Removal and recovery of nitrogen with the Aqua2®N-process demonstrated

The EU LIFE-financed project LIFE RE-Fertilize has demonstrated the Aqua2N-process in an operational environment. The process has been proven to remove and recover 95 per cent of the ammonium nitrogen in sludge liquor at wastewater treatment plants, increasing the capacity of the plants and significantly reducing their nitrous oxide emissions.

The challenge with nitrogen

Nitrogen is essential to life and is among the nutrients consumed in the largest quantities by all agricultural crops. However, today’s linear flow of nutrients (nitrogen, phosphorus and potassium), from fertilizer manufacturing to wastewater treatment plant (WWTP) via food production and human consumption, is not sustainable.

Humans and animals excrete a significant fraction of the nutrients contained in the food they ingest. Alongside other agricultural sources, these nutrients find their way back into the environment primarily as municipal wastewater effluents. Anthropogenic loading of nutrients is the main cause of the eutrophication of receiving water bodies. Therefore, WWTPs are needed for treating these nutrient-rich effluents.

Both the manufacturing of mineral nitrogen fertilizers and the biological methods for wastewater treatment consume large amounts of energy and chemicals. They also lead to ammonia and greenhouse gas emissions, causing acidification and eutrophication.

The nitrogen treatment process in, for example, WWTPs requires massive aeration to oxidize all ammonium to nitrate. An expensive carbon source such as methanol is usually needed to obtain an efficient conversion of nitrate to nitrogen gas by denitrification. The biological process is both costly and sensitive to disruption. It also entails emissions of nitrous oxide, a powerful greenhouse gas which has an impact on the climate that is 300 times greater than carbon dioxide. Nitrous oxide emissions are, in fact, the largest climate impact for a WWTP.

Traditional methods of purifying nitrogen usually release it back into the air instead of recycling it. Ammonia, the basic compound for the production of nitrogen fertilizers, is by far the largest contributor to the carbon footprint in cereal production. The ammonia production industry for manufacturing mineral fertilizers relies heavily on natural gas as a non-renewable precursor for hydrogen and energy. Recycling the ammonia removed from wastewater streams can reduce the need to produce virgin ammonia.

What we want to achieve

The LIFE RE-Fertilize project tackles the problem by removing and recovering nitrogen from liquid waste streams, such as sludge liquor from digested sludge in WWTPs and leachate water from landfills. For WWTPs having digestion of their sewage sludge, the sludge liquor flow is only 0.5–1.5 per cent of the total flow in the WWTP, but it stands for 15–30 per cent of the nitrogen load. Therefore, it is an important flow on which to apply nitrogen removal.

Removing the nitrogen from the sludge liquor in the WWTP with Aqua2N results in the following positive effects:

• reduced nitrogen load with >15 per cent in the main flow, making it possible to either
  - connect more people to the existing WWTP, since nitrogen is often the limiting factor
  - reduce the nitrogen levels in the effluent from the WWTP
  - reduce the need for nitrogen removal (saving energy and carbon source additive) in the main flow
• reduced nitrous oxide emission with >15 per cent for the WWTP
• recovery of >15 per cent of the nitrogen in a supply, e.g. agriculture as fertilizer.

LIFE RE-Fertilize project objectives

The project’s overall goal was to demonstrate a new, innovative removal and recovery process for ammonium nitrogen, which produces a nitrogen product suitable for use in society, e.g. as fertilizer.
A demonstration plant was built to validate the process. The plant has been running at leachate water at Ragn-Sells’ waste handling plant Högbytorp outside Stockholm, Sweden, and at BIOFOS’ WWTP Lynetten in Copenhagen, Denmark. The demonstration plant has a capacity of 4 m³ incoming water per hour and is built to run in three different modes on two different applications. The leachate application and sludge liquor application differ both in ammonium nitrogen (NH₄-N) concentration and composition, with sludge liquor having approximately four times higher NH₄-N concentration than leachate. The leachate is a more complicated water to handle, which was known before starting the project.

The project contained the following sub-objectives:
- validate the recycling process by upscaling from lab scale to pilot
- validate the market potential for the process and the product produced
- present and disseminate the project’s results to problem owners in Europe.

Achievements and results

Process validation and demonstration

The Aqua2N-process is a two-step process. In the first step, the ammonium nitrogen is caught with a precipitation chemical. The precipitated nitrogen enters after separation from the treated water the conversion step. In the conversion step, acid is added to regenerate the precipitant, which is led back to the catchment step, and to produce the ammonium salt. The process is patented by EasyMining. The LIFE RE-Fertilize project used sulphuric acid; hence ammonium sulphate was produced. It is for this acid and ammonium salt that the process has been validated.

"The precipitated nitrogen enters, after separation from the treated water, the conversion step."
With the results and learnings from the demonstration, a conceptual design for a plant with a capacity of 10 m³/h has been established. The conceptual design includes a:

- proof of concept
- design basis for different engineering disciplines
- process flow diagram
- mass- and energy balance
- cost estimate -30/+50 per cent.

Process validation achievements:
- Aqua2N-process is demonstrated in operational environment (TRL 7)
- 370 m³ leachate treated
- 3/3 ammonium liquor treated
- Conceptual design for the process established

Product validation

The first step within the project was to decide what product to produce. Ammonium sulphate was seen to be the most attractive option when considering the market for the product, the production process and the cost aspect. The product from the process is liquid ammonium sulphate.

"From measuring nitrous oxide emissions over some years, we have learnt that the nitrous oxide emissions in the main flow increases when nitrogen load peaks and the bacteria get overloaded. Removing the nitrogen in the sludge liquor should therefore reduce the nitrous oxide emissions to a larger extent than the reduction of the nitrogen load. For Lynetten, the nitrogen load from the sludge liquor is 15 per cent, if removing that we would reduce the nitrous oxide emissions with >15 per cent."

Dines Thornberg, Development manager, BIOFOS.

"We see great potential in recovered ammonium sulphate from the Aqua2N-process and will continue to cooperate with EasyMining regarding this product after finalisation of the LIFE RE-Fertilize-project."

Pär-Johan Löf, R&D Manager Agri at Lantmännen.

"The international exchange is very important and the Aqua2N-process is interesting around the world - in the OECD countries there are both treatment plants and increasing treatment requirements."

Anders Finnson, Senior Environmental Advisor at Svenskt Vatten and member of the reference group for the LIFE RE-Fertilize-project.

Beginning LIFE RE-Fertilize, the product from both applications was hindered by the FPR due to origin. With the new FPR entering into force in summer 2022, the product from the sludge liquor in WWTPs is approved but still not for the leachate application. This is one of the reasons why the roll-out of the Aqua2N-process will focus on the sludge liquor application to start with.

"The requirement for nitrogen removal differs between regions. Markets in focus at the beginning of the roll-out will be the Nordics, Benelux, Germany, Austria, Switzerland and Great Britain. The size of the WWTPs differs, which is why it is important to be able to scale the process up and down."

There is also a market for the Aqua2N-process outside Europe. Even though the focus currently is on the European market, the project and the process have been presented to other markets, e.g. at a conference held by the Asian Development Bank.

An important task in the project was to validate that the process is efficient and competitive. The conceptual design, including the results and learnings from the demonstration runs, has proven that the Aqua2N-process is competitive and efficient compared to nitrogen removal and nitrogen production today.

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“If we are serious about creating a sustainable society, we have to start using the resources we already have produced over and over again. The Aqua2N-process is one solution for nitrogen recovery, which also has a positive effect on the climate since reducing nitrous oxide emissions significantly.”

Anna Lundbom, Project leader LIFE RE-Fertilize at EasyMining

Way forward

The Aqua2N-process has been demonstrated in an operational environment in the LIFE RE-Fertilize project. However, optimisation of the process is possible. In the first half of 2023, the focus will be on optimising the process and evaluating the possibility of splitting the two steps, the catchment step and the conversion step, into two separate plants.

At the same time, the commercialisation of the Aqua2N-process will start, presenting the results to potential customers who showed interest in the process during the LIFE RE-Fertilize duration. The ambition is to have the first commercial contract for an Aqua2N-plant in late 2023. Work on commercialising the ammonium sulphate product will also continue.

As highlighted in the market validation, the market potential for the Aqua2N-process is huge, and the interest from the market is large. By rolling out the Aqua2N-process, significant value can be achieved by the wastewater treatment plant in increasing capacity, reducing nitrous oxide emissions and offering agriculture a recycled ammonium sulphate. The roll-out of this process will be positive both for the climate and for moving towards a sustainable society.

Values added by the Aqua2N-process

Even though the product is of good quality, it was not allowed in the European FPR. Advocacy work has been conducted in Brussels by meeting politicians and experts, raising the question at COP conferences and a number of events, e.g. within Ragn-Sells’ cooperation with the WeDon’tHaveTime organisation. Since summer 2022, the product from the wastewater treatment application has been approved in the new fertilizer regulation!

Partners

EasyMining is a Swedish innovation company within the Ragn-Sells Group. The company develops patented processes for recovering valuable materials from waste flows. It offers a range of solutions that help solve some of today’s most critical problems relating to the recovery of nutrients.

BIOFOS is Denmark’s largest wastewater treatment utility, treating wastewater from 1.4 million population equivalents in three plants around Copenhagen. Lantmännen is an agricultural cooperative and Northern Europe’s leader in agriculture, machinery, bioenergy and food products. Ragn-Sells is a private company collecting and treating waste in four countries.

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