The future of sewage treatment: Nereda technology exceeds high expectations

● The Nereda aerobic granular sludge process is now in operation at several industrial and three municipal wastewater treatment plants sites and is outperforming the stringent conditions in place, paving the way for the expansion of this innovative technology. **PAULO INOCÊNCIO, FERNANDO COELHO, MARK VAN LOOSDRECHT** and **ANDREAS GIESEN** outline the successful first two years of operation of the first full-scale Nereda treatment plant and how this process can be used to future-proof wastewater treatment facilities.

The innovative and sustainable biological wastewater treatment technology Nereda has proven to exceed its high expectations. The first full-scale municipal treatment plant using Nereda in the Netherlands at Epe has now been in operation for almost two years. Extensive plant performance monitoring confirms that the very stringent targets for effluent quality, sludge treatment, use of chemicals and energy consumption are easily met. Also, the results of an extensive demonstration project by Simtejo, a wastewater concessionaire responsible for the operation of the main sewers and treatment plants of the Great Lisbon area, at the Portuguese Frielas WWTP validate that compared to traditional activated sludge the innovative technology outperform on process stability, effluent quality and energy savings.

Nereda is an innovative and advanced biological wastewater treatment technology that uses aerobic granular sludge instead of the conventional activated sludge flocs (see also *Water21* April 2012, p28-30). Invented by the Delft University of Technology and developed within a unique public-private-partnership between the university, the Dutch Foundation for Applied Water Research (STOWA), several Dutch Water Boards and Royal HaskoningDHV, the technology revolutionizes wastewater treatment. The technology is classified by experts as the most important process breakthrough in decades and regarded as the upcoming new standard for biological treatment of domestic and industrial wastewater.

Important milestones in Portugal

Following the success of several greenfield industrial and municipal references, the Nereda demonstration plant at the Frielas WWTP (Portugal) (see box) was the first worldwide retrofit application in which an existing continuous activated sludge (AS) reactor was converted to a Nereda reactor. Regarding effluent quality and energy savings, the performance results obtained were outstanding and mark an important milestone in the development of this technology. Conversion from demonstration to full-scale Nereda is underway.

Since the start-up back in 1997, the Frielas WWTP has suffered from several operational constrains 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 the Nereda performance under realistic field conditions, one of the six continuous activated sludge reactors was retrofitted into a Nereda reactor with a volume of approximately 1000m^3, which was then run by Simtejo in parallel with the remaining five AS reactors.

Besides providing a robust and efficient operation throughout all influent conditions, a driver for the retrofit was related to evaluating the possibility of substantially lowering the electricity bill 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.

Main conclusions demonstration reactor Frielas

After more than one year of practical plant operation the results are outstanding and crystal clear: the effluent quality is significantly better and is far more consistent than the quality obtained in the original continuous AS system (see Figure 1). Moreover, the energy savings are very substantial. Since Nereda is operated in parallel with the conventional aeration tanks using the same water depth, existing and common air supply equipment, etc., 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

The Frielas WWTP

The Frielas WWTP is a 70,000m^3/d plant, operated by Simtejo, which is currently at 70% of its biological design capacity, which receives, mainly, domestic wastewater from 250,000 inhabitants. Regarding effluent quality, the WWTP has carbon removal and disinfection requirements (i.e., COD < 125mg/l and TSS < 35mg/l) and no specific discharge limits for nitrogen and phosphorous.

The treatment scheme is based on a conventional activated sludge system with six 4000m^3 complete mix biological reactors and 12 rectangular settlers. The reactors have a water depth of 6m and aeration is undertaken by a fine bubble diffusion system fed by four centrifuge blowers. The water line is complemented upstream by primary sedimentation with rectangular lamella settlers and wastewater equalization, and downstream by a polishing step with Biostyr type biofilters and UV disinfection before discharge to ribeira da Póvoa, a small tributary of the Trancão river. The sludge line includes the usual operations of sludge thickening, mesophilic anaerobic digestion with energy recover and dewatering. The dewatered sludge is reused in agriculture after composting in an external facility.

Nereda aerobic granules compared with conventional activated sludge process

performance of the AS 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 for aeration. Combining this with the energy saving, that Nereda brings by not using settling tanks, sludge recirculation pumps and post-filtration units, the overall electricity saving potential for the plant was computed to an astonishing 50%.

Future developments

Following the positive results obtained with the Nereda demonstration reactor, Simtejo requested Royal HaskoningDHV to design and implement an extension of the demo to a full-scale reactor operated parallel to the existing continuous AS treatment reactors. The reactor will have a treatment capacity of 12,000m³/d and 40,000 inhabitants and is projected to be online later this year. After this upgrade the Frielas WWTP will be operated as a hybrid Nereda plant; the granular excess sludge from the Nereda reactor is pumped to the continuous AS lines. By this inoculation process, the sludge characteristics and settling performance of the existing AS plant will improve, resulting in a further increase of its hydraulic and biological treatment capacities. It is expected that in the near future more reactors at the plant will be retrofitted. Extrapolating the findings demonstrated to date, the retrofit of all six secondary reactors to Nereda would result in a WWTP that will be future-proof against stricter effluent requirements, has a robust operation and achieves important operational savings.

Performance success in Epe

It was already clear that Nereda requires only a very small footprint (up to just 25% of conventional technologies) and proves more cost-effective than comparable systems (savings more than 25% in investment and operational costs). Two years of successful operation of the Epe WWTP – designed to treat flows up to 1500m³/h – also demonstrates the sustainable character of Nereda.

Extensive plant performance monitoring shows that the performance of Nereda exceeds expectations. The energy consumption of the WWTP, including sand filtration and sludge treatment, is significantly lower than any type of similar-sized and designed conventional treatment plant in The Netherlands. Furthermore the effluent quality meets the highest standards in The Netherlands, i.e. total nitrogen and phosphorus concentrations lower than 5.0 and 0.3mg/l. Table 1 shows more detailed performance results.

Remarkably, robustness and stability of the treatment process was observed under strong varying influent load conditions and extreme influent pH fluctuations. Another interesting observation is that even in wintry conditions, extensive nitrogen removal could be established at surprisingly high biological sludge loads.

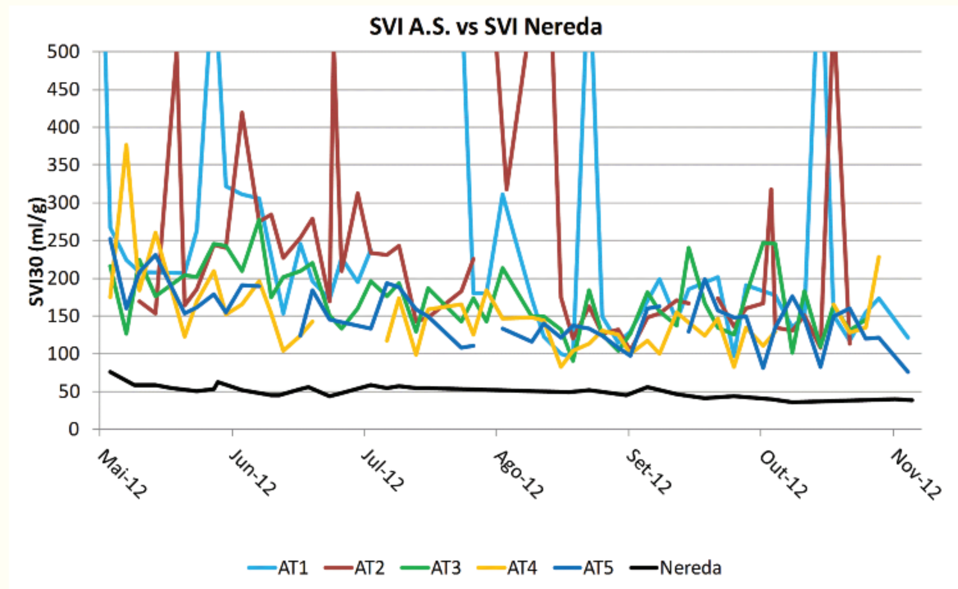

Figure 1: Comparison between the settling characteristics of the biomass in the Nereda reactor and the five other activated sludge reactors at Frielas WWTP

Developing into the new standard for wastewater treatment

In the previous April 2012 *Water21* article it was mentioned that this technology has to be adaptable if it will become the new world standard for aerobic wastewater treatment. It is still too early to confirm, but with multiple new Nereda plants scheduled for start-up in 2013, a steadily growing number of international applications in the pipeline, tank size close to the largest sequencing batch reactor tanks worldwide and the Epe plant receiving almost every week international delegations, all signs are pointing towards this.

One thing is clear: aerobic granular biomass has matured from an emerging innovation into an applied technology that is now proven for even the largest industrial and municipal treatment applications.●

Table 1: Epe WWTP performance results during process verfication March-May 2012. The wastewater temperature ranged from 14°C to 16°C.

Parameter	Influent (mg/l)	Effluent (average) (mg/l)	Removal
COD	879	27	96.9%
BOD	333	< 2.0	>99.4%
N_{Kj}-N	77	1.4	98.1%
NH_4-N	54	0.1	99.8%
N-total		< 4.0	>94.7%
P-total	9.3	0.3	97.2%
Suspended solids	341	< 5.0	>98.5%.

Nereda demonstration reactor at Frielas WWTP, Portugal

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Lessons learned from Dutch MBR cooperation

Over the past 13 years, The Netherlands has contributed significantly to membrane bioreactor (MBR) development, with an extensive research period at the Beverwijk sewage treatment plant (STP) and research at the Hilversum, Leeuwarden and Maasbommel STPs.

The Varsseveld MBR was the first Dutch municipal full-scale plant and was seen as a demonstration plant for MBR technology. During eight years of operation many fundamental lessons were learned and used for subsequent Dutch demonstration projects.

The uniqueness of the Dutch MBR development programme is shown by the fact that it was supported by all Dutch Water Boards, united in the Foundation for Applied Water Research (STOWA), and was executed in cooperation with consultants, Dutch universities and membrane suppliers. Ten years after the start of this programme, in 2010, the last national MBR platform meeting took place and an interesting period of close cooperation was ceased with excellent results. Despite only five of an original 25 'high potential' projects being realised, two of which are now being taken out of service for various reasons, the eight year operation of Varsseveld STP produced a significant amount of valuable information which can be used by MBR system designers and operators around the world.

Lessons learned from Varsseveld STP

After eight years of operation of the Varsseveld STP, which has produced positive effluent quality, membrane performance and energy consumption results, a number of important lessons have been learned. The first lesson was that influent components, which do not cause any problem in conventional activated sludge systems, can do so in an MBR installation. In Varsseveld it was an industrial polymer used in a local cheese factory that caused the membranes to stick together. A serious analysis of the wastewaters is therefore recommended before deciding to implement an MBR installation.

Other lessons included the need to completely cover MBR installations to prevent leaves infiltrating the membrane tanks, the size of the mesh in the micro-screens was increased from 0.8mm to 1mm due to constant clogging problems, and the coating of the tanks should be considered with regards to the cleaning procedure, chemicals and frequency and the concentration of chemicals used to prevent damage.

It was also found that the operational costs of an MBR plant are significantly higher compared to a conventional activated sludge plant (approximately €150,000 ($194,700) per year for a conventional plant compared to €210,000 ($272,500) per year for an MBR), though the effluent quality is different.

At Varsseveld replacement of the membrane modules is foreseen in the next couple of years and this year the cheese factory will close, meaning that the excellent effluent quality produced by the MBR is no longer required. The high energy consumption and high operational costs have therefore gained importance.

In the meantime the water sector in The Netherlands is focusing on recovery and reuse of resources from wastewater and making processes energy neutral or energy producing. The cooperation around the MBR development project can be seen as a nice example and starting position.

The full report on which this item is based, 'Ten years of MBR development: lessons learned from The Netherlands', appeared in the 2012 Water21 Wastewater Treatment Supplement, available to download at www.iwapublishing.com/template.cfm?name=w21reportwastewater.