Dutch Environmental Biotechnologist Wins the **Lee Kuan Yew Water Prize 2012**

Text by Anoop K. Menon
Photograph courtesy of Delft University of Technology

Professor Mark van Loosdrecht from Delft University of Technology (TU Delft), Netherlands, was recently awarded the prestigious Lee Kuan Yew Water Prize 2012 for his breakthrough contributions towards the development of sustainable wastewater treatment solutions. A major highlight of the annual Singapore International Water Week (SIWW), the Lee Kuan Yew Water Prize is an international water award that recognises outstanding contributions towards solving global water problems by either applying technologies or implementing policies and programmes that benefit humanity. Named after Singapore's first prime minister, the award, which is sponsored by the Singapore Millennium Foundation, comes with a cash prize of SGD300,000, a certificate and a gold medallion.

Van Loosdrecht, who is the fifth recipient of the Lee Kuan Yew Water Prize, was selected from 61 nominations received from over 25 countries. The prize recognises his pioneering efforts towards the development of an innovative biological process, Anammox, which provides a cost-effective, robust, and sustainable method to remove unwanted pollutants from wastewater, while reducing overall energy consumption, chemical usage, and carbon emissions associated with conventional wastewater treatment.

The development of Anammox process was the result of almost 20 years of work and dedication by a team of microbiologists and engineers at TU Delft led by Van Loosdrecht. At the core of the process is a unique group of autotrophic bacteria, first discovered in the 1990s by a team of researchers, also from TU Delft and led by Professor Kuenen. These bacteria possess a set of enzymes that enables them to convert ammonia to harmless nitrogen gas for discharge into the environment without the use of oxygen or other additives. In other words, this bypasses the undesirable intermediate nitrate stage in the traditional nitrogen removal process, known as nitrification/denitrification, resulting in reduced energy consumption in wastewater treatment.

Advantages of Anammox

- Energy used to introduce oxygen can be reduced by up to 60 percent.
- The Anammox process does not require organic carbon, unlike the traditional nitrification or denitrification process. In turn, this reduces carbon dioxide emissions by up to 90 percent.
- Anammox bacteria produce biomass very slowly, which reduces the amount of sludge to be disposed off.

1. Van Loosdrecht's breakthrough nitrogen removal technology, Anammox, represents a paradigm shift in the understanding of wastewater treatment process.

Reengineering Nitrogen Removal

Essentially, nitrification/ denitrification involves the conversion (through aeration) of ammonium to nitrite, to nitrate, followed by the denitrification of nitrate, to nitrite, and finally to nitrogen gas, using organic carbon compounds as an energy source. However a significant amount of energy is expended to maintain the aerobic conditions for nitrification to take place. In fact, as per various estimates, in a conventional wastewater treatment plant, nearly 50 percent of the energy consumed can be linked to aerobic processes, followed by sludge treatment (30%) and pumps (15%).

Van Loosdrecht and his team devised the engineering tools and systems to harness the natural properties of the autotrophic bacteria that constitute the heart of the Anammox process. The first step, which he termed Sharon, involves the use of ammonia oxidising bacteria (AOB) to oxidise half of the ammonia to nitrite instead of nitrate. Essential in this engineering is the prevention of the growth of nitrite-oxidising bacteria, which forms the unwanted nitrate intermediate. The second step uses the anaerobic ammonia-oxidation bacteria, or Anammox, to convert the nitrite and the rest of the ammonia to nitrogen gas, without the need for additional organic carbon.

Achieving Energy Self-sufficiency

In most industrialised countries, traditional wastewater treatment accounts for nearly one to three percent of the total energy budget; moreover, part of this energy may be considered "wasted", as the end product is discharged back into the environment. Anammox promises to reduce aeration energy needs by up to 60 percent and carbon dioxide emissions by up to 90 percent, while occupying 50 percent less space compared to the traditional nitrogen removal process. The application of Anammox technology to biological nitrogen removal systems worldwide can potentially generate substantial energy savings.

Chairman of the Lee Kuan Yew Water Prize Nominating Committee Tan Gee Paw said: "Professor van Loosdrecht's technology is set to create a paradigm shift in the used water treatment industry. The adoption of such energy-saving technology is essential for water treatment plants seeking complete energy self-sufficiency and will be the future of the used water treatment industry. For that, the Lee Kuan Yew Water Prize celebrates Professor van Loosdrecht's outstanding achievement in the development of Anammox and honours his relentless pursuit [of] highly sustainable technologies that are critical for the future sustainability of urbanised cities."

The first Anammox demonstration plant was constructed in 2002 by Paques BV, the licensee of Van Loosdrecht's technology, in Rotterdam. The 80-cubic-metre plant was built to treat high-ammonium sludge water from the Dokhaven-Sluisjesdijk wastewater treatment plant. A reactor was directly upscaled from laboratory scale to full scale without building a pilot plant. By the third quarter of 2006, the reactor was in full operation and converting eight to 10 kilograms of nitrogen per cubic metre a day, a rate twice its design capacity.

While Anammox was initially implemented only in wastewater treatment plants in the Netherlands, it is now being adopted globally, as the technology can be applied to any stream with high concentrations of ammonia or organic nitrogen, such as wastewater from the chemical industry, the food industry, power plants, and animal waste. As of January 2012, 16 referenced full-scale Anammox plants have been implemented by Paques, and more than 30 full-scale variant plants are in operation around the world, including in Austria, China, Japan and the US. Singapore's national water agency Public Utilities Board is currently looking into the adoption of this technology to improve energy efficiency. It is conducting a pilot trial of the process at its water reclamation plant.

Huge Potential in Wastewater Treatment

The full potential of Anammox technology can be realised when it is applied to mainstream wastewater treatment. If successful, it could revolutionise the nitrogen removal process and possibly result in aeration energy savings of up to 60 percent for the whole plant, and most of the organic carbon content of the influent can be used to produce methane gas for energy recovery. The current challenges for the process are the stability of operations and maintaining good effluent quality. With several laboratory and pilot testings of mainstream Anammox underway, Van Loosdrecht expects the first full-scale mainstream reactor to be ready in two to four years' time.

In addition to Anammox, the Lee Kuan Yew Water Prize citation also acknowledges Van Loosdrecht's work on the development of other wastewater treatment technologies, including Sharon, Nereda, CANON, and BABE. The Nereda technology, for example, is a granular sludge technology like Anammox. In this case, the bacteria form compact sludge granules that quickly sink to the bottom, increasing the processing speed of the reactor and saving significant amounts of energy. Research on Nereda is currently being carried out at TU Delft with the support of STOWA and engineering consultancy DHV.

Van Loosdrecht is currently a full Professor and the Group Leader of Environmental Technology at TU Delft, where he has been lecturing since 1988. He did his Masters of Science in Environmental Engineering at Wageningen University and obtained his PhD in Microbiology/Colloid Chemistry in 1988. His research interests include biofilm and granular sludge systems, microbial storage polymers, nutrient removal processes and microbial ecology of engineered systems. He is also developing a start-up company, BiAqua, based on ferritin technology, and addressing the process of converting waste into chemicals. CG