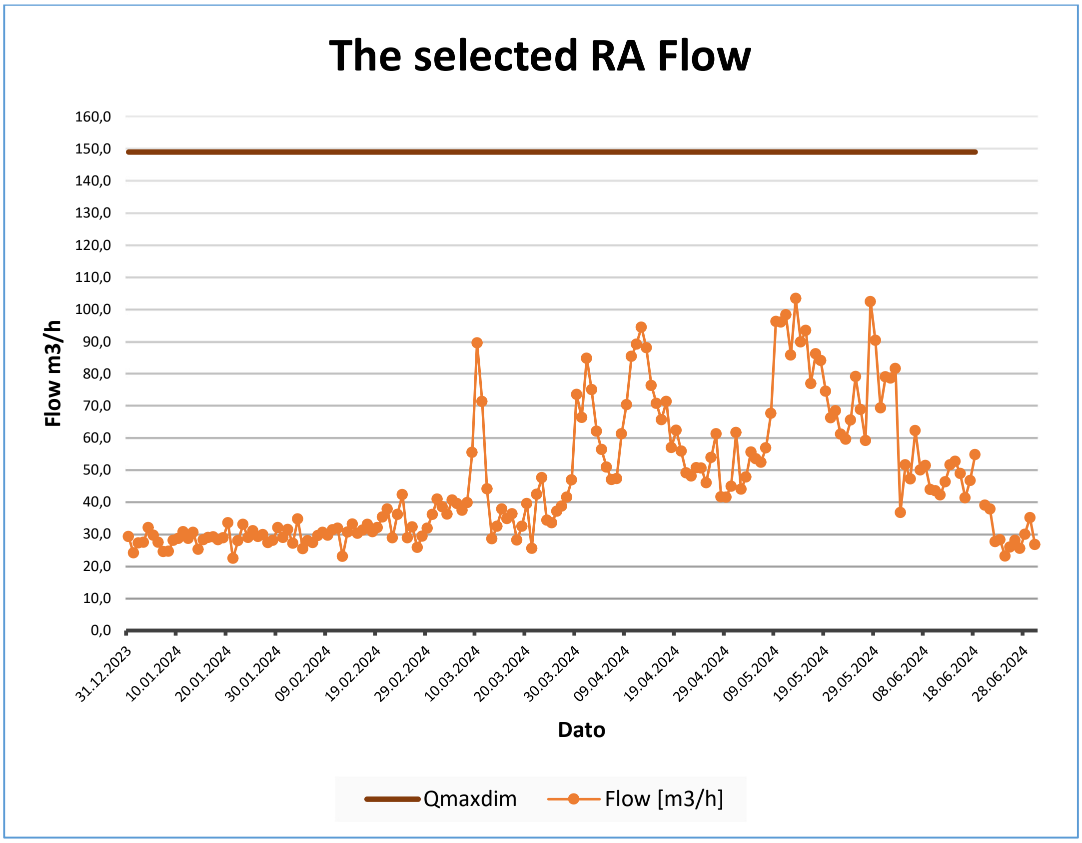

Figure 4 Design flow: 149 m³/h

BOD load to biological stage: **Average: 227 kg/d, Max: 385 kg/d, Min: 114 kg/d**

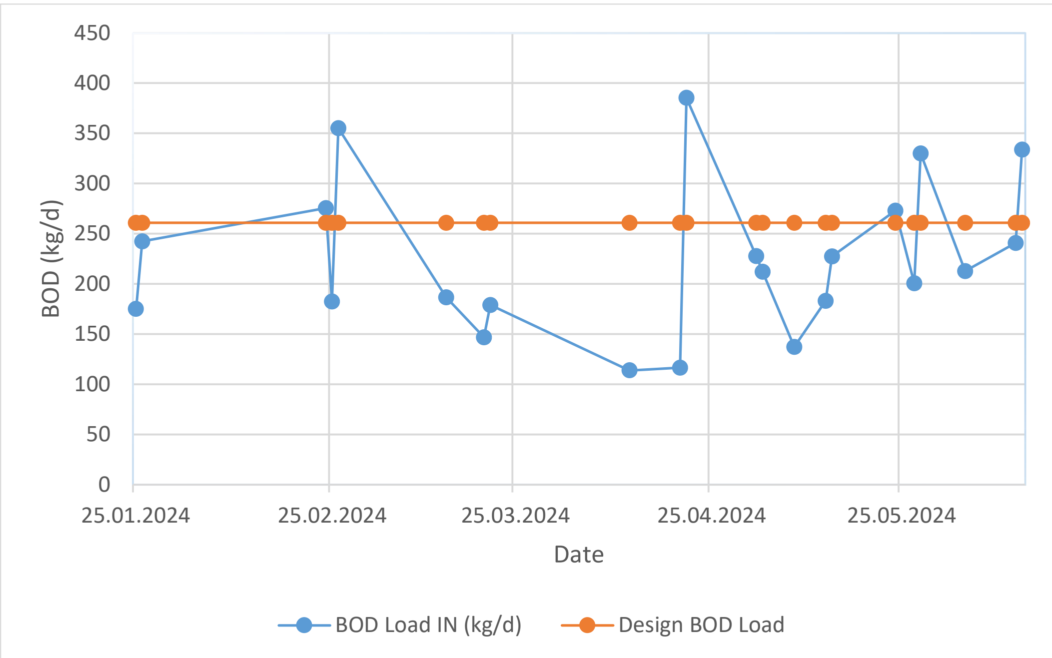

Figure 5 BOD load to the plant

1.3 The facility performance

The BOD concentrations out from the treatment plant are in the range of 4 to 25 mg/L with an average below 10 mg/L. The average BOD removal from the treatment plant is 95,6%. Maximum achieved BOD removal is 98,1% and minimum were 92,9% (Fig 6).

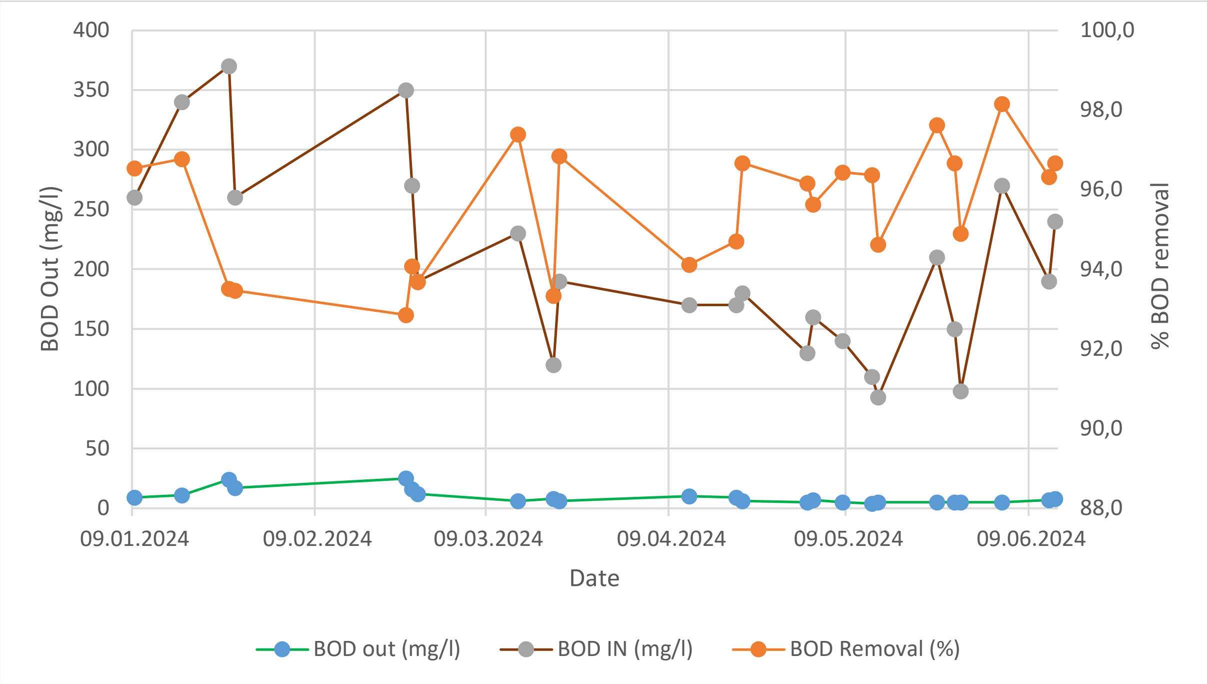

Figure 6. BOD in and out from the treatment plant and the BOD removal efficiency

1.4 Performance summary

The treatment plant operational data is summarized in Table 2. The plant was not desiged for TN removal, about 20% of the TN removal can be observed from the sample analysis. That can be explained by biomass uptake (about 5% TN) and some denitrification happening in the downstream processes.

Table 2, treatment plant data overview for 2023 and part of 2024

Parameters	Design values	Values in the whole 2023*	Values from 01.01.2024 to 30.06.2024*	comments
Flow rate, m^3/h	149	46.4	47.1	For both lines
Temperatur, ^0C	6/16	11.4		
COD influent, mg/L	369	676	633	
COD load kg/d	1317	668	645	
COD effluent, mg/L	<125	89	75	
COD removal efficiency %	75	83.4	86.3	
BOD to Biological stage, mg/l	156	263	204	
BOD out of Biological stage, mg/l	<25	25	9	
BOD load to Biological stage, kg/d	558	260	227	
BOD removal efficiency, %	70	88.6	95,6%	
Ortho-P influent concentration, mg/L	-	6.3	5.9	
Ortho-P effluent concentration, mg/L	-	0.49	0.33	
Ortho-P load, kg/d	-	6.4	5.9	
Ortho-P removal efficiency, %	90	90.3	91.9	TP removal for design values
TN influent concentration, mg/L	-	53.0	44.9	Average 49.0
TN effluent concentration, mg/L	-	40.6	34.2	Average 37.4
TN load, kg/d	-	52.3	48.8	Average 50.6
TN removal efficiency, %	-	21	22	
NH4-N influent concentration, mg/L	-	-	32.5	
NH4-N effluent concentration, mg/L	-	-	30.3	
NH4-N load kg/d	-	-	35.1	Removal efficiency 5.2%
NOx-N influent concentration, mg/L	-	-	0.58	
NOx-N effluent concentration, mg/L	-	-	1.16	

*average values

2 Space availability

The treatment plant is taking about 1100 m^2 (72 x 15 m). Potential extension for the current plant including nitrification and denitrification can be around the existing buildings.

3 Hydraulics

Fig. 8 shows the hydraulic of the treatment plant. Wastewater is pumped to the CFIC® reactor from a balancing tank. The water level of CMFF® is at a height of 198.7 m over sea level, which is 0.8 m over the CFIC® water level. The reactor is 3 m underground and 1.5 m over the group at the plant (including the floor of the reactor).

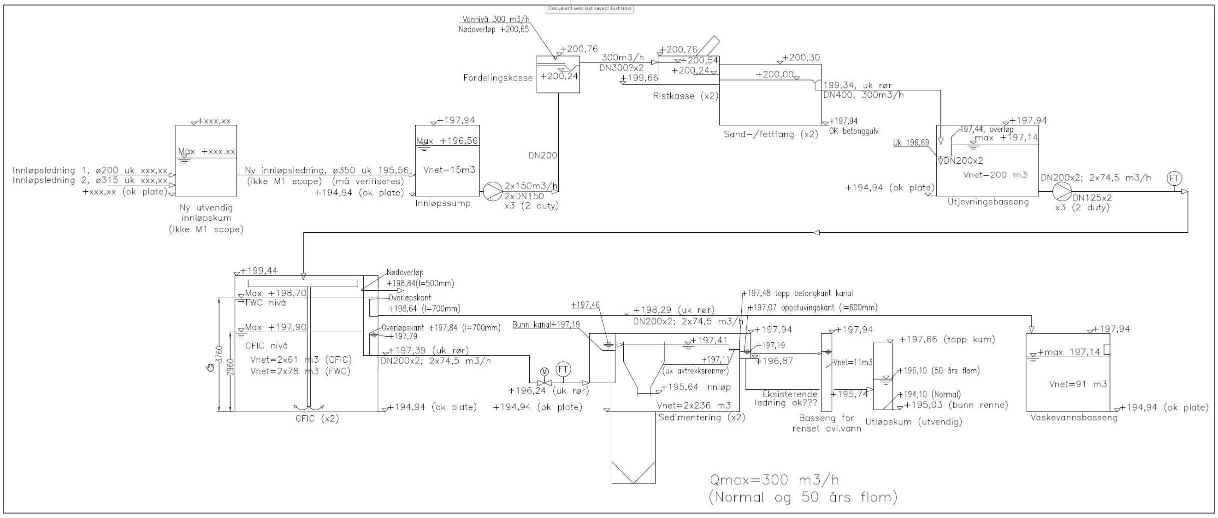

Figure 7: Hydraulic of current treatment plant

4 N removal design basis

Parameters for N removal design is based on the current plant design basis (Table 1 and Table 2) and Table 3, the measurement of NH_4-N and TN during operation.

Table 3 Design basis for the Nitrogen removal plant

Parameters	Values		Effluent requirements	comments
	Inlet	Plus reject water		
Flow rate, m^3/h	149	154	-	
Temperatur, ^{0}C	6/16	-		
COD influent, mg/L	369	413	>75%	10 mg/l (10 000 – 150 000 p.e.)

COD load kg/d	1318	1475	-	Based on 150 m3/h for TN
BOD to Biological stage, mg/l	156	172	>70%	
BOD load to Biological stage, kg/d	558	616		Based on 150 m3/h for NH4-N
TS mg/l	203	232	35	-
TP	4.3	4,7	>90%	
TP load, kg/d	15,3	16,9		
TN influent concentration, mg/L	31,2	35	>80%	Estimated from 12gTN/PE/day
TN load, kg/d	112	125	-	
NH4-N influent concentration, mg/L	31,2	32	3	
NH4-N load kg/d	112	125	-	

5 Proposal of N removal for the existing treatment plant

The simplified flow diagram (Fig. 9) is arranged that the flow upstream initially to the BOD reactors is pumped to an inlet channel and distributed to the parallel Pre-denitrification reactors and then flow to the parallel BOD reactors. Effluent of the BOD reactors in both CFIC® and forward washing models will be pumped to the nitrification reactors, and gravity flow to the subsequence post denitrification and aerobic reactor, and eventually through DFA unit.

The proposed arrangement can fulfil discharge requirement listed in Table 3.

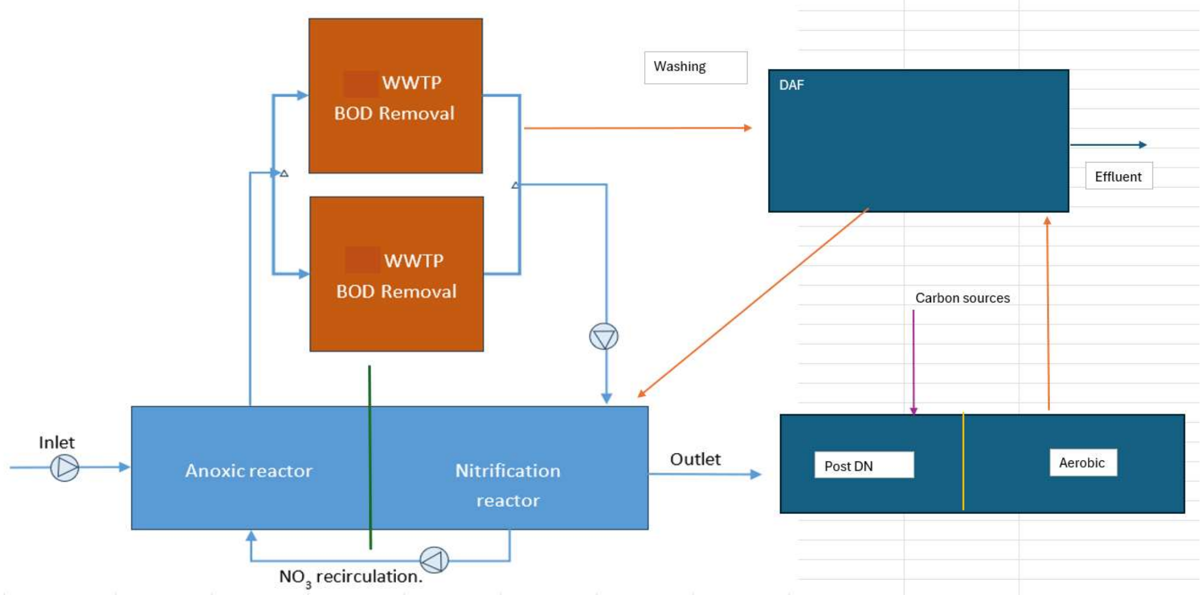

Figure 8 Flow diagram of the plant with N removal integrated.

The outlet level from the BOD removal reactors is +197,79 m and the inlet to the separation stage is +197,46 m (Fig. 8). There is not room to include a nitrification reactor by gravity. In that case, it is needed a pump station out the BOD removal to the nitrification reactor. From the nitrification reactor the water can flow by gravity to the downstream stage.

The proposed N removal plant will consider two scenarios on the conditions mentioned in Table 4, while based on two flow conditions of 149 m3/h and 50 m3/h (practical flow rates in 2023 and partly 2024) at Temperature of 11 ^{0}C (average wastewater temperature).

Fig.10 and Fig .11 present potential arrangements of the N removal plants for scenarios 1 and 2 by integrating with existing BOD removal reactors using skid reactors of dimensions. The reactors distributions for each treatment sections are given in Fig 10 and 11.

Table 4 Summary of skid reactor units for the test scenarios.

Scenarios	Flow rate m3/h	Pre DN	Nitrification	Post DN	Post Aerobic	Total skid reactor	Space required (m2)*
1	50	6	2	1	1	10	144
2	149	15	10	3	1	29	419

*Based on 3.8 m X 3.8 m for each skid reactor, not considering pump and control skids etc.

Scenario 1

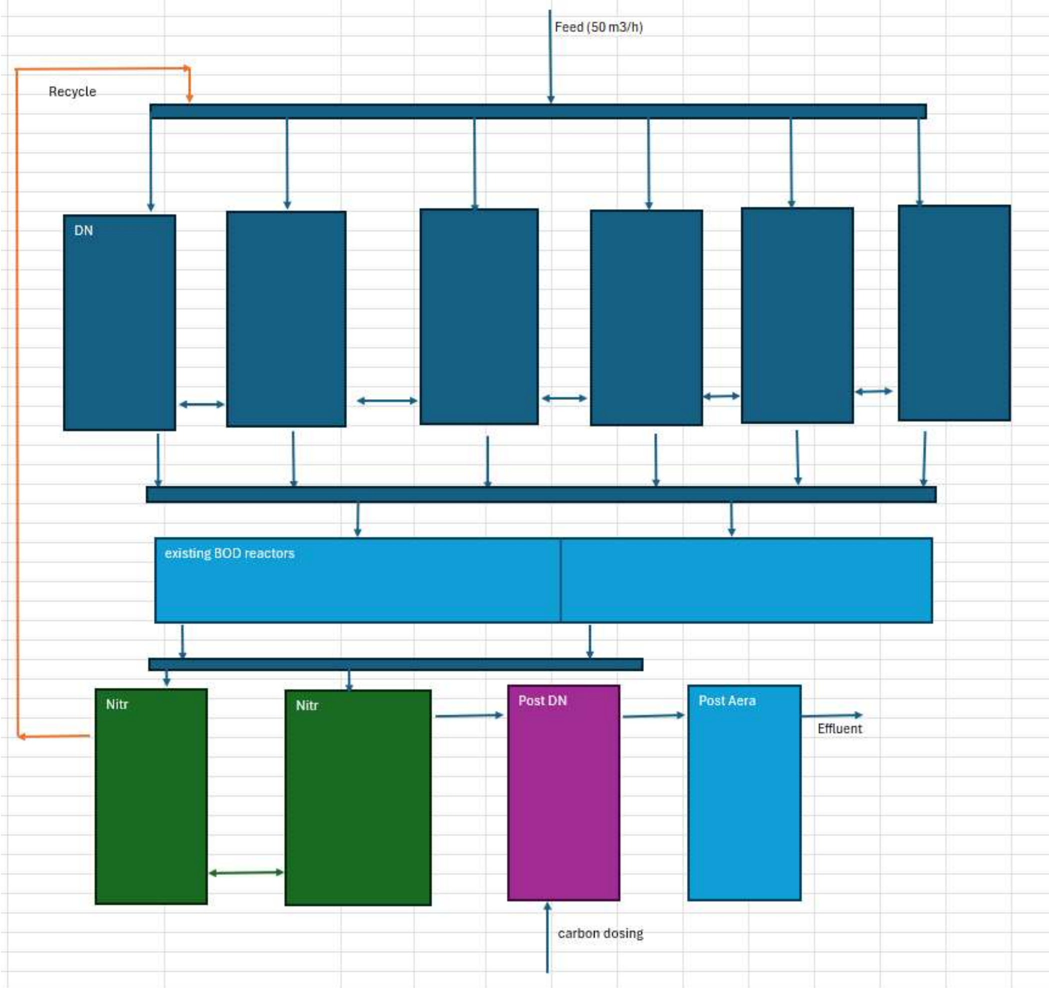

Figure 9 Scenario 1 with potential reactors arrangement for a practical flow rate 50 m3/h considered.

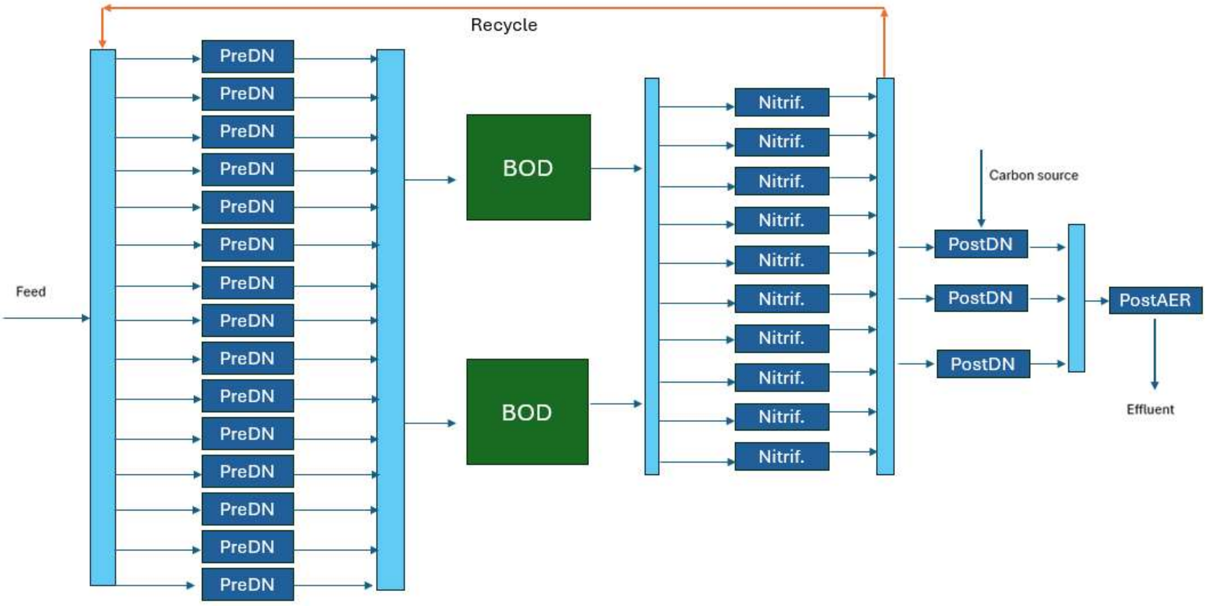

Figure 10 Scenario 2 potential reactors' arrangement for 149 m3/h full capacity design.

6 Conclusion

Skid reactors as N removal stage can be integrated to the selected existing BOD treatment plant with full adaptation to existing design and arrangement. The skid system is standardized, and scalable and can greatly reduce the deployment cost and complexity. This will facilitate decision making by municipalities. A summary of the findings and integration to an existing plant is given below. Detailed specifications of the equipment and instrument and arrangement of the system are prepared in a separate internal document.

Process

The existing treatment plant does not deliver Nitrogen removal performance. The plant is designed for the BOD removal. The expected load to 2040 is 9300 PE. Two scenarios of designs based on the skid system are proposed. The current load condition is about half of the designed BOD removal capacity. Scenario 1 is proposed to handle such condition and scenario 2 is handling the full capacity of 9300 PE Both scenarios took N removal considered and designed based on the parameters collected or initially given in design stage. By providing Pre-DN stage, part of the influent BOD is consumed by denitrification organisms which reduces the organic load to the initial BOD stages and potentially reduce the BOD concentration after the BOD removal stage for an effective nitrification process.

Additional carbon source will be required for the post denitrification stage to further reduce N to fulfil 80% TN removal. Effluent from the post aerobic stage can flow back to the current DAF system by gravity without needs for further stages or treatment.

The proposed treatment plant applying skid system will meet the potential regulations on N and organic removals.

Hydraulics

Pumps will be needed to deliver wastewater treated after the BOD reactors to the nitrification stage due to height differences at the treatment plant and potential position of the nitrification stage. Recycle pump is also needed to pump nitrification effluent back to Pre-DN stage for denitrification.

Footprint

The presented scenarios of designs show a space requirement of from 130 to 419 m2 for the skid reactors for both scenarios, not including other equipment such as pump stations and control facilities.