The Nereda® Process – Wastewater Treatment with Aerobic Granular Biomass

Introduction

One of the most critical aspects of the activated sludge process has always been the separation of biomass and treated water. Besides the development of physical separation techniques (membrane bioreactors) the improvement of settling properties of the activated sludge has been an important research topic. The basic requirement for biomass with good settling properties is a granular structure based on compact, dense, large particles with a high specific gravity.

Discovered in 1995 and further developed by Mark van Loosdrecht from the Delft University of Technology (DUT), the process of using aerobic granular biomass for wastewater treatment has been scaled up and engineered to suit commercial applications by Royal HaskoningDHV, a Dutch E+C company and has been commercially branded as Nereda® Technology.

The Nereda® technology has been applied in various industrial and municipal applications and demonstrated its robustness and stability. The first full-scale industrial applications date back to 2005, while in parallel the technology was further scaled-up for municipal application. Following the first demonstration plants in South Africa and Portugal, a full-scale municipal Nereda® was started up in 2011 at the WWTP of Epe (59,000 PE) followed in 2013 by the WWTP of Garmerwolde (140,000 PE). On both plants significant improvements regarding process stability, effluent quality (e.g. Epe meets TN <5 mg/L, TP <0.3 mg/L) and energy savings (>30 %), compared to traditional activated sludge processes, have been demonstrated. Meanwhile a total of 25 Nereda® plants and 8 process improving units are in operation or under design, with capacities ranging from 15,000 to 950,000 PE.

Aerobic Granular Biomass

The design and control mechanisms of the Nereda® process favor the formation of granules rather than flocs. Aerobic granules are defined as "aggregates of microbial origin, which do not coagulate under reduced hydrodynamic shear, and which subsequently settle significantly faster than activated sludge flocs"*. The main features defining aerobic granules are a minimum diameter of 0.2 mm and a 5 minute sludge volume index (SVI5) being comparable to a 30 minute sludge volume index (SVI30) of activated sludge.

Aerobic granular biomass has several advantages over conventional activated sludge flocs, including good settling ability which leads to better biomass retention and higher biomass concentrations. Furthermore the particles formed provide a structured matrix for biomass growth, containing spheres with anaerobic, aerobic and anoxic conditions which are populated by different microorganisms including phosphate accumulating organisms (PAO), nitrifiers, denitrifiers, and glycogen accumulating organisms (GAO).

This allows for a simultaneous execution of the processes required for nutrient removal, and provides the foundation for a process that is both simple and requires minimal space.

** First Aerobic Granule Workshop 2004, Munich*

The Nereda® Process

The Nereda® process uses an optimized sequencing batch reactor (SBR) cycle in which the 4 steps of a typical SBR cycle are reduced into 3 steps (Figure 1):

1. Simultaneous fill/draw. During this stage the wastewater is pumped into the reactor and at the same time the effluent is drawn.
2. Aeration. During the aeration phase, biological conversion take place. The outer layer of the granules are aerobic and it is here where nitrifying bacteria accumulate. This forms nitrate that is then denitrified in the anoxic core of the granules. In the final step phosphorous uptake occurs.
3. Sedimentation. Following the biological processes, a sedimentation phase separates the clear effluent from the sludge. The time for phase separation is short due to the excellent settling properties of the sludge. Then system is then ready for a new cycle.

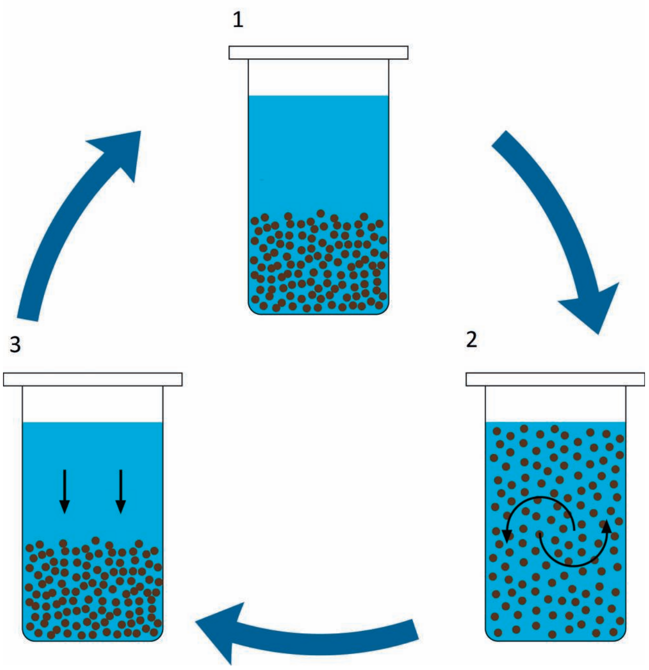

Figure 1: The Nereda® cycle
1. Simultaneous fill / draw, 2. Aeration, 3. Sedimentation

The key advantages of Nereda® are summarized as follows:

Cost-effective
- Compact and uncomplicated tank design
- Less mechanical equipment
- No separate clarifiers needed

Easy to operate
- Robust and reliable process performance
- Fully automated plant operation possible

Sustainable
- High effluent purity and efficient nutrient removal
- No or minimal use of chemicals
- Significantly lower energy consumption

Controlling the Nereda® process

To meet the effluent demands and energy efficiency requirements of the WWTP, optimisation of the Nereda® process can be controlled by online process analysers measuring ammonium, ortho-phosphate, oxygen, and the oxidation reduction potential (ORP). For less stringent effluent requirements, typically the main process control parameters are oxygen and ORP. Like for all advanced controls it is desirable that the measurement values are highly reliable.

At the Epe wastewater treatment plant reliability of the ammonium, phosphate and nitrate measurements is ensured by a predictive diagnostic system called Prognosys that monitors and interprets the instrument's internal signals to inform the user of the instrument condition. The reading is expressed as a percentage value and is designed to inform operators about upcoming maintenance needs before measurements become questionable and might affect the process.

Ammonium and phosphate are measured using the outdoor versions of the Amtax sc (NH_4^+) or Phosphax sc (PO_4^{3-}) analyser respectively. These analysers do not measure directly in the process medium, but the sample for analysis is pumped from the Nereda® reactor, pre-filtered (<0.45 microns) in a self-cleaning module and transported to the analyser. Both analysers have an analysis time of approximately 5 minutes. Oxygen (LDO sc) and pH/ORP (pHD-S sc) sensors can be directly placed in the medium thereby delivering measurement values in real time.

In figure 2 the different measurement signals of sensors and analyzers during the aeration phase are shown as a trend line. It can be seen that during the aeration cycle, the oxygen concentration is kept constant and there is a decrease of the ammonium and the ortho-phosphate concentration. The ORP signal increases in accordance with the increasing ratio of oxidised to reduced species.

At Epe and Garmerwolde, a signifikant parameter for process control in the aeration phase of the Nereda® process, is the NH_4^+ concentration value delivered by the Amtax sc analyser. The reliability of the NH_4^+ and other measurement values is constantly monitored by Prognosys and classified in percentage values as the so-called measurement indicator. In case the value of the measurement indicator starts decreasing from 100% there is still enough time to take action before results get questionable. If the value should drop below 50%, an alternative strategy to control the aeration is activated using the mV value delivered by the ORP sensor as backup signal.

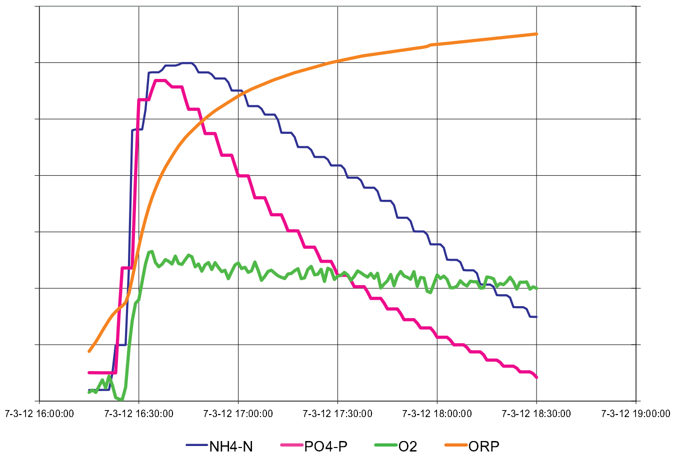

Figure 2: Trend lines from the online measurements during the aeration cycle of the Nereda® process

Data transfer and communication

All measurement signals from one reactor are captured by a single SC1000 controller. TCP/IP is used for the communication between the controller and the AquaSuite® Nereda® PLC. Controller and attached instruments can be remotely monitored via the network. I.e. measurement values as well as the status of the instruments provided by Prognosys can be retrieved and maintenance steps like a calibration can be remotely started.

Results from Epe WWTP, The Netherlands

Epe WWTP is a full scale Nereda® plant which was designed and constructed by Royal HaskoningDHV in 2010-2011 and has been operational since September 2011. 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 average daily flows of 8,000 m^3/day and a peak flow of 36,000 m^3/d. The waste sludge is thickened via a gravity belt thickener and transported off-site. The performance of the plant is outlined in table 1.

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

Parameter	Influent [mg/L]	Effluent – average [mg/L]	Effluent (95%ile)
COD	879	27	32
BOD	333	<2.0	<2.0
N-Kjeldahl	77	1.4	1.8
NH_4-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

One key advantage of Nereda® is reduced power consumption. At Epe, the original plant energy consumption was approximately 3,500 kWh/d. With Nereda®, the average daily consumption is now 2,000 kWh – 2,500 kWh. This is approximately 35 % less than all types of similar sized conventional plants in the Netherlands.

Conclusions

Existing Nereda® plants demonstrated that the technology is capable of effectively treating wastewater for removal of ammonia, total nitrogen and phosphorus. The process is effective at removing these parameters to low levels, in line with future effluent consent limits that might be put in place by the EU water framework directive. Notably, the technology is delivering wastewater treatment at a significantly reduced CAPEX (plant size, footprint) and OPEX (energy, chemicals) compared with conventional technologies on the market.

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