Ultrakompakt biologisk nitrogenfjerning ved bruk af fortettet biomasse

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1 Preface

This is the preliminary main report for the development study “Ultrakompakt biologisk nitrogenfjerning ved bruk af fortettet biomasse” funded under the programme “Fremtidens renseanlegg”. A final version of the report will be delivered in December 2024.

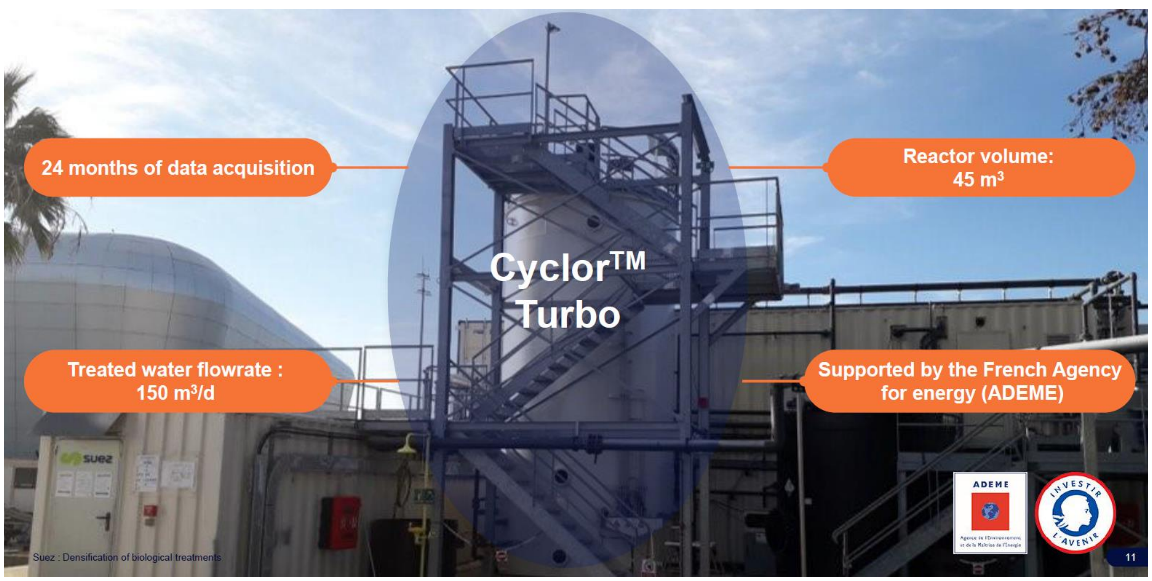
2 Introduction

In order to protect the Oslofjord, there is a strong need for fast implementation of nitrogen removal on all WWTPs discharging into the precipitation region of the Oslofjord.

In recent years, several new solutions for biological nitrogen removal has been developed, including membrane-aerated biofilm reactors (MABR), aerobic granular sludge (AGS) and as well as an enhanced version of conventional activated sludge process based on densified biomass. It is generic for all of these new solutions that they offer compact and highly efficient ways of biological nitrogen removal. MABR is first of all an approach to increase the nitrogen removal capacity of existing biological nitrogen removal processes while AGS is a compact solution for greenfield plants. Densified biomass is on the other hand a solution that can be either implemented on existing activated sludge plants through the use of densification solutions such as inDENSE (patented by SUEZ' partner NewPort) and also in greenfield or retrofitting of existing plants, and thus this solution can be adapted for implementation or enhancement of nitrogen removal on most type of cases.

SUEZ has developed and patented a densified biomass soluition called Cyclor Turbo.

The solution is the new development of SUEZ' sequenced batch reactor (SBR) CyclorTM and has been proven and validated through a fullscale demonstration plant operated for 24 months on a WWTP in France (demonstration plant with capacity equal to 600 PE). The demonstration plant is directly scalable to fullscale installations and the design and control philosophy has been optimized throughout the demonstration project.



The solution is now being implemented in 3 fullscale installations, two retrofit of existing WWTP's in France (47.000 and 120.000 PE) and one big greenfield WWTP in Philippines (800.000 PE).

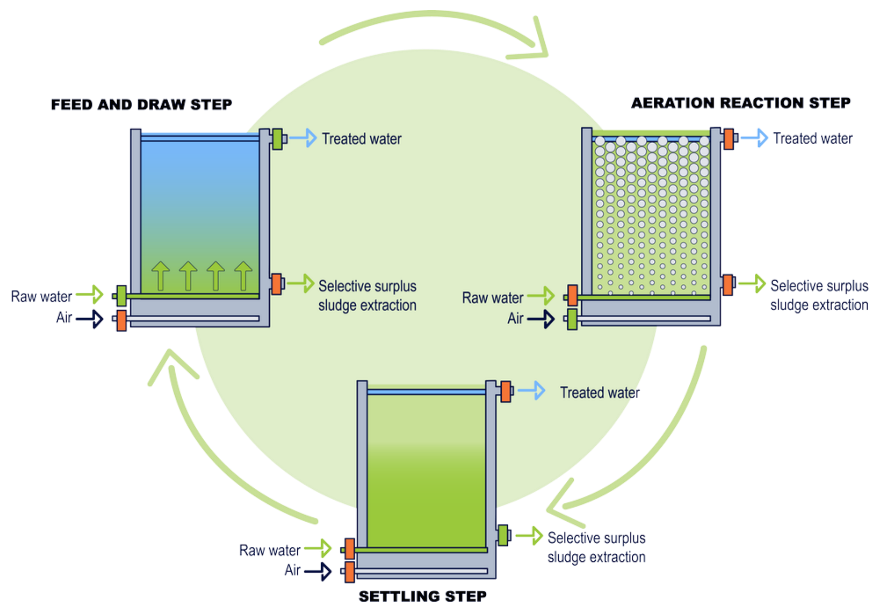
Pictures from 3D model of the Cyclor Turbo currently under installation in Libourne, France (47.000 PE).

The key feature of CyclorTM Turbo is that it is based on densified biomass with biological phosphorus removal and a constant level operational approach. The densified biomass selection is developed in a way that ensures only partial granulation of the sludge which means that the biomass is much more robust towards seasonal load variations compared to Aerobic Granular Sludge (AGS) systems but still provides much better settling properties than conventional activated sludge. Thus, the solution is expected to be more well adapted to the challenges with seasonal variations including periods with low temperature and low loads during the snow-melting period.

3 Cyclor Turbo

The SBR (Sequenced Batch Reactors) is a wastewater treatment processes using compact activated sludge designed to carry out successively and sequentially, all the treatment phases in the same tank: Filling, aeration, settling and emptying. They treat carbon, nitrogen and phosphorus pollution and are particularly suitable for discharges in sensitive areas.
The solution combines the hydraulic and biological conditions to naturally develop a consortium of densified activated sludge with high settling capacity. The raw water is fed under anaerobic conditions into the sludge bed, and simultaneously the treated water is taken from the upper part of the reactor by a water recovery system, and the different sequences are as follow:

1. Feed & draw phase
   The cell is fed at its bottom with raw water while the treated water flows out at its top, maintaining a constant liquid level in the cell.
2. Reaction phase
   It treats effluent by removing carbon, nitrogen by nitrification-denitrification and phosphorus by enhanced biological phosphorus removal
3. Settling phase
   Treated water Is separated from sludge through rapid sedimentation due to the sludge densification, with no filling or aeration. Excess sludge is removed.



Advantageous from this process:

- Constant outlet water flow
- Sludge settling velocity increased
- Treated water quality: TSS <15 mg/L

4 Overview of cases

During the study, SUEZ has been in dialogue with wastewater treatment plants within the 22 municipalities including in the programme.

Based on the screening and dialogue with specific municipalities, the following three cases has been identified:

- Small (~1.000-5.000 PE): Bjørkelangen WWTP (Aurskog-Høland)
- Medium (~20.000-50.000 PE): Remmendalen WWTP (Halden)
- Large (> 100.000 PE): Tangen WWTP (MIRA)

Bjørkelangen WWTP is designed for 10.000 PE, so it is a bit above the interval stated above but still seen as a good representative for typical, existing WWTPs in the small range.

Remmendalen WWTP was in 2016 extended from a design capacity of 30.000 PE to 42.000 PE and the plant will now also need to implement nitrogen treatment (existing plant has requirement for phosporus, BOD and COD reduction).

For Tangen WWTP, MIRA is currently looking into a scenario for future extensions to a design capacity of 80.000 PE and also has a need to implement nitrogen removal. While this plant is in between the above stated range for medium and large plants, this is seen a good representative for larger WWTPs and there are not many WWTPs in the region above 100.000 PE.

With these three plants included in the case studies, the study covers a good range of the typical WWTPs in the Oslo-fjord region.

5 Case 1: Remmendalen WWTP (Halden)

Remmendalen WWTP is the main plant in Halden commune and it was in 2016 extended from a design capacity of 30.000 PE to 42.000 PE. The existing plant is an MBBR plant treating phosphorus (chemical), BOD and COD but with the new regulations the plant needs to be upgraded to treat nitrogen. However, the plant is placed in a location with very limited space available for extensions, and therefore it is required to evaluate compact treatment solutions such as Cyclor Turbo for the extension.

5.1 The design basis of the feasibility study for upgrade based on Cyclor Turbo

The technical team in SUEZ were given the following numbers for feasibility study of Remmendalen RA:

CARACTERISATION RAW WW				
			Currently received	
Average yearly flowrate			13180	m3/d
Reference flowrate			23068,55	m3/d
Dry weather peak flow			7500	m3/d
Wet weather peak flow			13000	m3/d
		Average	95%ile	
Corresponding average flowrate		13180		m3/d
BOD5 load		1364,34	2416,04	kg/d
DCO load		3656,84	5556,96	kg/d
TSS load		2263,46	3666,31	kg/d
TKN load		356,4	495,14	kg/d
TP load		39,95	53,88	kg/d
Is the WWTP's max hydraulic flowrate known?			37200	m3/d
OUTLET GUARANTEES			**Reduction**	
BOD5	If BOD >	25	75%	
COD	If COD >	125	75%	
Total-N			70%	
Total-P			90%	
Min. temperature for nitrogen removal			8°C	
Max temperature during summer			25°C	
TYPE OF OUTLET GUARANTEES				

Concentration OR removal rates			Yes	
PRETREATMENT				
What is the smallest size of screens in pretreatment?			6 mm	
Is there grease removal?			Yes	
Is there sand/grit removal?			Yes	
Is there primary treatment ?			Yes	
If yes, which type?			Salsnes filters	
Is there a buffer tank?			No	
BIOLOGY				
Is there an anaerobic zone?			No	
Is there an anoxic zone?			No	
Aerobic zone configuration:				
Aeration			Continuous	
Type of aeration			Coarse bubbles	
Aeration regulation			Yes	
If yes, precise			O2 sensor on each tank	
Volume of aerobic zone			1800 m3	
AERATION SYSTEM (if different than brushes)				
Number of blowers			4	
Number of tanks			3	
Digestion				
Is there digestion on site			Yes	
DRAWINGS AND DOCUMENTS TO PROVIDE				
General plant layout			Yes	
P&ID drawings			Yes	
Plant design reports for water and sludge lines			Yes	
Technical specifications of sludge thickening step			Yes	
Expansion of the plant				
Possible available area			~750 m2	
Available free height			5m	
Water quality				
Inlet and outlet data available			Yes	

5.2 Preliminary process design

SUEZ has run some simulations for Cyclor Turbo, to determine the needed capacity to guarantee the discharge limits expected in the future in Norway.
The simulations are based upon the design basis described in chapter **Fejl! Henvisningskilde ikke fundet.**, as SUEZ couldn't fully describe the current WWTP there are some hypotheses for the simulations, which are shown here below:

- Primary treatment: Salsnes without reagent. SUEZ experiences: 30-70% TSS removal.
    - **Hypothesis:** 30% and 50% removal were used for simulations
    - **Hypothesis:** 60 g/L for sludge extracted
- Sludge line: Digestion of primary and bio sludge
    - **Hypothesis:** Centrifuges running 24/7
- Guarantees: Removal of NGL 70% and increased to 85%
    - **Hypothesis:** Used the pure removal rate, not concentration. Which will mean concentrations below 6 mg/l, which would be the expected concentration limit in the new Urban water directive.
- Max hydraulic flowrate is used, but existing MBBR tanks are included as buffer tanks, evening the max flow rate to 1100 m^3/h.
- The Cyclor turbo water height is set to 7 meters.

All the above hypothesis and specifications are used for both the 70% and 85% removal rate scenarios.

5.3 70% NGL removal

As indicated above, the simulations were performed with a TSS removal of both 30% and 50%, which are hypothesis from SUEZ, if the actual removal rate is higher than 50%, this could help minimizing the area needed.
The results of the simulation are shown in Table 1.

Table 1: The results of the Ondeor simulations of Cyclor turbo

SALSNES REMOVAL RATE OF TSS:	**30%**	**50%**
NUMBER OF CYCLOR TURBO CELLS	**4**	**4**
AREA NEEDED PER CELL [M^2]	**380**	**355**
TOTAL AREA [M^2]	**1520**	**1420**

So with the high removal of TSS in the Salsnes filter would still require four cells of Cyclor Turbo and an area of 1420 m^2. As shown in Figure 1 there is a possibility to expand around the plant.

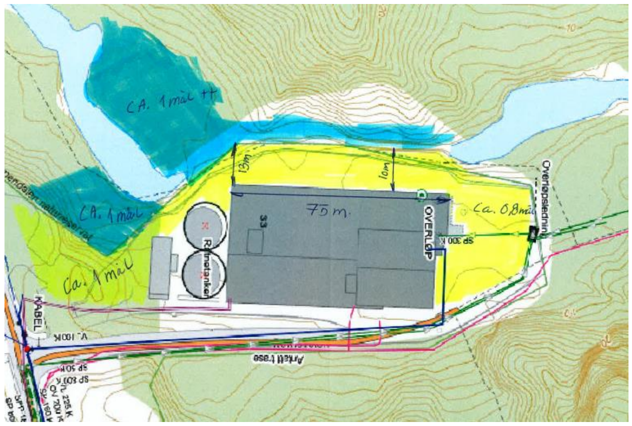


Figure 1: Area around the current plant, that could be included in an expansion. Yellow area is inside the nature limit, and everything in blue would mean negotiation with Statsforvalter.

The most obvious area is on the vest side where there is 10 x 75 meters, equaling 750m^2, where it would be possible to erect something within the nature reserve.
These 750m^2 are just half of the needed area, so it would be needed to either negotiate using more of the blue area with the Statsforvalter or building in a weird shape to have the Cyclor turbos be within the yellow area. This would probably not be ideal, as the hydraulics could be even harder to calculate.

5.4 85% NGL removal

It would not be possible to reach the 85% removal rate without the addition of methanol, due to the ratio of BOD/NTK = 3,2. It is not possible to add methanol to the process with cyclor turbo, as there is no mixing in the tanks, so it isn't possible to ensure homogeneity.

What could be done, is a possible reuse of the current MBBR-C, which would be converted to an MBBR PostDN and achieve additional removal of ~3 mg/l of NNO_3. Which would installation of buffertank as the MBBR were used as buffertanks in the simulations to even the maximum hydraulic flow to 1100 m^3/h, and the flow would be as shown in Figure 2.

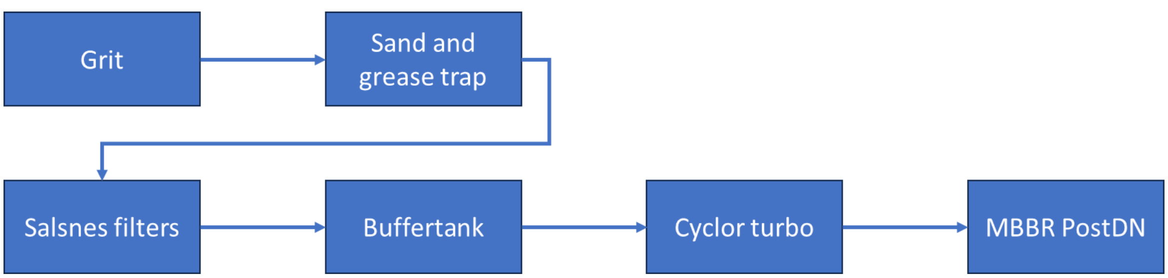


Figure 2: The process flow if the MBBR was converted to PostDN

This conversion would only apply to a discharge limit without concentration limits. If Norway was to apply the limits described in the Urban wastewater directive, the lower limit of nitrogen would be 6 mg/L. If this was also to be included in the Norwegian legislation, a Cyclor Turbo unit would reach this concentration without the additional MBBR postDN.

6 Case 2: Hagen WWTP (MIRA)

Hagen WWTP is a WWTP from 2016 that needs to be upgraded to meet the coming requirements for nitrogen removal.

The feasibility study for this case is currently being prepared.

7 Case 3: Bjørkelangen WWTP

Bjørkelangen WWTP is a 10.000 PE plant that will need to be upgraded to include nitrogen removal.

The feasibility study for this case is currently being prepared.

8 Contribution to achieve the targets for “Fremtidens renseanlegg”

In the project application phase, it was foreseen that the possibility to use densified biomass solutions would potentially providefollowing key benefits that will enable faster implementation of nitrogen removal in Norway and in particular in the Oslofjord precipitation area:

- Extremely compact solution that requires 2 times less footprint compared to conventional activated sludge plants due to patented selector system that ensures densified biomass with very good settleability
- Modular pre-engineered design that can be fitted both to small, medium and large WWTPs enabling fast implementation
- Simple mechanical design and control philosophy that requires minimal additional training of operators
- Highly adaptable to seasonal variations in load as sequences can be changed in operational settings
- Low OPEX with less chemical usage due to design based on biological phosphorus removal and low energy consumption due to optimized hydraulic design (10% energy saving)
- Can be adapted to coming requirements for micropollutants treatment e.g. by use of inline ozonation or compact activated carbon filters without need for intermediate tertiary treatment

SUEZ has already technically validated the solution through many years of thorough solution development including years of pilot testing under different operating conditions, and it is being implemented in fullscale plants globally. However, there is always a barrier in local markets to implement new solutions and the end-users wants to be ensured that the solution also matches the local requirements and conditions including water quality and weather conditions. Therefore, there is a need for additional investment in local studies of the solution.

The approach here where three cases are selected that represents well the spectrum of different plants in the region, will make it much more efficient to do this «local validation» and the results will be shared accross all the municipalities that can all make use of the information, instead of more normal case by case studies for individual plants.

The outcome of this study is still expected to be a recommendation of a pilot test validation on the best case among the plants studied.

9 Status on activities and milestones

The project was in the application scheduled to start on 15/8 with the kick-off meeting, but due to delays in project award and contract signature, the project was delayed with some preparational activities in early September while the project was finally launched with a one month delay.
This delay has also impacted the remaining schedule of the project.

The status at this point is that all three cases for the feasibility study has now been identified and feasibility and pre-design is done for one out of the study has been started for the two remaining cases. It is expected that the two remaining cases is finalised by 12th of December and the final report is expected ready on 18/12.
The project presentation for all project stakeholders can also be planned on 18th December.
The initially scheduled milestones and current status is listed below.

Initial schedule and milestones for the project:

	Status per 26/11-24:
- 15/8: Kick-off	Done
- 15/9: 3 cases identified after screening of all plants	Done
- 30/10: feasibility and pre-design done for the 3 cases	1 of 3 done
- 15/11: Final report done with recommendation for next step	Expected 18/12
- 31/11: Open presentation of the report for all project-stakeholders	Expected 18/12

10 Status on project costs according to budget

10.1 Planned budget

Kostnader	Beløp
Oppstartsmøte	12 000 NOK
Forundersøkelse	504 000 NOK
Undersøkelse/forprosjekt	470 250 NOK
Plan & Budsjett utarbeidelse	60 000 NOK
Avslutningsmøte	8 000 NOK
Administrative kostnader	18 000 NOK
Prosjektledelse	270 000 NOK
Sum kostnader	**1 342 250 NOK**

Finansiering	Beløp
Samlet kostnad	**1 243 250 NOK**
- Egne midler (timer)	671 125 NOK
- Andre offentlige tilskudd	0
- Annen finansiering	0
Omsøkt tilskudd	**671 125 NOK**

10.2 Status on costs (man hours)

The project costs are solely linked with man hours.
So far the project costs are borne mainly by Thomas Bugge (project management and process management linked to feasibility studies) and Johan Fredriksson (project management) while a few hours has been spent by Martin Dau (process engineering).

Thomas Bugge has been working on internal planning and administration, project presentation at "spredningskonferensen", initial screening of potential cases for the study, review of specific plants selected for the cases.

The main contribution from Johan Fredriksson has been involvement in project management, coordination and follow-up with local stakeholders, participation and coordination of meetings with stakeholders including the plants included in the study, as well as gathering data inputs from the different plants for the feasibility studies.

Person	**Week**	Hours spent
Thomas Bugge	38	5
Thomas Bugge	39	3
Thomas Bugge	40	2
Thomas Bugge	41	2
Thomas Bugge	42	4
Thomas Bugge	43	5
Thomas Bugge	44	13
Thomas Bugge	45	0
Thomas Bugge	46	2
Thomas Bugge	47	3
Thomas Bugge	48	10
Sum per 26/11 2024	**-**	**49**

Person	**Week**	Hours spent
Martin Dau	48	2
Sum per 26/11 2024	**-**	**2**

Person	**Week**	Hours spent
Johan Fredriksson	36	19,5
Johan Fredriksson	37	7,5
Johan Fredriksson	38	15
Johan Fredriksson	39	2
Johan Fredriksson	40	1
Johan Fredriksson	41	3
Johan Fredriksson	42	1
Johan Fredriksson	43	2
Johan Fredriksson	44	1

Johan Fredriksson	45	3
Johan Fredriksson	46	2
Johan Fredriksson	47	1
Johan Fredriksson	48	5
Sum per 26/11 2024	**-**	**63**

10.3 Remaining costs for finalization

In the remaining month of the study, following activities are outstanding:

- gathering of data from the two last cases
- performing the feasibility study for the two cases
- final report writing
- evaluation of budget and schedule for a potential pilot study
- presentation meetings with all stakeholders including preparation

11 Summary of findings from the study

As two of the cases are still not finalized, the overall findings from the project is still pending and will be included in the final version of the report.