Nereda, a Proven Technology

Worldwide Nereda Variants and Applications

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1 Introduction

This report gives an overview of all full scale Nereda® [1)] installations worldwide. It is shown that Nereda can be tailor made for every project based on its specific demands. Several process configurations currently applied are shown including back ground information on one project for each process configuration. Additionally a complete overview of all Nereda projects is given.

[1] Nereda® Technology is a patented and proprietary technology for biological treatment of wastewater with aerobic granular biomass, branded with the registered trade name Nereda® which is owned by HaskoningDHV Nederland B.V.

2 General description of the Nereda® system

The Nereda® Aerobic Granular Biomass Technology was developed by Royal HaskoningDHV in close collaboration with the Dutch water sector and the Delft University of Technology. Following the success of the first full-scale implementation in 2006, the Nereda® technology is quickly becoming the international standard for aerobic wastewater treatment. More than 20 Nereda® plants are currently in operation or under construction in Europe, Africa, Australia and South America, whilst many more plants are currently being planned or designed. Nereda® reactors in operation are amongst the world's largest SBR tanks, showing that the Nereda® system has matured and is applicable for even the largest municipal and industrial wastewater treatment challenges.

Figure 1. Settling Properties of the Aerobic Granular Biomass (left) compared to Activated Sludge (right).

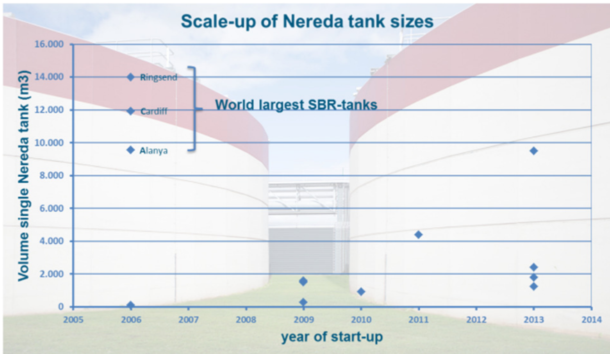


Figure 2. Scale-up meeting world largest SBR tanks

Main characteristics of the Nereda® technology:

- One-tank solution
- Greenfield, retrofit and hybrid
- Cost-effective in CAPEX and OPEX
- Plant footprint up to a factor 4 smaller
- Up to 50% energy savings
- No/minimal waste generating chemicals
- Excellent effluent quality
- Easy to operate
- AquasSuite® Nereda® Controller inside

Biomass in Nereda® develops as fast settling aerobic granular sludge which is a major advancement from the slow settling flocculent bio-sludge used in conventional Biological Nutrient Removal (BNR) systems. Nereda® offers the following key advantages over conventional BNR systems:

- Significant plant footprint reductions:
  Due to high design biomass concentrations and high sludge settling velocities the required bioreactor volumes are smaller. In addition, sludge settling and enhanced biological nutrient removal is performed in the same reactor and there is therefore no need for secondary clarifiers and anaerobic/anoxic tanks. This makes the system even more compact and significantly reduces the required footprint. A reduced footprint results in additional savings for land acquisition (see Figure 3).

- Low energy requirements:
  Since all biological and settling processes take place in one reactor, less mechanical equipment is required. For instance, sludge recycle pumps, mixers and moving decanters are redundant and not required for the Nereda® technology. As a result of this reduction in mechanical equipment, the

overall energy consumption of a Nereda® is substantially reduced when compared to a conventional BNR plant.

- Low investment costs:
  As a result of the compact and uncomplicated reactor structures and the reduction of mechanical equipment required, the investment costs for Nereda® systems are significantly lower than for conventional BNR systems.

- Low operating costs:
  The minimization of required mechanical equipment reduces both operational (energy) and maintenance costs. Because of the high uptake of phosphorous (P) by the Nereda® granules, the amount of chemicals required to achieve low P-effluent values is reduced or made redundant completely, thereby further reducing the operational costs for chemicals and sludge processing.

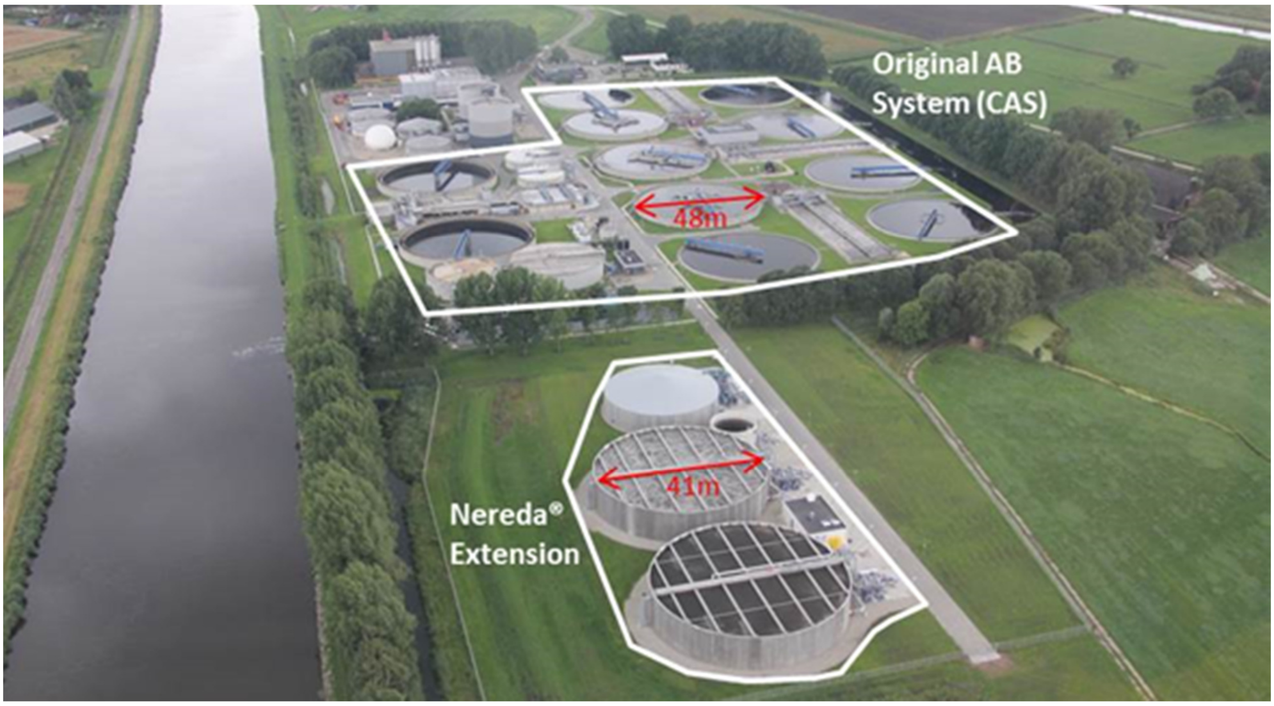


Figure 3. Garmerwolde WWTP with the Nereda® extension in the lower part of the picture

Figure 3 of the Garmerwolde WWTP (The Netherlands) illustrates the efficient footprint of the Nereda® technology compared to conventional BNR systems. The two ø 41 m Nereda® reactors in the bottom of the picture treat 50% of the total flow, whereas the conventional WWTP in the upper part of the picture treats the other half of the flow. Note that the clarifiers of the conventional WWTP (ø 48 m) are bigger than the Nereda® reactors. Overall footprint saving for rectangular Nereda reactors is even bigger.

The following sequential steps and processes occur in the Nereda® system (see also Figure 4);

1. **Simultaneous fill and draw.** During the fill phase, influent wastewater is fed to the bottom of the reactor and flows under near-plug flow conditions through the settled granular biomass. As a result of the plug flow there is no contact between the purified effluent at the top of the reactor and the raw influent wastewater at the bottom, enabling wastewater treated in the previous cycle to be displaced or "pushed" out of the reactor as well-treated effluent, whilst the reactor is simultaneously being fed. Therefore, unlike SBR systems, Nereda® does not require a separate time consuming decant

phase. More importantly, static fixed overflow weirs (as shown in Figure 8) are used instead of the moving and maintenance intensive decanters typically applied in SBR systems.

2. **Aeration.** During the aerated reaction phase all biological processes take place. Fine bubble aeration generates an oxygen gradient in the compact structure of the granular biomass. At the aerobic outer layer of the granule organic pollutants are efficiently oxidized. Nitrifying bacteria also accumulate in the outer layer of the granules and convert ammonium to nitrate. The produced nitrate diffuses into the anoxic core of the granule where it is simultaneously denitrified. In addition enhanced and extensive biological phosphate fixation takes place.

3. **Fast settling.** In this phase the biomass is separated from the treated effluent. As result of the excellent characteristics of the biomass, the required duration for settling is short and this phase is also used to discharge excess biomass formed as a result of growth and accumulation during the aeration phase.

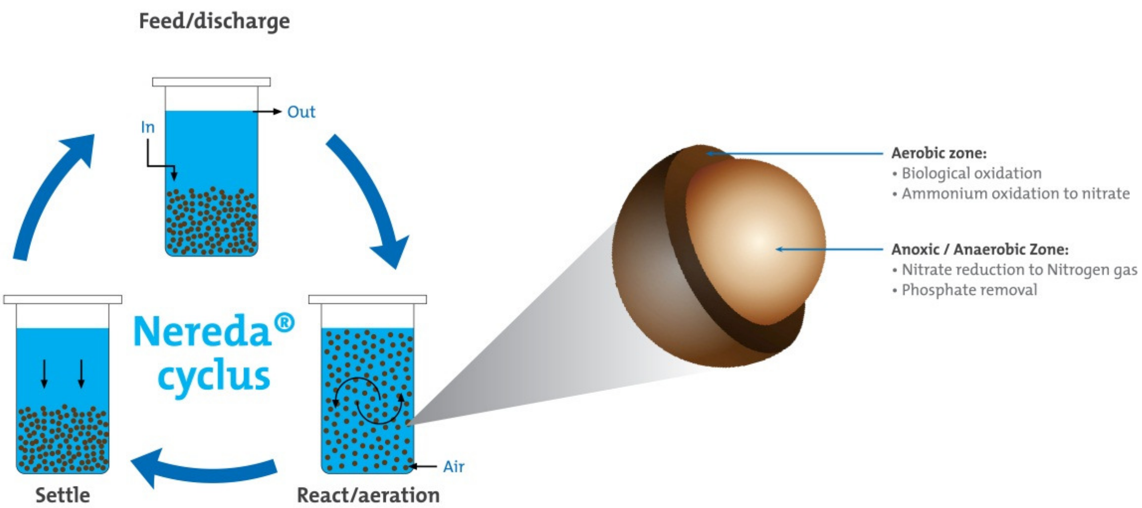


Figure 4. Nereda® Process Cycle.

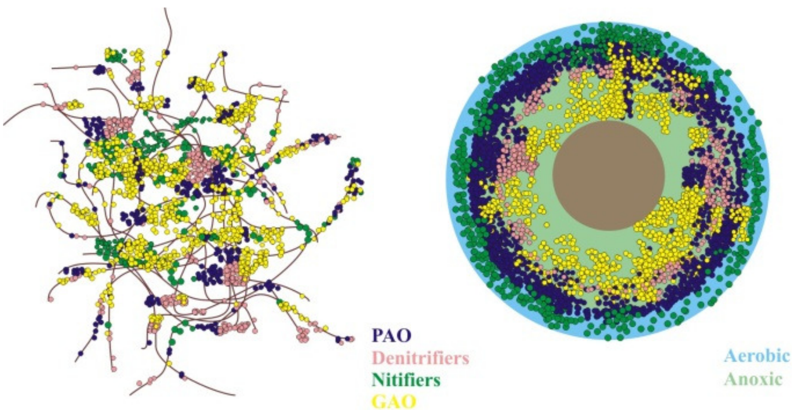


Figure 5. Difference between Activated Sludge (left) and Granular Biomass (right).

3 Nereda® Variants and Applications

Since implementing the first full-scale Nereda installations new insights have emerged allowing for further innovation, system development and design optimisation. New system configurations have been developed to suit a variety of scenarios experienced from site to site and from country to country. Two 'greenfield' or parallel extension approaches have been used and are detailed below (see Figure 6):

1. 3+ Nereda® reactors
   - At least one Nereda® reactor is fed at any given time
   - E.g. applied at Epe WWTP (the Netherlands)

2. Buffer(s) followed by Nereda® reactor(s)
   - Typically 1 buffer followed by 2 Nereda® reactors.
   - Often results in overall lower tank volumes and capital cost savings (case dependent).
   - E.g. applied at Wemmershoek WWTP (South Africa), Ryki WWTP (Poland), Garmerwolde WWTP (the Netherlands)

In addition two 'brownfield' options have been developed:

3. Nereda® and Conventional Activated Sludge (CAS) hybrid
   - Waste sludge from Nereda® system is fed into the CAS system.
   - Improves CAS treatment efficiency and / or capacity in addition to the expanded capacity achieved via the Nereda® system.
   - E.g. applied at Vroomshoop WWTP (the Netherlands)

4. Nereda® retrofit
   - Convert existing tank(s) into a Nereda® reactor (SBR, CAS aeration basin or any other suitable tank)
   - Make use of existing infrastructure whilst increasing system capacity and reducing energy, chemical use.
   - E.g. applied at Frielas WWTP (Portugal) (in combination with the hybrid approach)

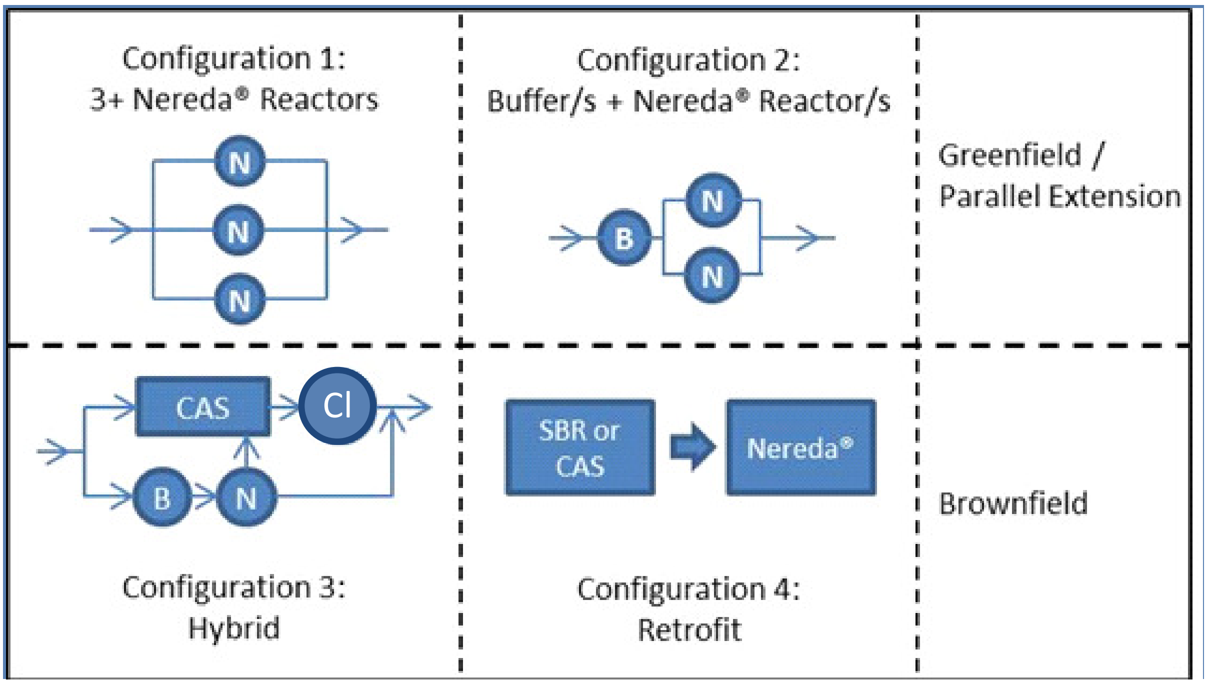


Figure 6. Nereda® configurations/approaches.

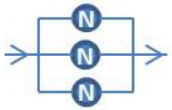
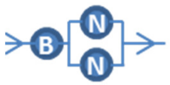
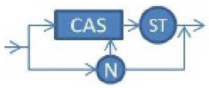
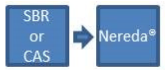
	Nereda Configuration	Typical Layout		Attributes	Advantages	Reference examples	Potential Applications
1	3+ reactors	3 reactors		At least 1 reactor fed at all times	Scalable for application to the world's largest treatment challenges	Epe WWTP (Netherlands) 	Greenfield sites; extension to existing plants with parallel Nereda line
2	Buffer followed by X reactors	1 buffer + 2 reactors		Buffer stores between feeds to reactors	Optimized investments (2 reactors vs 3).	Wemmershoek WWTP (South Africa) 	Greenfield sites; extension to existing plants with parallel Nereda line
3	Hybrid	1 or more Nereda reactor – connected to activated sludge system		Waste Nereda sludge to activated sludge system	Improve activated sludge system performance/ optimise existing infrastructure	Vroomshoop WWTP (Netherlands) 	Brownfield sites Extension / optimisation scenarios with optimal use of existing infrastructure
4	Retrofit	Convert existing SBR/ activated sludge reactor or any suitable existing tank		Use existing infrastructure	Cost-effective way to increase capacity and improve performance whilst using existing infrastruc-ture	Frielas WWTP (Portugal) 	Brownfield sites. Space or budget constraints / capacity increase or improved performance required

Figure 7. Nereda® configurations

The four basic configurations or approach options outlined above have covered all of the treatment scenarios experienced to date at full-scale.

Further details of the Epe WWTP (configuration 1), Garmerwolde WWTP, Ryki WWTP and Wemmershoek WWTP (configuration 2), Vroomshoop WWTP (configuration 3) and Frielas WWTP (configuration 4) are presented.

Epe WWTP (configuration 1)

Client: Water Board Vallei & Veluwe
Wastewater type: Municipal & Industrial
Location & start-up: Epe, The Netherlands, 2011
Average capacity: 8,000 m^3/day | 54,000 p.e. inclusive 13,750 p.e. from industrial discharges
Peak flow: 1,500 m^3/h

The first Dutch municipal full-scale plant was constructed at Epe WWTP. The Epe WWTP was designed and constructed by Royal HaskoningDHV in 2010-2011 and is operational since September 2011. Prior to design, a pilot trial was carried out for four years and the data was used to design the full scale plant. The plant consists of the following main processes; inlet works with screens and grit removal, followed by three Nereda® reactors and effluent polishing via gravity sand filters. The Nereda® reactors are designed to take flows with an average daily flow of 8,000 m^3/day and a peak flow of 36,000 m^3/day. The waste sludge is thickened via a gravity belt thickener and transported off-site.
Since September 2011 the influent to the plant was progressively increased to 100% over a period of four months. The existing plant continued to process the influent along with Nereda® Bioreactors whilst granules were building-up within the bioreactor. It should be noted that part of the "granulation period" was over the winter months when the average wastewater temperature was well below 10°C.

Even though the overall start-up took 4 months, the reactors were able to produce a good quality effluent within just a few days of having been seeded with standard activated sludge. Whilst a 4 month start-up period could be seen to be to detract from the process, these results show that a good effluent quality can be obtained rapidly.

Figure 8. Epe WWTP

The official process proving period for Epe WWTP was completed between March - May 2012. The effluent quality achieved, based on twenty-four hours/ seven days a week composite samples, is summarised in Table 1. Whilst Dutch effluents standards are typically based on average values, 95 percentile values are also shown for comparison to other plants.

Table 1. Epe WWTP – Performance Results during Process Verification March - May 2012.

Parameter	**Influent** *(mg/l)*	**Effluent (Average)** *(mg/l)*	**Effluent (95%ile)** *(mg/l)*
COD	879	27	32
BOD	333	< 2.0	< 2.0
NKj	77	1.4	1.8
NH4-N	54	0.1	0.1
N-total		< 4.0	5.1
P-total	9.3	0.3	0.34
Suspended Solids	341	< 5.0	< 6.0

Due to industrial discharges, the plant has to cope with large fluctuations in influent characteristics and loads – in particular with pH-values frequently peaking to above pH 10. During the pilot trials, that ran in parallel to the existing CAS, the remarkable process stability of Nereda was noticed: whilst pH peaks caused complete loss of nitrification in the CAS system taking several weeks to recover, the Nereda pilot unit receiving the same influent resumed smooth operation after a few cycles and was back to normal operation in 1-2 days after the occurrence.

A key advantage of Nereda is reduced power consumption. At Epe, the original plant energy consumption was approximately 3,500 kWh/day. With Nereda, the average consumption is now 2,000 kWh/day - 2,500 kWh/day. This is approximately 40% less than all types of similar sized conventional plants in the Netherlands. This was further demonstrated at the demonstration plant at Frielas WWTP, Portugal, discussed below.

Garmerwolde WWTP (configuration 2)

Client: Construction consortium GMB/Imtech for Water Board Noorderzijlvest
Wastewater type: Municipal
Location & start-upr: Garmerwolde, The Netherlands, 2013
Average capacity: 30,000 m^3/day | 140,000 p.e.
Peak flow: 4,200 m^3/h

The Garmerwolde WWTP was retrofitted into an AB activated sludge system in 2005 and was subsequently not able to meet the required nutrient removal targets, which necessitated a plant upgrade. Nereda® was selected as the preferred solution to extend the capacity and improve the biological nutrient removal capabilities of the plant. The solution, which commenced operation in 2013, involved the addition of two 9,500 m^3 Nereda® reactors – tank sizes similar to the world's largest SBR-tanks – preceded by a 4,000 m^3 buffer in parallel to the existing plant. The extension was designed for 140,000 P.E. of pollution load and hydraulically for 20,000 m^3/day (average flow) and 4,200 m^3/h (peak flow).

The use of 1 buffer and 2 Nereda® reactors (configuration 2) enabled an overall tank volume saving of approximately 35% when compared to the 3 Nereda® reactor option (configuration 1, e.g. Epe WWTP) for this specific case.

The Nereda® performance requirement for nutrient removal (without any downstream filtration step) is a Total-N of 7 mg/l (yearly average) and Total-P of 1 mg/l (average of ten successive samples). After a year-long monitoring period (2014) the Garmerwolde WWTP was found to fully comply with the overall effluent requirements, despite receiving on average 28,500 m^3/day (designed for 20,000 m^3/day).
The Garmerwolde WWTP offers the possibility to directly compare the performance of the Nereda® and activated sludge technologies. The energy consumption of the Nereda® installation (including intermediate pumping) was consistently more than 40% lower than the energy consumption of the parallel AB system in 2014. Furthermore, the AB system requires chemical dosing, including C-source (denitrification), coagulants (sludge properties) and iron salts (phosphorous removal). Apart from the high chemical costs incurred, the dosing also results in a sludge production almost double that of the parallel Nereda® extension. Consequently the overall operational costs (energy, chemicals, sludge treatment) of the activated sludge plant are significantly higher than that of the Nereda® extension.

Considering that the Nereda® installation treats 41% of the daily influent flow and the original installation (AB-system) 59%, Figure 3 showed Nereda®'s advantage in terms of system footprint.

Ryki WWTP (configuration 2)

Client: Przedsiebiorstwo Gospodarki Komunalnej i Mieszkaniowej **Wastewater type:** Municipal & industrial **Location & year:** Ryki, Poland, 2015 **Average capacity:** 5,300 m^3/day | 41,000 p.e., high portion of tanked-in septic and industrial discharges which can go up to 60% of the total COD load **Peak flow**: 430 m^3/h

Based on the outcome of a public tender process, the municipal-owned utility company selected Nereda® technology-based offer for the design and engineering of their new wastewater treatment. Important criteria in the tender evaluation process were capital expenditure and total costs of operation. The wastewater is a mixture of sewage, tanked-in septic and industrial discharges from primarily vegetable processing. Start-up of this plant was mid-February. The effluent of the two reactors is discharged into a pond which overflows to the surface water. When the pond is overflowing the effluent is measured. Effluent quality is well within standards.

Table 2. Nereda® Ryki data from the end of March 2015.

Parameter	Units	Influent	Effluent R1	Effluent R2	Outlet effluent pond	Effluent standard
COD	mgO_2/l	623	39	42	50	125
BOD	mgO_2/l	227	5.6	6.3	8.2	15
TN	mgN/l	72	4.8	4.8	6.6	15
TP	mgP/l	7.7	0.5	0.5	1.0	2
TSS	mg/l	238	15	17	10	30

Figure 9. Ryki WWTP: Nereda® testing during cold conditions

Wemmershoek WWTP (configuration 2)

Client: Stellenbosch Municipality
Wastewater type: Municipal
Location & start-up: Wemmershoek, South Africa, 2015
Average capacity: 5,000 m^3/day | 39,000 p.e.
Peak flow: 625 m^3/h

In 2010 the Stellenbosch Municipality decided to centralise wastewater treatment for the Franschhoek area by decommissioning two existing treatment plants (Franschhoek and La Motte WWTPs) and treating all wastewater at the Wemmershoek WWTP. To realise a cost-effective centralisation of treatment capacity a new 5,000 m^3/day treatment system was required at the Wemmershoek works. The Franshhoek area falls within the sensitive Berg River catchment which meant stringent effluent requirements (special limits). Royal HaskoningDHV proposed the Nereda® technology and effluent reuse as a cost-effective and sustainable means to meet the project requirements. By utilising effluent reuse (irrigation) the need for extensive tertiary treatment to meet expected future (even more stringent) standards was not required. Details of the treatment plant are provided in Table 3.

Table 3. Wemmershoek WWTP design details.

Design Component	**Unit**	**Wemmershoek Design**
Primary Treatment	-	Screening and grit removal
Secondary treatment	-	1 x 600m^3 Nereda® Influent Buffer; 2 x 1 800m³ Nereda® reactors
Tertiary treatment	-	Chlorine disinfection, maturation pond
Sludge treatment	-	Mechanical thickening and dewatering
Average Dry Weather Flow	m^3/day	5,000
Peak Wet Weather Flow	m^3/h	625
Effluent discharge	-	Discharge to Berg River and re-use for irrigation (pumped to Franschhoek)
Influent Characteristics		Design (actual)
COD	mgO_2/l	870 (796)
Total Kjeldahl Nitrogen	mgN/l	60
Ammonium	mgN/l	45 (79)
Nitrate	mgN/l	-
Total Phosphorus	mgP/l	12 (11.7)
Ortho-phosphate	mgP/l	- (8.6)
Suspended Solids	mg/l	- (381)

( )_The data in parenthesis are averages over the last 4 independently analysed samples (24 March to 1 April 2015)

The new 5,000 m^3/day system was commissioned in August 2014 and following the development of granular sludge the treatment plant is producing excellent effluent quality (well below requirements) – see Table 4 with recent effluent results.

Figure 10. Nereda® reactor at Wemmershoek discharging effluent.

Table 4. Effluent quality at Wemmershoek WWTP.

Parameter	Unit	Average CSIR Lab Results – Final Effluent	Effluent Requirement (General Limit)
COD	mgO_2/l	48	<75
Ammonium	mgN/l	0.3	<6
Nitrate	mgN/l	0.1	<15
Nitrite	mgN/l	0.1	-
Total phosphorus	mgP/l	2.6	-
Ortho-phosphate	mgP/l	2.3	<10

The data presented in Table 4 is based on average effluent results from March to April 2015 independently verified by an external laboratory (CSIR). The Wemmershoek treatment plant has a discharge limit of 10 mgP/l. Although the phosphorus concentrations in the final effluent are well below this limit, the process control has not yet been fully optimised for biological phosphorus removal. If optimal Nereda® biological phosphorus removal is implemented, effluent ortho-phosphate concentrations below 0.9 mgP/l could be achieved without chemical dosing (concentrations of 1.5 mg/l, 0.6 mg/l and 1.2 mg/l were achieved during March 2015, giving a clear indication of the potential).

The Berg River Improvement Plan (BRIP) was developed in 2012 by the Western Cape provincial government, the Department of Water Affairs and local stakeholders. The main aims of the BRIP are the sound management of this sensitive catchment and to improve water quality. The Wemmershoek WWTP project is positively contributing to achieving the BRIP's goals by limiting pollution loads from the Franschhoek area. This is an example of how innovative wastewater treatment solutions (Nereda®) in conjunction with exceptional municipal operations and management (Stellenbosch Municipality) can fit into broader integrated water resource management as envisaged by South Africa's National Water Act (2008).

Vroomshoop WWTP (configuration 3)

Client: Water Board Vechtstromen
Wastewater type: Municipal
Location & start-up: Vroomshoop, The Netherlands, 2013
Average capacity: 1,500 m^3/day | 12,000 p.e.
Peak flow: 400 m^3/h

In 2008, the Dutch Waterboard Vechtstromen became interested in participating in the development of the Nereda® technology as a part of their strategic commitment to advancing the wastewater treatment technology field. At the Vroomshoop WWTP an opportunity emerged to use Nereda® for the expansion and replacement of the existing treatment plant, which consisted of an ageing oxidation ditch system that would not be able to meet future effluent requirements, especially with regard to nutrient (nitrogen and phosphorus) removal.

A hybrid configuration (configuration 3) was selected because it was found to be an effective means of making use of an existing settling tank at the site, an optimal way to deal with the high rain weather to dry weather flow ratio at the plant and this option provided an opportunity to meet innovation and sustainability targets such as reducing energy usage. The hybrid arrangement of the treatment plant is schematically shown in Figure 11 below.

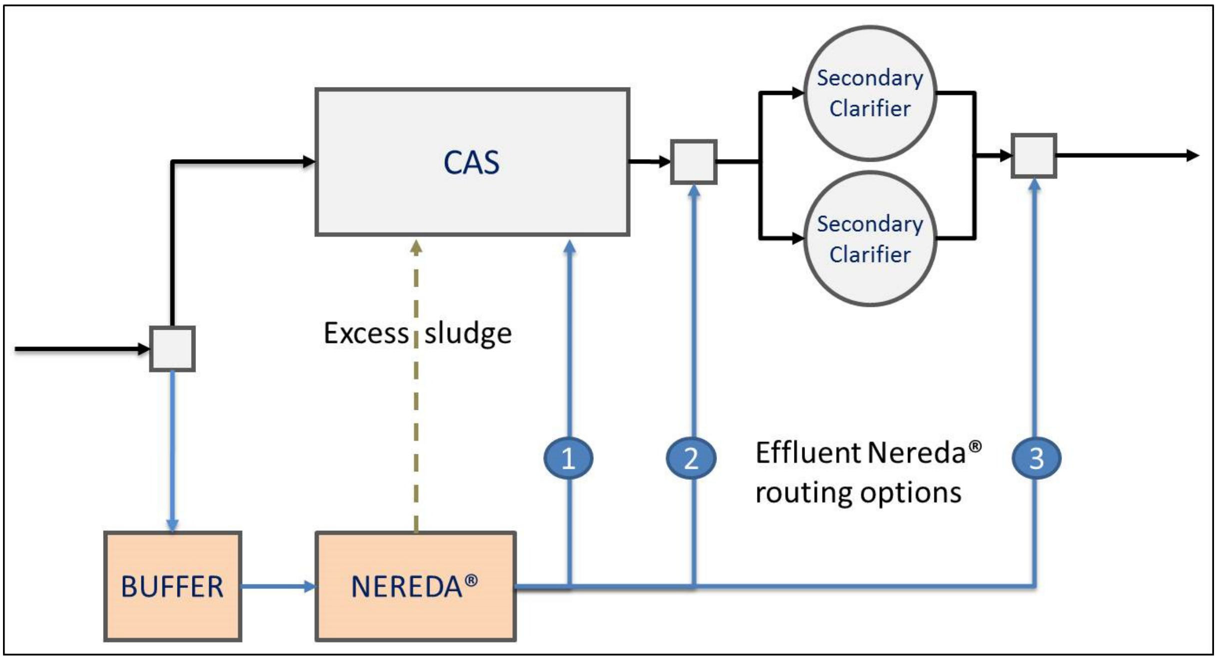


Figure 11. Flow scheme at Vroomshoop WWTP with full hydraulic routing options (1, 2 and 3)

The new Vroomshoop WWTP entered operation in mid-2013. The plant is designed for a pollution load of 22,600 P.E. (150 gTOD) and hydraulically to receive 156 m^3/h of wastewater during dry weather conditions and 1,000 m^3/h during rain weather conditions. The introduction of Nereda® excess/waste sludge into the CAS system has proven to be an effective way to improve the performance of the CAS system. The settle ability of the CAS sludge showed a marked improvement (lower SVI) as can be seen in Figure 12.

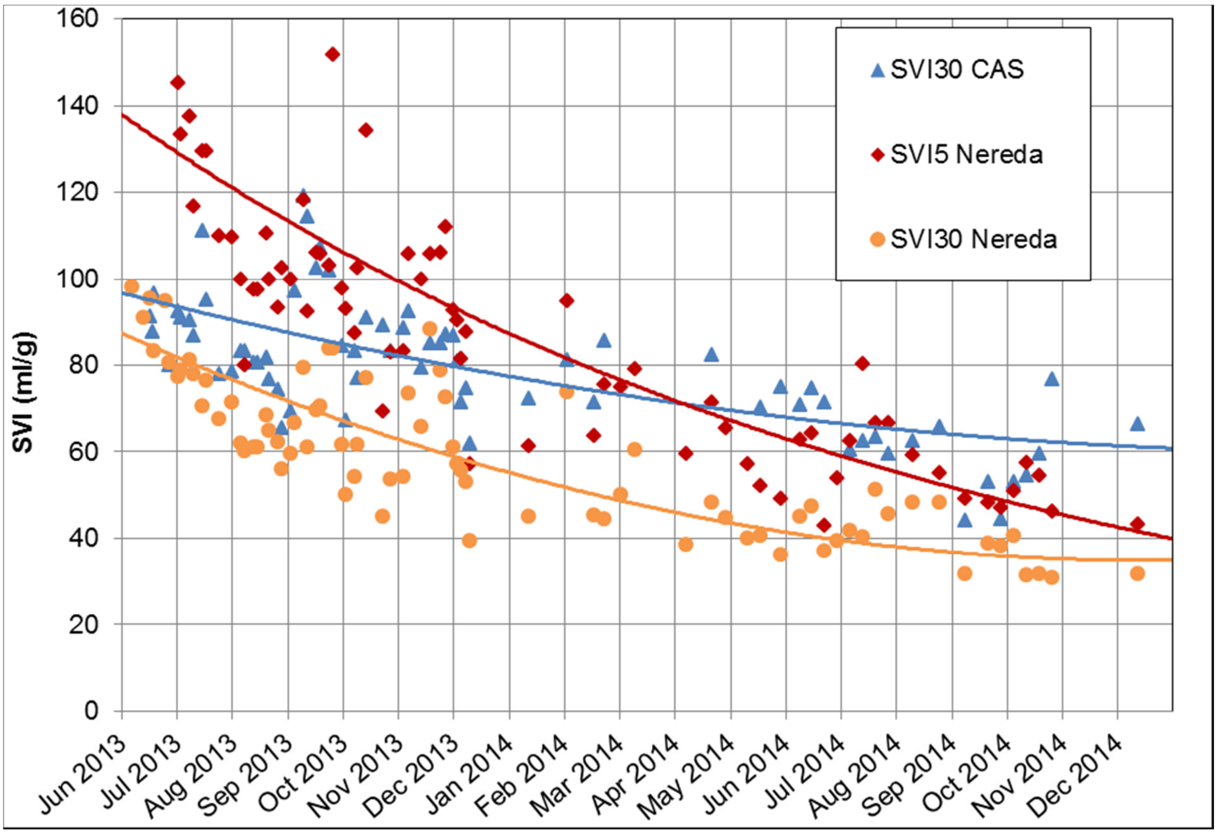


Figure 12. SVI comparison of the Nereda® and CAS systems at Vroomshoop from start-up in June 2013 until the end of 2014.

Using Nereda® waste sludge to improve settleability in CAS systems (hybrid – configuration 3) offers numerous advantageous possibilities, such as:

- the potential to increase biomass concentrations in the CAS system, thereby increasing biological treatment capacity and;
- enabling higher hydraulic loading through the CAS system.

Furthermore, Nereda® waste sludge contains a high fraction of Phosphate Accumulating Organisms (PAOs) (which drive bio-P removal) and therefore improvement in biological phosphorus removal in the CAS side of a hybrid system is possible. With the plant at full loading, the performance in terms of effluent quality has met all requirements (see Table 5). Furthermore, energy consumption monitoring at Vroomshoop (June-November 2014) showed the Nereda® side of the treatment plant used approximately 35% less energy than the CAS side.

Table 5. Vroomshoop WWTP - overall treatment performance in 2014 (data from Waterboard Vechtstromen).

Parameter (mg/l)	Influent	Effluent	Requirement	Compliance Conditions
COD	720	55	125	Limit (3 x per year up to 250)
BOD5	263	4	10	Limit (3 x per year up to 20)
TN		7.2	10	Yearly Average
TKN	66	5.2	-	-
NH_4-N	-	2.2	Summer = 2 Winter = 4	Average (1 May - 1 Nov.) Average (1 Nov. - 1 May)
NO_x-N	-	2.0	-	-
TP	8.9	0.9	2	Moving average of 10 successive samples
PO_4-P	-	0.6		-
TSS	317	10	10	Limit (3 x per year up to 30)

Frielas WWTP (configuration 4)

Client: Agua de Portugal – Simtejo
Wastewater type: Municipal & Industrial
Place & year: Lisbon, Portugal, 2012 + 2014
Average capacity demo: 3,000 m^3/day | 10,000 p.e.
Average capacity full scale retrofit: 12,000 m^3/day | 40,000 p.e.

The Frielas WWTP is a 70,000 m^3/day plant currently at 70% of its biological design capacity and receives, mainly, domestic wastewater from 250,000 inhabitants, in the Greater Lisbon area. Regarding effluent quality, the WWTP has carbon removal and disinfection requirements (i.e., COD < 125 mg/l and TSS < 35 mg/l) and no specific discharge limits for nitrogen and phosphorous. Since start-up in 1997, the Frielas WWTP suffered from several operational constraints related to some technological decisions made at the design phase but also because the wastewater characteristics became quite different from those used for the original plant design. To validate if Nereda could improve the plant performance under realistic field conditions, one of the six continuous activated sludge reactors was retrofitted into a Nereda® reactor (Figure 13) with a volume of approximately 1,000 m^3, which was then run in parallel to the remaining five activated sludge reactors. This was the first continuous Activated Sludge Nereda® retrofit application.

Figure 13. Conversion of reactor nº6 of Frielas WWTP to Nereda® technology.

Besides providing a robust and efficient operation during all influent conditions, a driver for the retrofit was to evaluate the possibility to substantially lower the electricity demand of a conventional WWTP. Another important motivation for the implementation of Nereda® was the possibility of working at higher hydraulic loads and achieving nutrient removal without the (eventual) future need for increasing reactor volume. The demonstration reactor start-up was made with normal activated sludge from one of the other aeration streams. Operation reached a steady state SVI30 around 40 ml/g, a SVI5 as low as 60 ml/g, a granulation fraction above 80% and an increasing biomass concentration in the range of 6 to 8 g/l. It is important to note that the start-up was made partially during winter time with diluted wastewater (i.e. COD levels below 300 mg/l) contributing to a slower biomass growth and transformation rate.

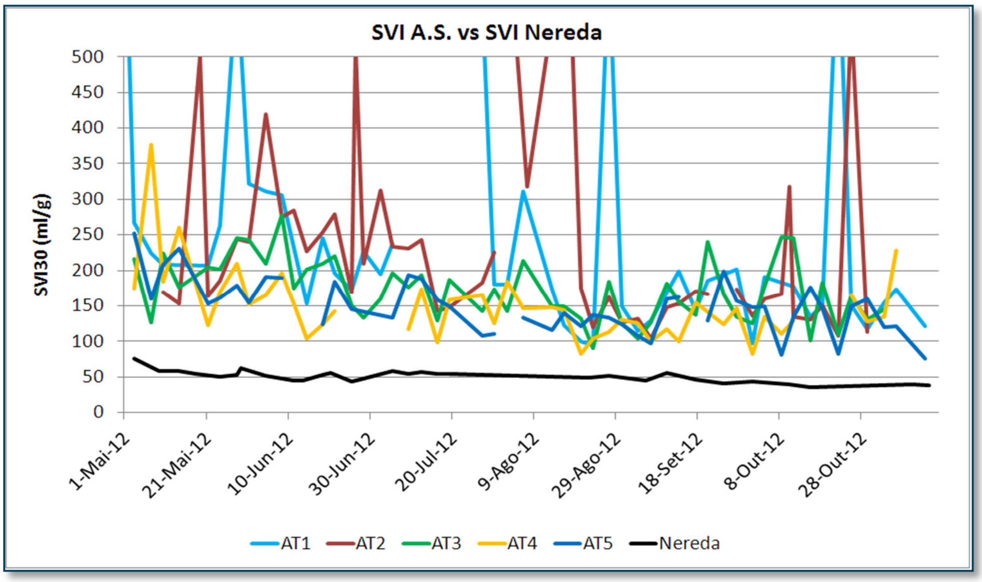


Figure 14. Comparison between the settleability of the biomasses from the Nereda reactor and the activated sludge (AS) from the other five biological reactors (AT) in the Frielas WWTP.

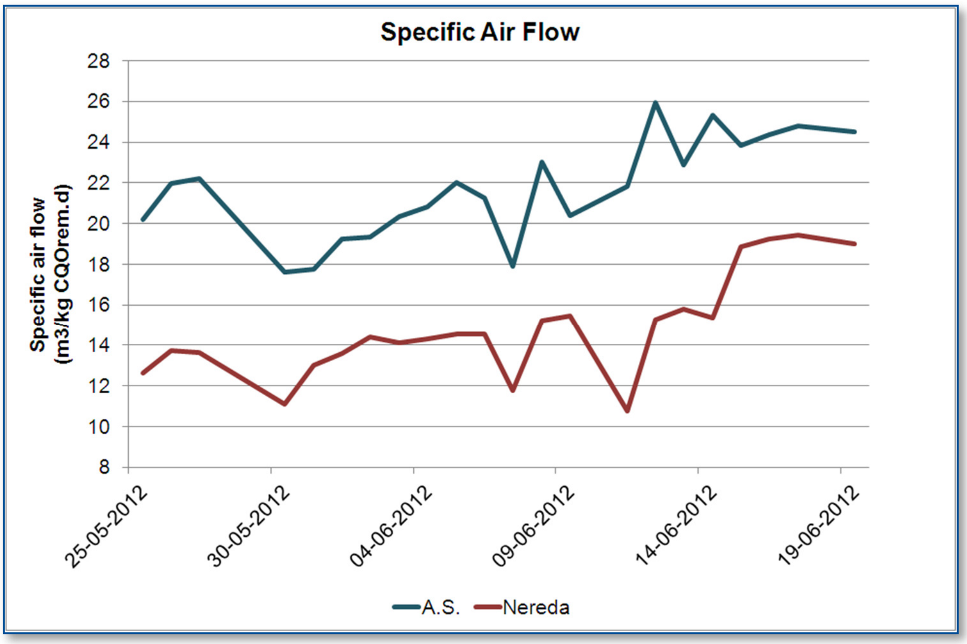


Figure 15. Comparison between the airflow rates to activated sludge and Nereda plants.

After more than one year of plant operation the effluent quality was shown to be significantly better and far more consistent than the quality obtained in the original CAS. This plant also gave a unique opportunity to observe the power consumption of Nereda® in parallel to a CAS. Airflow rates are shown in Figure 15. A significant decrease in energy consumption was observed. Since Nereda® is operated in parallel with the conventional aeration tanks using the same water depth, existing and common air supply equipment, the comparison between the two technologies is reliable and representative. During a two month monitoring period the air consumption of both systems was measured with the dissolved oxygen (DO) levels similar and nitrification in Nereda® fully suppressed to mimic the biological performance of the CAS reactors.

Taking into account the efficiency of the air blowers, the measured air flow consumed in each system per mass of chemical oxygen demand (COD) removed was translated into the specific electricity consumption. It was observed that the average specific consumption for the Nereda amounts to 0.35 kWh/kg COD removed, representing approximately 30% electricity savings compared to aeration for the AS system. Combining this with the energy saving that granules bring by not using settling tanks, sludge recirculation pumps and post-filtration units, the overall electricity saving potential for the plant was computed to 50%.

Following the positive results obtained with the Nereda® demonstration reactor, Simtejo has implemented an extension of the demo to a full-scale reactor (4,000 m^3) operated parallel to the existing continuous activated sludge reactors. The reactor has a treatment capacity of 12,000 m^3/day and 40,000 inhabitants with a start-up in the summer of 2014. Although using only 9% of the total biological volume of the plant, the Nereda® technology will treat 25% of the total flow and will produce an effluent with a better quality.

During two months the air flows were compared. Taking into account the efficiency of the air blowers, specific electricity requirements were computed and savings of about 30% were calculated, with a specific average consumption of 0,35 kWh/kgCOD. Combined with savings regarding the fact that Nereda® does not need separate settlers, sludge recirculation and post-filtration, the potential savings on the plant are 50%.

4 Nereda® References Overview

Operational plants	Daily average flow (m^3/day)	Peak flow (m^3/h)	Person Equivalent	Start-up
Vika, Ede (NL)	50-250		1,500-5,000	2005
Cargill, Rotterdam (NL)	700		10,000-30,000	2006
Fano Fine Foods, Oldenzaal (NL)	360		5,000-10,000	2006
Smilde, Oosterwolde (NL)	500		5,000	2009
STP Gansbaai (RSA)	5,000	400	63,000	2009
STP Epe (NL)	8,000	1,500	54,000	2011
STP Garmerwolde (NL)	30,000	4,200	140,000	2013
STP Vroomshoop (NL)	1,500	400	12,000	2013
STP Dinxperlo (NL)	3,100	570	15,730	2013
STP Frielas, Lisbon (PT)	12,000		40,000	2014
STP Ryki (PL)	5,300	430	41,000	2015
STP Wemmershoek (RSA)	5,000	625	39,000	2015
STP Clonakilty (IRL)	4,896	626	20,500	2015
Plants under construction				
Westfort Meatproducts, IJsselstein (NL)	1,400	1,400	43,000	2015
STP Carrigtohill (IRL)	6,750	844	30,000	2015
STP São Lourenço, Recife (BR)	19,093 (1st phase); 25,123 (2nd phase)	1,674	139,600	2015 2024
STP Jardim Novo, Rio Claro (BR)	23,500	1,764	133,000	2015
STP Deodoro, Rio de Janeiro (BR)	86,400	6,120	480,000	2016
STP Jardim São Paulo, Recife (BR)	19,529 (1st phase) 78,117 (2nd phase)	5,859	434,000	2016 2025
STP Tatu, Limeira (BR)	57,024	3,492	517,000	2016
STP Hartebeestfontein (RSA)	5,000	1,250	44,000	2015
STP Kingaroy (AUS)	2,700	450	16,000	2016
Plants under design				
STP Jaboatão, Recife (BR)	109,683 (1st phase) 154,483 (2nd phase)	11,588	858,330	2016 2025
STP Breskens (NL)	5,400	1,100	37,000	2016
STP Simpelveld (NL)	3,668	945	11,880	2016
STP Cork Lower Harbour (IRL)	18,500	1,830	65,000	2016
Pilots and demo's				
Nereda Research Program (NL)				2003-2010
Bavaria, Lieshout (NL)				2007
Tata Steel, Ijmuiden (NL)				2011
Anonymous Petrochemical (NL)				2011
Peka Kroef, Odiliapeel (NL)				2012
STP Frielas, Lisbon (PT)	3,000		10,000	2012
STP Utrecht (NL)	1,500	600	9,000	2013
Anonymous Chemicals (FR)				2014
STP Kloten Opfikon (CH)	1.5 – 5.0	1.0	10-30	2014
STP Davyhulme (UK)	1.5 – 5.0	1.0	10-30	2014
STP Daldowie (UK)	1.5 – 5.0	1.0	10-30	2014
STP Dalmarnock (UK)	1.5 – 5.0	1.0	10-30	2014
STP Crewe (UK)	1.5 – 5.0	1.0	10-30	2015
STP Werribee (AUS)	100-300	50	500-1,500	2015
Ringsend WwTW (IRL)	1.5 – 5.0	1.0	10-30	2015

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