RYKI WASTEWATER TREATMENT PLANT – FIRST NEREDA® IN POLAND

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Nereda® and Poland

In Poland, at the city of Ryki in the Lublin Province, there is a new Nereda® wastewater treatment plants in operation since February 2015. This is the first installation located in the eastern part of Central Europe dealing with very low process temperatures in the order of 7–8 °C during the winter period. The Ryki Nereda® plant is designed to treat 5,320 m^3/d (dry weather), corresponding to 38,600 PE (population equivalent). Beyond the temperature challenge, the plant combines the treatment of different incoming sewages (domestic, septic tanks and industrial) and has to handle extended industrial peak load periods. This plant has already been running for more than a year and continues to achieve a remarkable quality performance, meeting all effluent requirements and ensuring the Client's satisfaction.

Nereda® is Royal HaskoningDHV's patented full-scale municipal and industrial wastewater treatment technology that utilises aerobic granular sludge. Bacteria are responsible for the wastewater treatment and a natural selection process allows the microorganisms to grow in large and dense granules which settle much quicker than conventional flocs (up to 10 m/h compared to 1 m/h). The complete biological treatment takes place simultaneously in the granule. There is no need for clarifiers, moving decanters and mixers. Therefore the process is faster, less energy intensive and much more compact in terms of the size of the plant. The system uses a PC-based Aquasuite® Nereda® controller to control and optimise the biological process. Nereda® was developed through a collaborative public-private partnership involving Dutch wastewater treatment stakeholders, the Delft University of Technology (the Netherlands), various treatment plant end-users and Royal HaskoningDHV.

To date more than fifteen full-scale municipal and industrial Nereda® plants are in operation and another fifteen are under construction (with a total installed capacity of about 5 million PE). In Poland, the Netherlands, South Africa, Portugal, Ireland, United Kingdom, Switzerland, Sweden, Australia and Brazil there are already Nereda® plants in operation or under construction.

Nereda® technology

The Nereda® system consists of a cyclical process with three main cycle stages, namely: simultaneous fill (influent) and draw (effluent), aeration/reaction and settling – all of which occur in a single reactor with no compartments (Figure 1). The aerobic granules formed have enhanced settling properties (in comparison to activated sludge), allowing for higher biomass concentrations (8-15 g/ℓ). Secondary settling tanks, mixers and major sludge recycling pumps are not required for Nereda®.

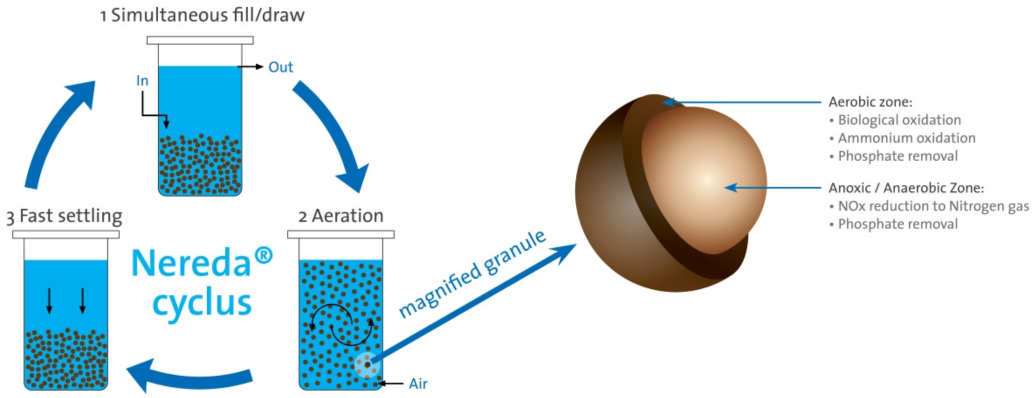


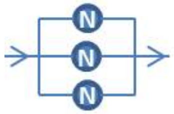
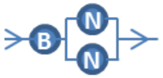
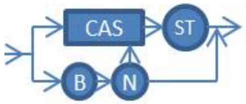
Figure 1: Schematic representation of the Nereda® cycle and an aerobic granule

The enhanced sludge settleability of aerobic granular sludge in comparison to conventional activated sludge is evident from a comparison of typical SVI (sludge volume index) values – for aerobic granular sludge the SVI_5 (5 minutes) tends to be equal to the SVI_{30} (30 minutes), with typical values around 30-60 mℓ/g, whereas for activated sludge the SVI_{30} (non-bulking sludge) is typically in the range of 110-160 mℓ/g (Figure 2).

Figure 2: Sludge settleability: activated sludge (left side cylinder) vs. Nereda® aerobic granular sludge (right side cylinder)

The structure of aerobic granules combined with a cyclical process facilitates biological nutrient (nitrogen and phosphorus) removal. Aerobic granules contain PAOs which enable enhanced biological-P removal since phosphate uptake occurs during aeration and waste sludge (containing phosphates) is subsequently removed from the system. During the aeration phase, an oxygen diffusion gradient develops in the granules resulting in an aerobic outer layer and an anoxic or anaerobic core. In the aerobic outer layer heterotrophic bacteria and nitrifiers proliferate which enables degradation of organics (COD removal) and nitrification (conversion of ammonia to nitrite/nitrate) respectively. The formed nitrates (from nitrification) are denitrified (conversion of nitrate to nitrogen gas) in the anoxic core of the granule i.e. nitrogen removal occurs via a simultaneous nitrification-denitrification process. Several system configurations (Table 1) have been developed to match different treatment scenarios ranging from new 'green field' treatment plants to hybrid Nereda®-activated sludge systems. For Ryki different Nereda® configurations were evaluated and it was proven that configuration 2 (including an influent buffer and two Nereda® reactors) would be the most cost effective.

Table 1: Nereda® configurations

No.	Nereda® Configuration	Typical Layout		Attributes	Advantages	Examples of References	Potential Applications
1	3+ reactors	3 reactors		At least 1 reactor fed at all times	No influent buffer required	Epe WWTP (Netherlands) 	Greenfield sites; extension to existing plants with parallel Nereda® line
2	Buffer followed by n reactors	1 buffer + 2 reactors		Buffer stores between feeds to reactors	Optimal tank volumes; less equipment required (2 reactors vs 3).	Ryki WWTP (Poland) 	Greenfield sites; extension to existing plants with parallel Nereda® line
3	Hybrid	1 buffer, 1 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 infrastructure	Frielas WWTP (Portugal) 	Brownfield sites. Space or budget constraints / capacity increase or improved performance required

Nereda®
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Ryki Wastewater Treatment Plant

In 2012 DHV Hydroprojekt, a Polish company of Royal HaskoningDHV group won the public tender for the complete design of the new Ryki Wastewater Treatment Plant (WWTP) for Przedsiebiorstwo Gospodarki Komunalnej i Mieszkaniowej (PGKiM), located in eastern Poland in the Province of Lublin (Figure 3). The Nereda® solution successfully responded to important criteria in the tender evaluation process such as low capital expenditure and low total operating costs. The construction of the plant was awarded by SKANSKA (contractor) and DVH Hydroprojekt was appointed as the subcontractor responsible for the Nereda® detailed design, supply of equipment to the reactors and the start-up of the installation.

Figure 3: Aerial photograph of Ryki WWTP

The new Nereda® plant was designed to replace the old sequencing batch reactors (SBR) in operation since 1984, which were critically overloaded and not compliant with the effluent standards. The Ryki WWTP combines the treatment of 37% domestic organic load, 8% septic tanks and 55% industrial (vegetable industry) organic loads. The highest sewage contribution comes from Polski Ogród (vegetable processing industry) whose production peak period is from September to December. The seasonal load variations promote an additional challenge to the plant requiring flexibility to treat between 35% to 100% of the design load. The design influent characteristics are summarised in Table 2. During the first industrial peak period in 2015 the plant already almost reached its ultimate design capacity.

Table 2: Influent characteristics

Parameter	Design values			
	Domestic	Septic tankers	Industrial	Total
Daily dry weather flow (m^3/d)	2,400	120	2,800	5,320
Daily wet weather flow (m^3/d)	3,418	120	2,800	6,338
COD (kg/d)	1,680	384	2,500	4,564
BOD_5 (kg/d)	960	156	1,200	2,316
TSS (kg/d)	1,200	144	400	1,744
Total N (kg/d)	192	22	112	326

Total P (kg/d)	48	4	28	80

Ryki WWTP includes separate pre-treatment facilities (with screening and grit removal) for septic tankers discharges, domestic sewage from the city and industrial sewages. The combined pre-treated sewages end up in an influent buffer tank (500 m^3) from where two Nereda® reactors (2,500 m^3 each) are separately fed by three submersible pumps. The treated effluent from the Nereda® reactors is discharged into an outlet buffer pond and thereafter into the Irenka River. Due to the strict effluent requirements (Table 3) and to be able to ensure a robust effluent performance under all conditions, the treatment plant includes chemical phosphorous removal with the dosage of an iron salt. The waste sludge from the Nereda® installation is firstly buffered in a sludge buffer, then thickened in a picket fence thickener and subsequently mechanically dewatered in a belt press.

Table 3: Effluent requirements in Ryki WWTP

Parameter	Effluent requirements
COD (mg/ℓ)	125
BOD_5 (mg/ℓ)	15
TSS (mg/ℓ)	35
Total N (mg/ℓ)	15
Total P (mg/ℓ)	2

The start-up of the plant was initiated in February 2015 and the Nereda® reactors were both inoculated with conventional activated sludge, mainly transferred from the old works and a small portion from an external conventional WWTP. At the time of the start-up the biomass concentration in the Nereda® reactors was only 2 g/ℓ and therefore it was necessary to gradually increase the treatment capacity available in the new installation. Two months after the start-up was initiated the new Nereda® installation was able to treat the total incoming sewage reaching the plant and the old SBR reactors were decommissioned.

The challenge of cold temperatures

Since start-up the Ryki WWTP has been challenged by very low wastewater temperatures (Figure 4) as compared with the intended minimum design temperature (12 °C). The biological process in the Nereda® reactors was initiated in almost freezing conditions (approximately 4 °C) and only three months later (end of April) the design temperature was achieved. The highest process temperature (23 °C) was reached in August 2015 (in summer), and since then a strong negative trend has been noted and less than 8 °C in the reactors was measured during most of January 2016. Despite these unfavourable biological conditions, the consistency of the excellent effluent results and the capacity of the technology to maintain extraordinary nitrification and denitrification efficiencies has been remarkable.

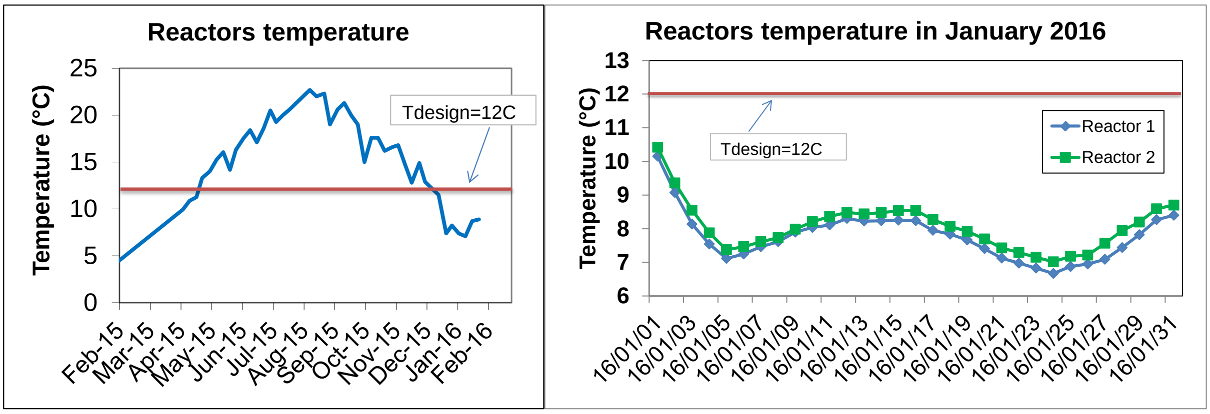

Figure 4: Reactors temperature in Ryki WWTP

Plant performance

Since April 2015 (two months after the initiation of the plant start-up) Ryki WWTP has been showing an excellent performance constantly meeting the effluent standard requirements. The plant operation is very stable and is positively responding to the peak industrial load (registered between September and December), as well as to extremely low wastewater temperatures (< 8 °C on average) noted in January and February 2016.

The average effluent quality from the Nereda® reactors and from the outlet buffer pond is detailed in Table 4. Figure 5 shows the progress of the main effluent quality parameters (COD, total nitrogen (TN) and total phosphorous (TP)) as well as the Nereda® sludge quality (MLSS, SVI_5 and SVI_{30}). It has been noted that the chemical phosphorous removal is seldom required to comply with the strict effluent standards. Even when it is required the PIX dosage (iron salt) has been very low (less than 6 mg/ℓ).

Table 4: Effluent quality in Ryki WWTP

Parameter	Effluent quality(*)		
	Reactor 1	Reactor 2	Outlet buffer pond
COD (mg/ℓ)	43	46	39
BOD_5 (mg/ℓ)	5.5	6.3	4.4
TSS (mg/ℓ)	13	13	4.5
Total N (mg/ℓ)	5.7	5.5	5.0
Total P (mg/ℓ)	0.9	0.8	0.8

(*) *Average values from April 2015 to February 2016*

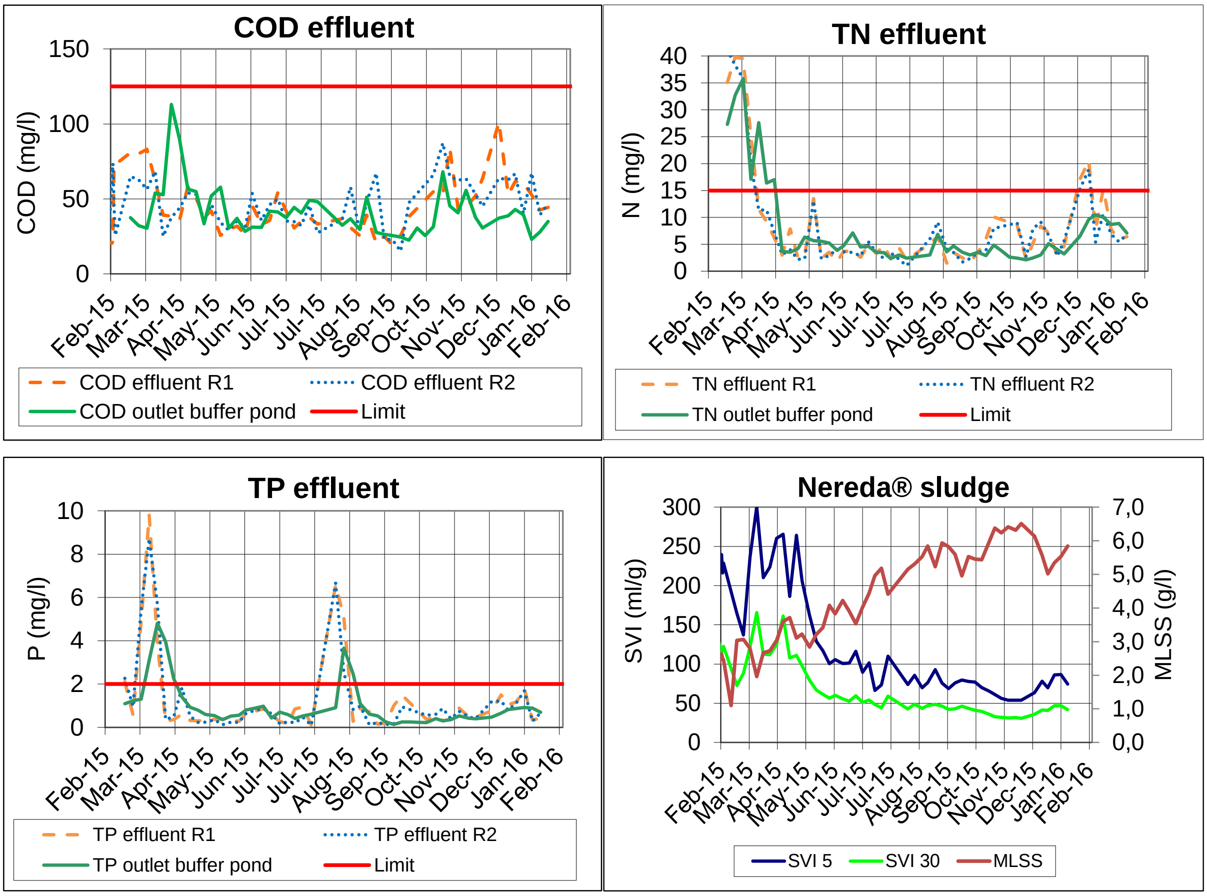

Figure 5: Effluent and Nereda® sludge results in Ryki WWTP

Energy consumption

For PGKIM (the plant end-user) the energy consumption/potential savings is an important operational goal. This was actually one of the favourable criteria in the selection of the Nereda® technology to the new Ryki plant. Optimized process control supported by the Aquasuite® Nereda® Controller combined with adequate equipment options and close plant monitoring are the key success factors for the energy optimisation in this installation.

The main energy consumers in the plant are the blowers, followed by the Nereda® influent feed pumps and the sludge pumps. The specific energy consumption of these main consumers is 0.40 kWh/m^3 (or 26 kWh/PE/Year based on COD removal). This Nereda® installation allows 25% to 30% energy savings compared with conventional activated sludge plants where the total energy consumption is typically up to 0,55 kWh/m^3.

Client satisfaction

The implementation of the first Nereda installation in Poland is a major success considering all facets of its intended application, achieving all important targets: (1) excellent effluent quality even in peak load periods and at very low wastewater temperatures, (2) stable and reliable operating conditions, (3) more than 25% energy savings, (4) optimised dynamic process control through the Aquasuite® Nereda® Controller, (5) easy maintenance and operation and (6) client satisfaction.

Mr Andrzej Waszczuk, Director for Municipal Services in PGKiM, highlighted the end-users satisfaction saying: “We are very glad to use the Nereda® technology in our WWTP. Thanks to Nereda®, treated sewages meet EU standards and we achieve established ecological effect. It should be emphasized, that it would not be possible without a very good cooperation with DHV Hydroprojekt.”

For Royal HaskoningDHV this project was an important step to fully confirm the potential of our Nereda® technology in cold climates and thereby opening doors in other similar markets.