NPHarvest – A new energy efficient nitrogen recovery technology

J. Uzkurt Kaljunen*, A. Mikola*, I. Konola*, M. Valtari*, R. Sah*, S. Pradhan*, R. Vahala* and A-M. Aurola**

* Aalto University Water Laboratory, PO Box 15200 FI-00076 AALTO FINLAND
Contact: anna.mikola@aalto.fi, juho.kaljunen@aalto.fi
**Nordkalk Ltd., Tytyrinkatu 7, 08100 Lohja, Finland

INTRODUCTION

Phosphorus and nitrogen are crucial elements for supporting the human population through the use of fertilizers. Even though the motives for their recovery and reuse are different, in the interest of energy and resource efficiency they are equally important. Avoiding environmental problems similar to the climate change or politically unstable situations such as the control of global phosphorus reserves are few examples of nutrient-related challenges we are facing for the next few hundred years. Developing the technology to recover nutrients efficiently as valuable products is important for this purpose.

The objective for this study was to develop a new innovative process for recovery of nitrogen and phosphorus. The innovations are using ammonia specific hydrophobic membranes for chemisorption of ammonia originating from liquid waste streams while precipitating phosphorus with a calcium product to enhance the precipitation process and quality of the final product.

Several research groups have studied recovering nitrogen with membranes (Boehler et al., 2014). The method is successful yet the method has not proven to be economically feasible due to the high level of expensive pre-treatment for removal of solids. We also tested a commercial membrane contactor but we were dissatisfied with its performance. The membrane contactor in this study was designed to withstand higher levels of water quality variance and solids.

METHODS

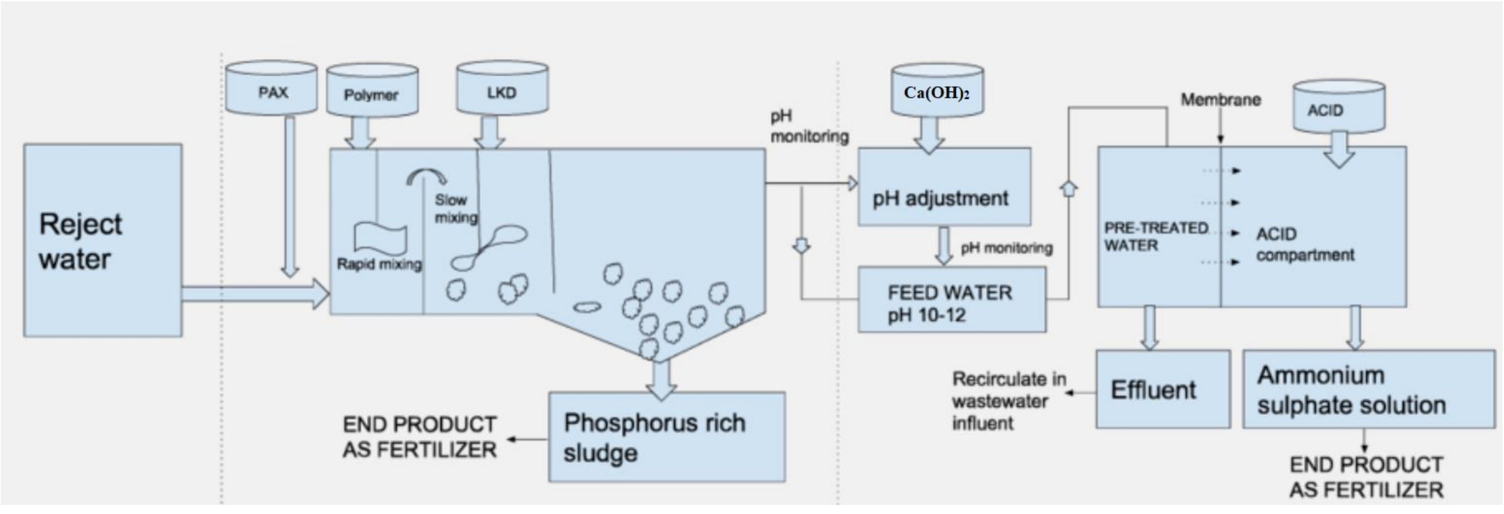

Figure 2: NPHarvest process schematic.

Figure 2 describes the entire process scheme to treat reject water from a mesophilic digester:

- PAX, polymer and Lime Kiln Dust (LKD) are added to reject water flow
- LKD is lime production side stream, mainly calcium carbonate
- After precipitation of solids and phosphorus, pH is increased with calcium hydroxide
- Ammonia is recovered in the reactor with membrane stripping and captured in sulphuric acid
- Our reactor is designed to withstand higher concentration of solids than conventional membrane module.
- **Figure 3** shows a membrane module that is underwater in the well-mixed reactor.

Figure 3: NPHarvest membrane module.

RESULTS

Figure 5 details the significant factors of a test run:

- Recovery efficiency was 80 %.
- 5,6 g/l sulphuric acid concentration was reached in 15 hours.
- Suspended solid concentration was between 100 and 200 mg/l.

Process costs were estimated:

- Pretreatment cost: **1** €/m$^{3.}$
- Membrane process chemical cost: **3** €/m$^{3.}$
  - With our case source water, this would translate to **5** €/kg-N$_{recovered.}$
- Total costs for the process are roughly **4** €/m$^3_{reject\ water.}$

Table 1: Pre-treatment cost estimation

Cost estimation for pre-treating one cubic meter of reject water			
Chemical	Amount (g/m^3)	Price (€/tn)	Cost (€/m^3)
PAX XL100	1300	250	0,32
Super floc A-120	1,30	2500	0,01
LKD	3500	30	0,1
Sum			0,43
Estimation for energy consumption			
Electricity consumption during test runs			4340 Wh
Electricity price in Finland			0,15 €/KWh
Electricity cost			0,65 €
Overall cost per m^3			**1,08 €**

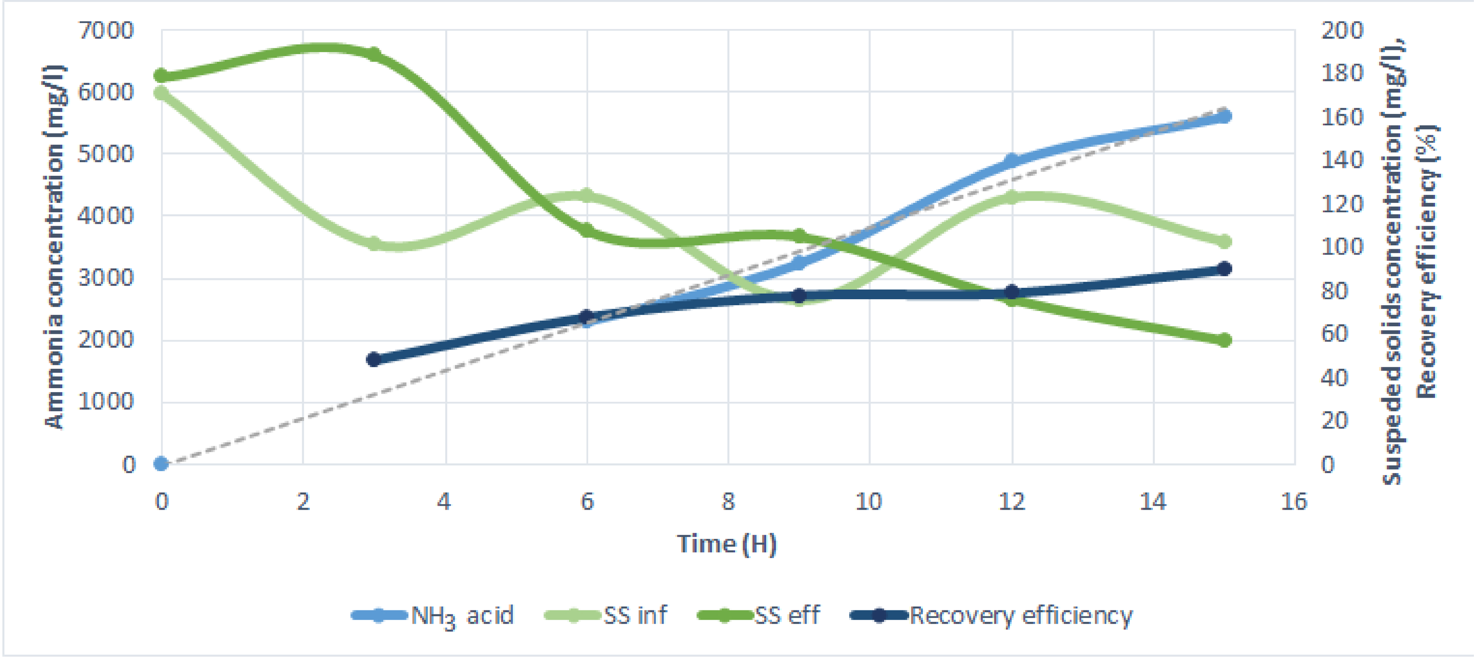

Figure 5: A 15-hour test run with our membrane reactor.

DISCUSSION

The motive for nitrogen recovery lies in energy efficiency. **Figure 1** describes simplified nitrogen cycle in anthropological environment.

- Energy is consumed to transfer nitrogen into and out of its reactive forms
- A significant proportion of global energy is produced with fossil fuels.
- Recovering nitrogen becomes a way to combat the climate change.

Suspended solids are a problem for membrane processes.

- The feasibility of ammonia membrane stripping from wastewater sources has been impaired by the need to pre-treat the waste stream by microfiltration.
- NPHarvest membrane reactor and the modules are designed to withstand a higher concentration of suspended solids.
- We want to prove that ammonia membrane process can be feasible if designed well.

We designed a mixed reactor with membrane modules underwater.

- Having a high recovery efficiency is counter productive:
  - Lower ammonia concentration in the reactor leads to lower ammonia flux over the membrane.
  - It is important to find an optimal ammonia flux from economic perspective rather than maximizing the ammonia removal efficiency.

The final products from our process are phosphorus rich solid material and ammonium sulphate solution.

- They can be used as fertilizer. The economic feasibility of the process is further increased by the value of the end products.
- Their value is strongly dependent on local industrial environment and legislation.
- We are currently testing the products' quality with growth tests.

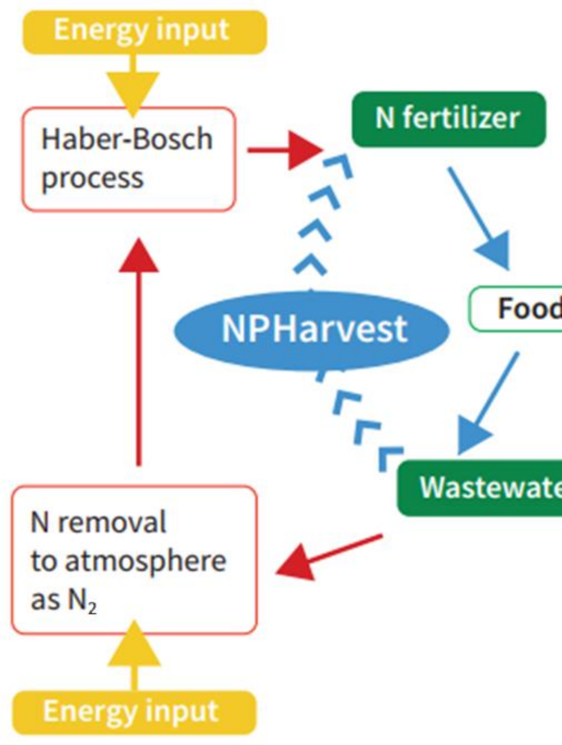

Figure 1: NPHarvest 'shortcut' for nitrogen.

Figure 4: Piloting area in Viikinmäki WWTP.

Tests have been conducted so far only in with a wastewater digester reject water. During this year we will conduct tests with a biogas plant's reject water and separately collected human urine to test the equipment in different environments and sources. We are greatly interested in the long term durability of our membranes as fouling or wetting are potential threats to the process efficiency but have not been observed in our tests so far.

CONCLUSIONS

Ammonia stripping with hydrophobic gas specific membranes was scaled up to pilot scale. Ammonia was recovered with 80 % efficiency and suspended solids concentration of 100-200 mg/l did not disturb the process.

Process was estimated to be feasible when compared to other reject water treatments.

More research and tests are needed to upscale and commercialize the process. It is vital to understand the membranes' lifespan to draw accurate estimations for the process feasibility from economic point of view.

Boehler, M., Heisele, A., Seyfried, A., Grömping, M. and Siegrist, H. (2014). (NH4)2SO4 recovery from liquid side streams. Environmental Science and Pollution Research, 22(10), pp. 7295-7305

Thank you to the laboratory personel: Antti Louhio, Aino Peltola and Heikki Särkkä. Without them the project would not exist.