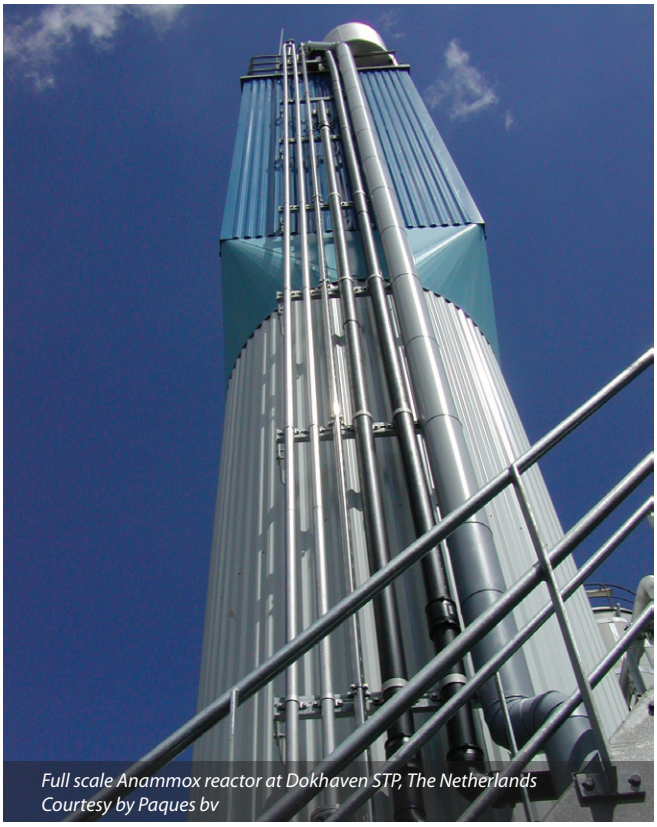
One-Step ANAMMOX Process

a sustainable way to remove ammoniacal nitrogen

by Willie Driessen and Gauke Reitsma

There is an increasing interest in anaerobic digestion of sewage sludge, organic waste and industrial effluents. Dewatering liquors and effluents derived from anaerobic digestion processes contain significant amounts of nutrients. Although small in volume, sludge liquors from wastewater treatment works can represent up to 30% of the nitrogen and phosphorous load on the overall treatment works. Dedicated separate treatment of these sludge liquors by the so-called One-Step Anammox process and the Phospaq (struvite reactor), reduces energy consumption and allows nutrient recovery. These processes can also effectively be applied on digestates from organics waste digesters and nutrient rich effluent streams from industry; for example, the fermentation and food industries. This article describes the One-Step Anammox process and its applications and installations.



Full scale Anammox reactor at Dokhaven STP, The Netherlands
Courtesy by Paques bv

Granular biomass from a One-Step-Anammox reactor
Courtesy of Paques bv

In comparison to conventional nitrification-denitrification for the conversion of ammoniacal nitrogen, the One-Step Anammox process does not require any organic carbon source, and uses a minimum amount of energy. As a result, the addition of an external carbon source (or bypass of effluents) providing COD, as is required for conventional denitrification, is not needed. Up to 60% savings on aeration energy can be achieved when using the Anammox process.

The process

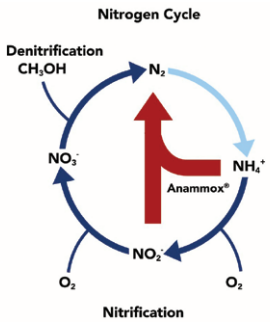
Developed in partnership by the University of Delft and Paques bv from The Netherlands, the Anammox (ANaerobic AMMonium OXidation) conversion is an elegant short cut in the natural nitrogen cycle. The Anammox process is characterised by removing ammoniacal nitrogen over nitrite rather than nitrate, requiring less oxygen. In the One-Step-Anammox reactor, partial nitritation (formation of nitrite) and the Anammox reaction occur simultaneously. The simplified overall conversion that takes place within the reactor can be described as follows:

$$NH_4^+ + 0.85\ O_2 \longrightarrow 0.45\ N_2 + 0.1\ NO_3^-$$

The biomass generated in the One-Step Anammox process is of a granular nature, and has a typical red color caused by specific enzymes. The Anammox reactor is equipped with a patented biomass separator on top of the reactor, which ensures effective biomass retention. The reactor is continuously aerated, and can be controlled by measurement of nitrite and ammonium.

Applications

The Anammox process is, in principle, suitable for treatment of anaerobic digestion liquors which are highly loaded with



The Anammox conversion (red arrow) as part of the overall natural nitrogen cycle (Jetten, et al) - Courtesy of Paques bv

Containerized One-Step-Anammox pilot plant on-site Courtesy of Paques bv

Full scale 1,200kgN/d Anammox installation with a Phospaq struvite reactor for phosphorous recovery at Olburgen - Courtesy Paques bv

ammoniacal nitrogen, including:

- Dewatering liquors from sewage sludge digestion.
- Dewatering liquors from (Thermal) Hydrolysis Plants.
- Organic waste digestate liquors.
- Anaerobic effluents from industry.

Returning untreated sludge dewatering liquors directly into the WwTW will affect the overall capacity of the works, as it will require large sums of aeration capacity, and when a WwTW's capacity is limited, this would require additional aeration basin volumes.

The application of (thermal) hydrolysis processes, prior to anaerobic digestion, will increase the level of ammoniacal nitrogen in the sludge dewatering liquors, and therefore increasing the nitrogen load to the overall WwTW.

Dedicated separate treatment of sludge dewatering liquors by the Anammox process, can overcome these issues, saving power and space. If existing basins can be utilised, the footprint can be minimised, and asset utilisation is maximized.

Pilot testing

In order to check the sustainability and performance of the One-Step-Anammox process, test work can be conducted by on-site mobile, transportable pilot plants. Successful on-site test work has been conducted at one of Severn Trent Water's sewage treatment works, to verify applicable loading rates and efficiency. The results from trials have been very promising, to the extent that a full scale application is under consideration.

Full scale installations

Full scale One Step-Anammox reactors are generally 8-10m tall and can be built as rectangular (concrete) or round structures (concrete or steel), and to date, there are 10 full scale Anammox projects using granulated biomass. The first plant was built at the Dokhaven STP in Rotterdam, The Netherlands. In addition to treating sewage sludge dewatering liquors, Anammox plants have also been constructed to treat anaerobic effluents from fermentation and food industry. Two examples of plants utilizing the Anammox process are:

Olburgen WwTW – The Netherlands

At the Olburgen WwTW, a blend of sludge dewatering liquors from the STP and effluent from a nearby food factory is treated by Anammox. As the process does not require COD, no bypass of industrial wastewater is needed allowing valorization of the complete effluent generating the maximum possible amounts of biogas. The Olburgen Anammox reactor has a design capacity of 1,200kgN/d. Long term operation has shown the plant achieves on average > 90% of ammoniacal nitrogen removal *(Ref: Abma, et al)*.

The One-Step Anammox process is preceded by a Phospaq struvite reactor to recover phosphorous in the form of magnesium-ammonium-phosphate (MAP). The struvite is used as a slow release fertilizer *(Driessen, et al)*.

Tongliao Meihua industry - China

At the Tongliao Meihua industrial complex, anaerobically treated effluent with ammoniacal nitrogen concentrations of over 600mg/l is treated in a One-Step Anammox reactor. The plant has a design capacity of 11,000kgN/d, treating effluent from monosodium glutamate production. A second One-Step Anammox reactor with a capacity of 9000kgN/d is currently under construction.

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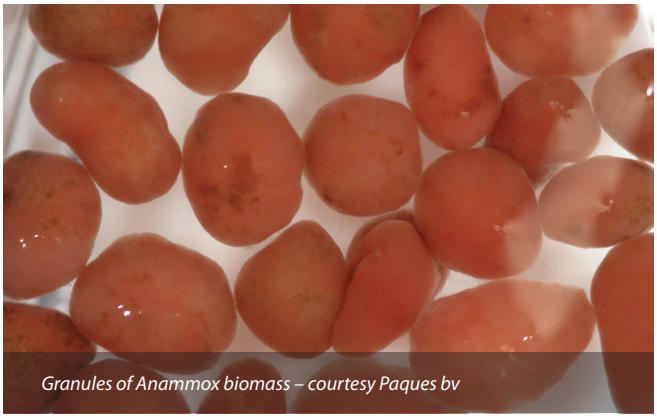
Granules of Anammox biomass – courtesy Paques bv


Full scale 11,000kgN/d One-Step Anammox installation at the Tongliao Meihua company in China - Courtesy Paques bv

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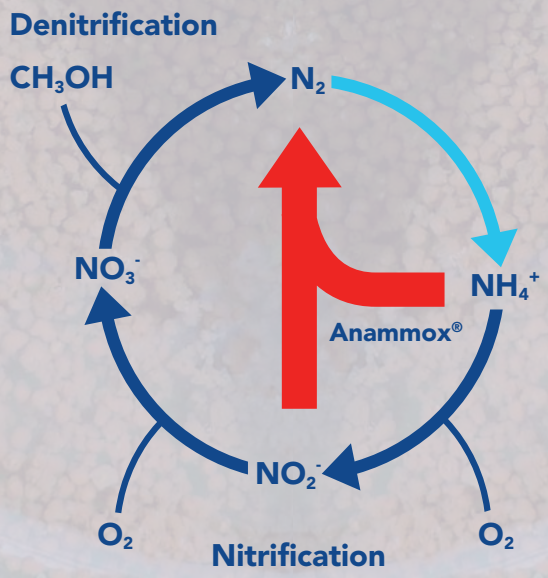

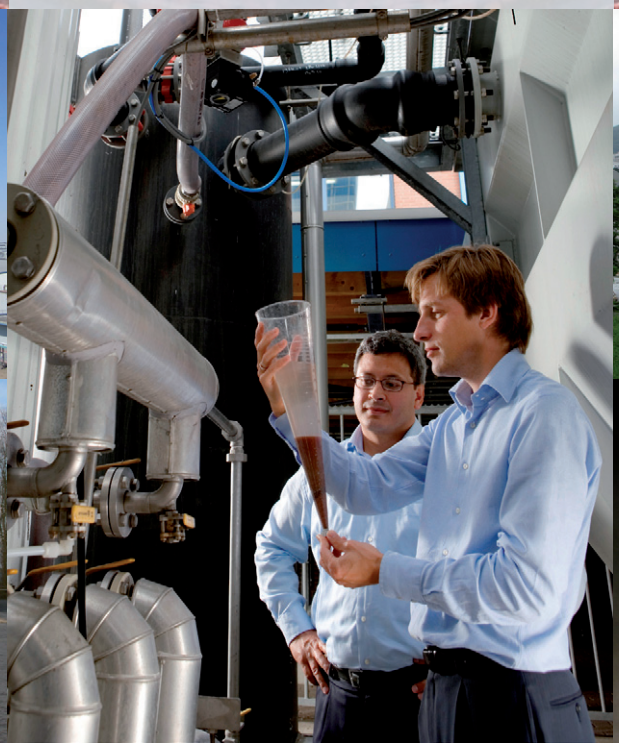

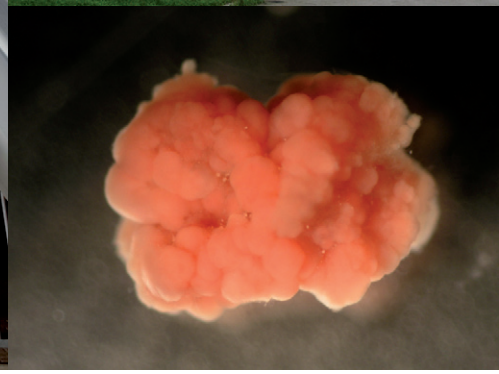

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