Purely based on character

In Epe, the Veluwe Water Board is pioneering a new generation of sewage water purification. The Nereda granular sludge technology saves around a quarter of the energy, while taking up just a quarter of the space. "In ten year's time, this will be the standard."

Project manager André Welmer, from the Veluwe Water Board, has his work cut out for him: Having just given a guided tour to two people from the Municipality of Epe, in comes a journalist wanting the same. Here, on the edge of an Epe industrial estate, there is a sense that the job is almost done. The major construction work involving cranes and concrete trucks is complete; it is now the turn of the consultants, project workers and various specialists to connect the cables, test subsidiary systems and agree on the final details.
Three huge concrete tanks - 9 metres tall, with a capacity of 4500 cubic metres - are lined up in a row. In front of them stands a small black building housing air compressors and the electronics that control the system. From various directions, cables emerge from the sand and run into the building via pipes.

The new granular sludge settles so quickly that no sedimentation tank is required

A thick steel drainage tube runs along the upper edge of the tanks, underneath a skywalk. From that height, the old installation is clearly visible. It is the type you see everywhere in the Netherlands: a large circular sedimentation tank and the noisy splash of blades moving air through the water. Welmer explains how this will soon be a thing of the past. In partnership with various Dutch water boards, TU Delft and engineering firm DHV have developed the Nereda® granular sludge technology. The new granular sludge – a type of bacteria that removes the organic carbon, nitrogen and phosphate from the waste water - sinks so rapidly that a sedimentation tank is no longer required. And as part of a new aeration technique, compressors blow bubbles from the bottom of the tank – much quieter and more energy-efficient than the splashing blades.
It was the favourite lab demonstration of biotechnologist, Dr Merle de Kreuk, when she was doing her PhD research under the supervision of environmental biotechnologist, Professor Mark van Loosdrecht (Faculty of Applied Sciences): To illustrate the difference between regular water purification and granular sludge technology, she would bring two closed cylinders of sludge along to the presentations and turn them around. In one of the cylinders, a murky layer spread out through the whole of the water column, while in the other granules of just a few millimetres in size whirled down through the clear water to the bottom in just a few seconds. What could be clearer?
The benefits offered by the granular sludge technology were equally clear: the new generation of water purification saves space (three-quarters of it, according to its designers), as well as a quarter of the energy due to more efficient pumping and aeration, buoyed by the fact that the waste water does not need to be pumped back and forth as much. The installation's limited surface area and low energy consumption also reduce the construction and operation costs. As Prof. Van Loosdrecht puts it: "Apart from being better, an innovation needs to be cheaper as well."
Finally, the water quality is better than with conventional purification, as demonstrated in a pilot project that preceded construction in Epe. The technology won the Vernufteling 2005, an award given by Kivi-Niria (the Dutch association for engineers, ed.)and NLingenieurs for the most innovative project by an engineering firm, before going on to win seven more awards.
So why has it taken 12 years for such award-winning technology to move from the laboratory into practice? "It's taken far too long," agrees Helle van der Roest, a leading professional at the engineering firm DHV. "Speed is essential, even more so than patents. You have to assume that technology which is so promising will be copied. You can only be sure of earning back the investment made on research if you stay ahead of the competition."

Granular sludge

What exactly is granular sludge? It looks like little balls, ranging from a few tenths of a millimetre to several millimetres in size, consisting entirely of bacteria. The crux is that, under certain conditions, the bacteria

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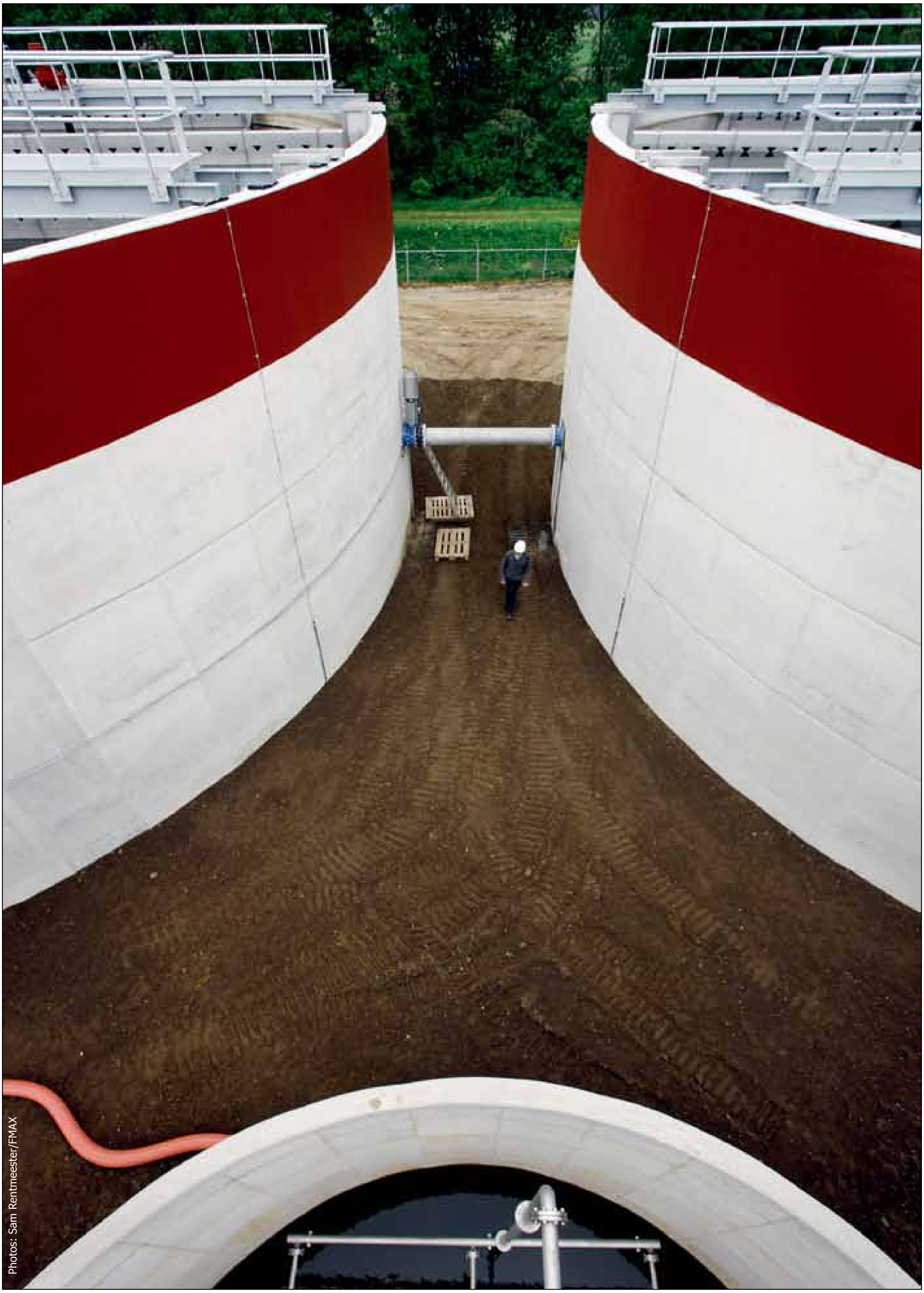
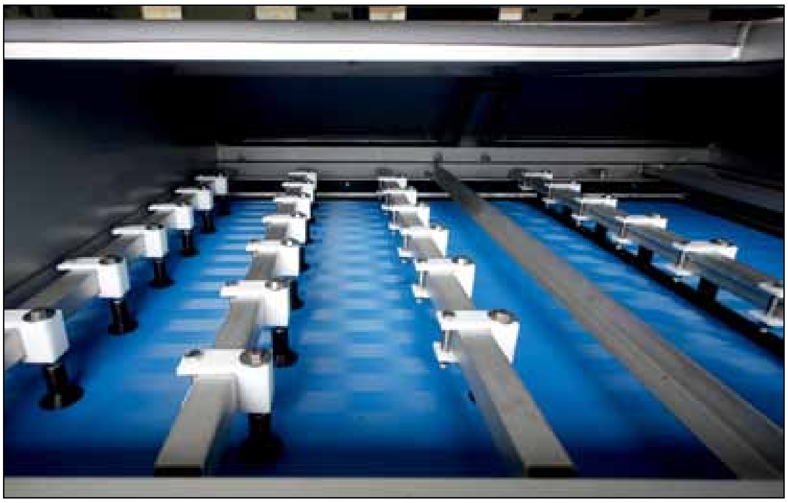


The purification process in Epe takes place in 3 tanks of 9 meters in height and 25 meters in diameter.


This machine filters the granular sludge out of waste water.


A tube removes the purified water.

spontaneously clump together to form granules. “The phenomenon was first identified in the late 1960s,” explains Prof. Van Loosdrecht. Professor Lettinga, from Wageningen University, had identified bacterial sludge granules in anaerobic water purification at CSM [a global food-bakery supply company, ed.]. This led to the idea that it might be possible to speed up water purification by using granular sludge, because this sludge sinks more rapidly. The technology based on anaerobic (without aeration) granular sludge became a successful export product in the 1980s and 90s. The bacteria removed organic pollution from wastewater, creating biogas as a by-product. However, nitrogen compounds and phosphates were left behind and the process proved less effective at low temperatures. Consequently, the search was on for aerobic granular sludge, which was expected to produce better results.

“Originally, the idea was that anaerobic bacteria were particularly suited for granular sludge because they form complex communities to convert the substrate [nutrients, ed.],” explains Prof. Van Loosdrecht. Personally, however, the professor was not convinced. In the early 1990s, his discovery of aerobic bacteria in granular-sludge form caused quite a stir among biotechnologists. His PhD student at the time, Dr Janneke de Beun, had demonstrated that even simple, fast-growing bacterial cultures could grow as granular sludge. “You have to exert the right selective pressure,” he says now. “The biology will then adapt accordingly.” In Epe, this selection involves the bacteria passing through a cycle of one period of nutrition under anaerobic conditions, followed by two periods of aeration. New waste water then flows into the tank and the purified water passes on. The alternating regime of anaerobic nutrition and aerobic growth promotes the development of slow-growing bacteria that can more easily form stable granules.

The engineering firm DHV became involved with the granular sludge technology in 1999, following a visit by Van de Roest to Prof. Van Loosdrecht’s lab. “Helle was the driving force within DHV,” Prof. Van Loosdrecht says. For the development process, a subsidy was obtained from the STW technology foundation, and financial support from the Stowa knowledge centre. PhD student Merle de Kreuk was enlisted to enable the bacteria to also remove nitrogen and phosphate compounds. In 2007, STW awarded her the title of Simon Stevin Fellow for the way in which she served as a linchpin between scientific research at TU Delft and the engineering work at DHV.

“Merle did an outstanding job,” Van der Roest says. “She played an instrumental role in the development of Nereda.” From 2005, Nereda was the trade name of the anaerobic granular sludge technology, derived from the name of a water nymph in Greek mythology.

Crisis

The process of upscaling and research went hand in hand. Van der Roest had the enviable job of challenging the biotechnologists to modify the process conditions for practical application, for example where the pump capacity is limited and the oxygen content can never be as high as in a laboratory setting.

Switching to real waste water instead of the laboratory concoction proved trickier than expected. A pilot set-up, 6 m in height and 60 cm in diameter, was the site of a Stowa study involving sewage water at the waste water purification plant in Ede (not Epe), designed to run from 2003 to 2005.

“It was completely different to the lab,” recalls Van der Roest. “We became quite desperate at times because the granular sludge refused to grow.” When, nine months later, some granular sludge was starting to develop, a disaster occurred. A computer was stolen one weekend, which meant that the process could no longer be monitored. When the researchers returned to work after that weekend, they also discovered that a technical fault had caused all the granular sludge to be washed away. This put DHV in a difficult situation. The losses almost equalled the turnover, but stopping the project would have meant both the commissioning parties and the water boards losing face. The project workers were so motivated that they decided to continue the work in their own time. But this crisis had also revealed something new. Van der Roest: “We realised that we had to treat the micro-organisms so badly that they had no choice but to grow in granular form, having to depend on each other for survival.” So the engineers’ stress led to stress for the

Prof.dr.ir. Mark van Loosdrecht with granular sludge: "Apart from being better, an innovation needs to be cheaper as well."

bacteria. And, lo and behold, after four months the test reactor was full of granules and the removal of nitrogen and phosphate (nutrients) was even more effective than expected.
In the ensuing period, TU Delft and DHV established the National Nereda Development Programme (NNOP), in alliance with six Dutch water boards. The programme will run until the end of 2012 and include the construction of several purification plants.
For the construction of the first full purification plant, a water board was needed as the commissioning body along with a guarantee fund in case the plant did not operate as predicted. The Hollandse Delta Water Board came forward as the first commissioning party back in 2007. But it proved impossible to secure the guarantee fund. "The

'The micro-organismen and granules have to depend on each other for survival'

first Nereda purification plants could have been up and running years ago," claims Van der Roest, "if a guarantee fund had been available." But what actually happened was different, and after three years of delay, the first Nereda purification plant is located not in Zuidland, but in Epe (Veluwe Water Board), soon to be followed by Dinxperlo (Rijn & IJssel Water Board) and Vroomshoop (Regge and Dinkel Water Board).
Prof. Van Loosdrecht, who received a knighthood this year for his services to water purification, is hard at work on new purification concepts, including the use of anammox bacteria at low temperatures and the production of chemicals from waste streams. "Universities shouldn't hold on to their inventions too long," he believes, "while continuing to pursue research into the questions that emerge as the scale increases."
Van der Roest, who describes himself as a "positive kind of guy", refuses to indulge in finger-pointing. "You can feel disappointed at times, or just accept the fact that innovation always involves setbacks." He does feel that rules often create obstacles for innovation and that the innovation process itself is in need of innovation. Experience has taught him to start by seeking out people with the courage to kick-start developments. "People like Merle de Kreuk, Douwe-Jan Tilkema [head of the water purification sector at the Veluwe Water Board, ed.] and Jacques Leenen [STOWA Director, ed.] had the courage to persist in the face of setbacks. That's crucial, because there will be many more obstacles to overcome." (JW)

Further information:
Professor Mark van Loosdrecht,
m.c.m.vanloosdrecht@tudelft.nl
Helle van der Roest
helle.vanderroest@dhv.com
www.nereda.net

Helle van der Roest: "Innovation always involves setbacks."

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Purification in three phases
In the granular sludge technique, all the purification processes take place in a single reactor tank that is periodically filled and emptied. The total purification process takes three hours and consists of three stages.

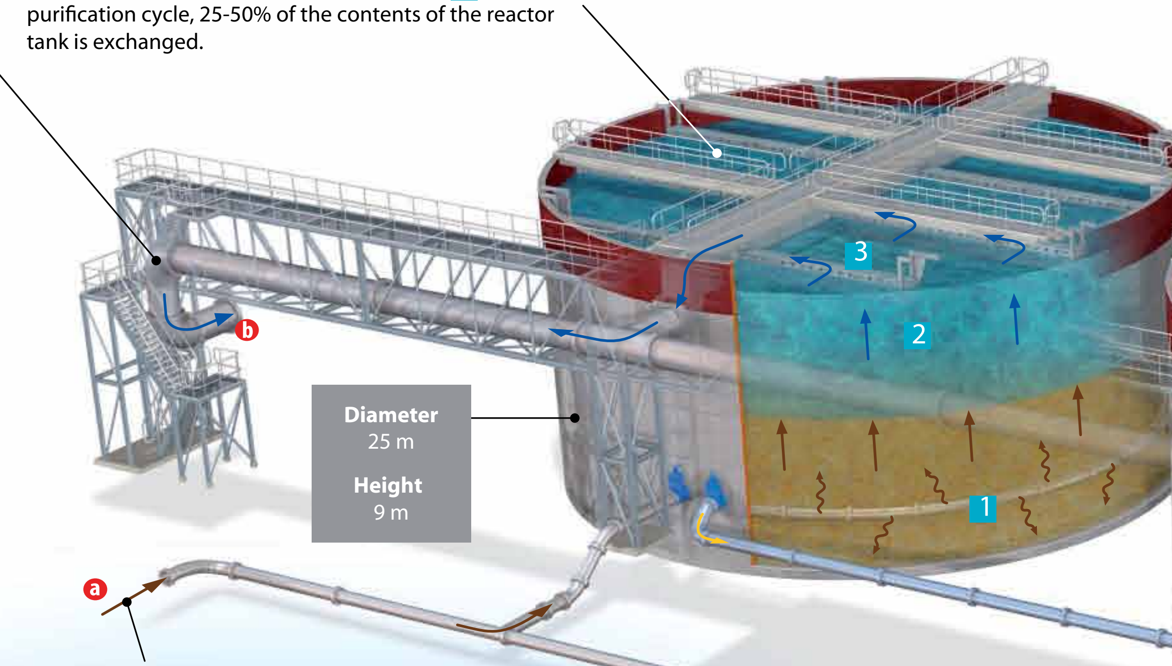
Test phase
Currently, all the pump and control systems in the new sewage water purification plant are undergoin testing.

Start-up phase cultivating
After the test phase, sludge flocs and a small quantity of sludge granules (from a small-scale trial set-up) are added to the water in a single reactor tank. The sludge flocs feed on the waste water, forming granules as they grow. Only those granules that clump together to form compact, heavy granules are allowed to remain. The cultivation of granules on this scale has never been undertaken before and is expected to take six to nine months.

PURIFICTION USING GRANULAR SLUDGE
1 Filling and draining
1 hour

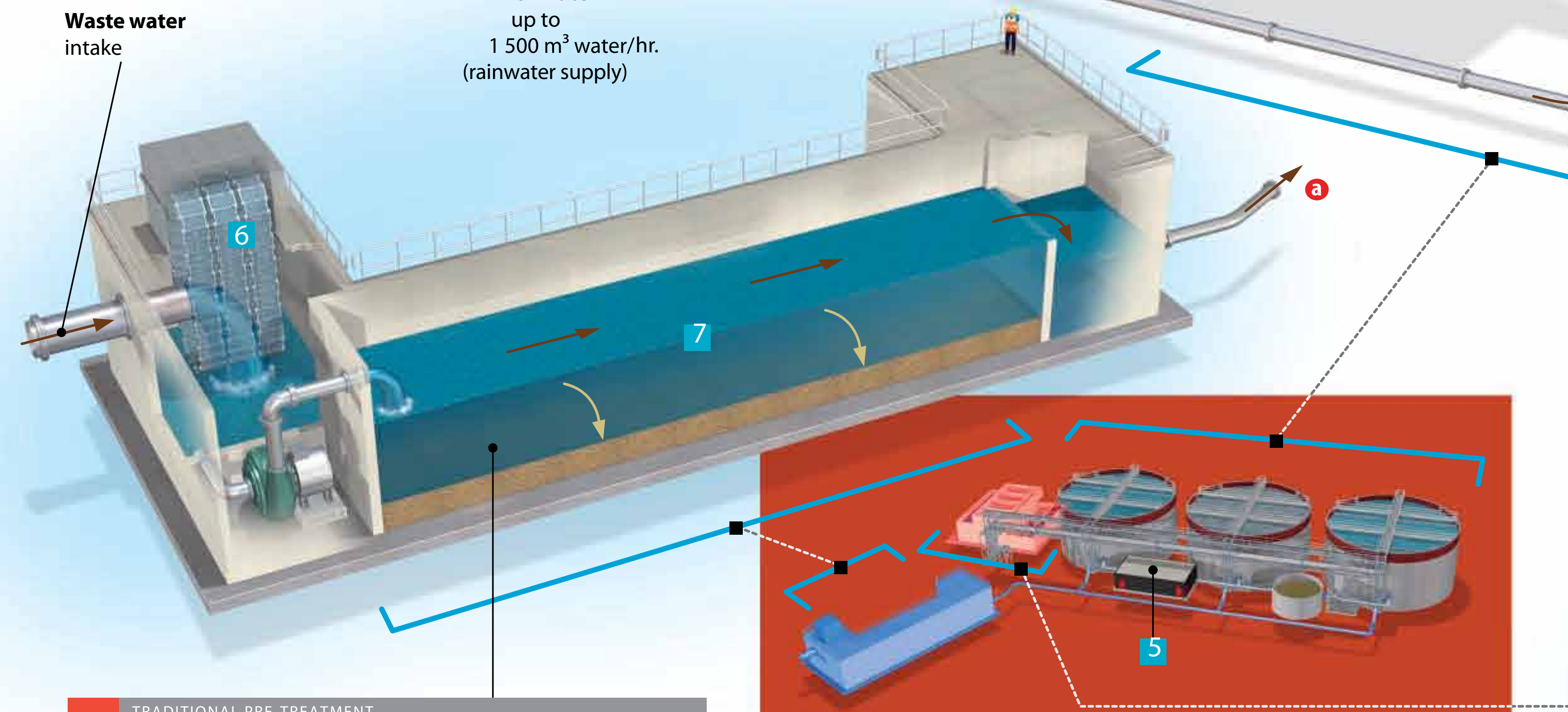
The reactor tank is filled 1 with waste water from below. The granules remain at the bottom while the rising waste water propels the clean water 2 out of the reactor. The key is adding the dirty waste water in equal amounts without creating turbulence, which would cause the dirty water to mix with the clean water. The purified water flows away through a network of drainage gutters 3. In each purification cycle, 25-50% of the contents of the reactor tank is exchanged.

Sludge granules
The innovative Nereda® water purification technology uses sludge granules rather than floccular sludge. Sludge granules sink far more rapidly than sludge flocs, enabling the separation of the granular sludge and purified waste water to occur in the reactor tank itself. There is no need for large sedimentation tanks.



Flow rate
up to
1 500 m^3 water/hr.
(rainwater supply)

Waste water
intake



TRADITIONAL PRE-TREATMENT
0 Screening filter & sand and grease trap

Screening
The waste water passes through a screening filter 6 (with 2 mm holes) that removes any undissolved substances, such as plastic and wood, from the water.

Aerated sand and grease trap
The water flows through a shallow container 7 . Aeration generates vertical whirlpools in the water forcing the sand to the bottom of the container where it remains. A scraper collects particles of fat and grease that remain floating on the surface.

Construction of new plant in Epe

The world's first, full-scale sewage water purification plant that will purify waste water using aerobic sludge granules has been constructed in Epe. The purification process starts with pre-treatment, followed by biological purification using sludge granules, and ends with the final treatment. The waste water that arrives is always sent to one of the three reactor tanks in the filling phase, making it possible to have a continuous stream of household waste water. With its new plant in Epe, the Veluwe water board can biologically purify the waste water from 59,000 residents every 24 hours.

2 PURIFICATION USING GRANULAR SLUDGE **110 minutes**

Aeration

Aeration plates at the bottom of the tanks are used to add oxygen 4 to the water. The sludge granules mix throughout the whole reactor tank. The bacteria in the granules break down the pollution in the water The three compressors 5 that compress the air account for most of the energy consumption in the purification plant.

ADVANTAGE

75% reduction in surface area

The concentration of bacteria in a granule is greater than in a floc, which means that pollution is removed more effectively. It is therefore possible to use a smaller reactor tank. No large sedimentation sinking tanks are required, either. Consequently the capacity of existing plants can be increased without the need for extra land.

ADVANTAGE

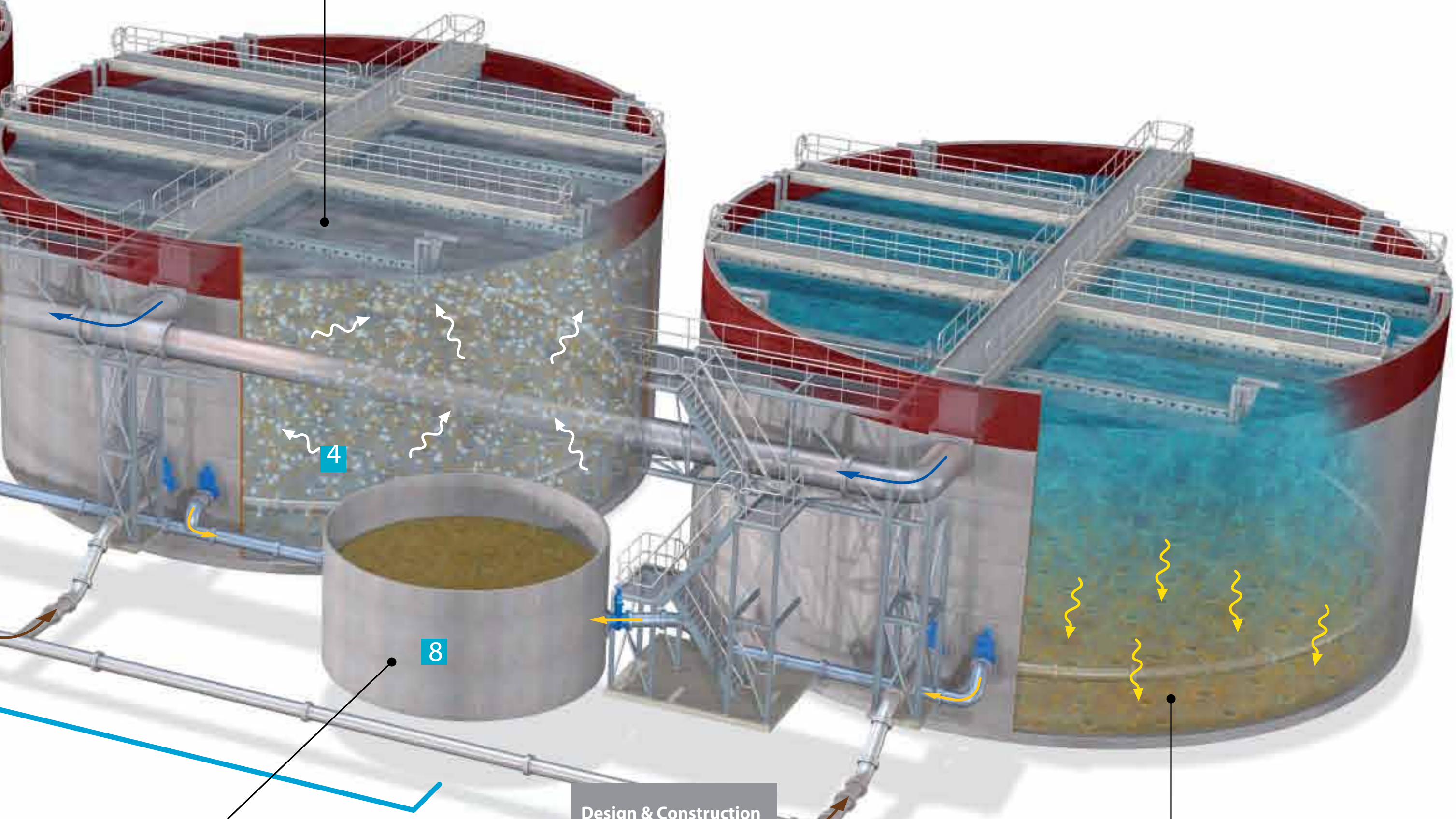
20% reduction in construction and operation costs

Construction and operation costs for the compact and relatively simple reactor tank with only one compartment are significantly lower than for conventional purification plants.

ADVANTAGE

20% reduction in energy consumption

All the stages of purification take place in a single reactor tank, which means less water needs to be pumped and mixed. The total energy saving compared to traditional purification using sludge flocs is at least 20%.



Removal of granules

Because the bacteria eat waste materials, they continue to grow. For an optimum effect, the concentration of granules in the reactor tank should not be too high. Sludge containing sludge granules is periodically drained into a sludge tank. 8 The sludge is then mechanically thickened, dehydrated and taken to a waste processing plant

Design & Construction
DHV

Costs
15 million euros

In operation in
2012

3 PURIFICATION USING GRANULAR SLUDGE **10 minutes**

Sedimentation

The relatively heavy granules rapidly sink to the bottom. The process repeats itself from phase 1.

4 TRADITIONAL FINAL TREATMENT

Sand filtration

Sand filtration is used to remove the remaining dust and residual phosphate and nitrogen. The addition of a (chemical) flocculating agent causes the residual substances in the water to clump together so that they can be filtered out more quickly and effectively. The water flows down through a sand bed. Any impurities larger in size than a grain of sand are retained. There are pipes under the sand bed with holes that allow the water to pass through, leaving the sand behind.