Factsheet:

Ammonium sulphate production via membrane stripping in a hollow fibre membrane contactor

AUTHORS: A. Kleyböcker, J. Kim, J. Hofman, A. Nättorp

DATE: 08/12/2020

VERSION: v4

Disclaimer

This project has received funding from the European Union's Horizon 2020 research and

Ammonium sulphate production via membrane stripping in a hollow fibre membrane contactor

Unique selling points:

- ✓ High ammonia recovery rates related to the influent to the recovery unit of up to 99%
- ✓ Market-ready product: ammonium sulphate solution as liquid fertilizer

Description of the technology

Ammonia is a key component for fertiliser production, while ammonia and related compounds in wastewater streams have adverse effects on the receiving water such as algal blooms and toxicity problems. The **hollow fibre membrane contactor (HFMC)** technology is promising for the recovery and removal of ammonia via stripping from highly-concentrated wastewater flows.

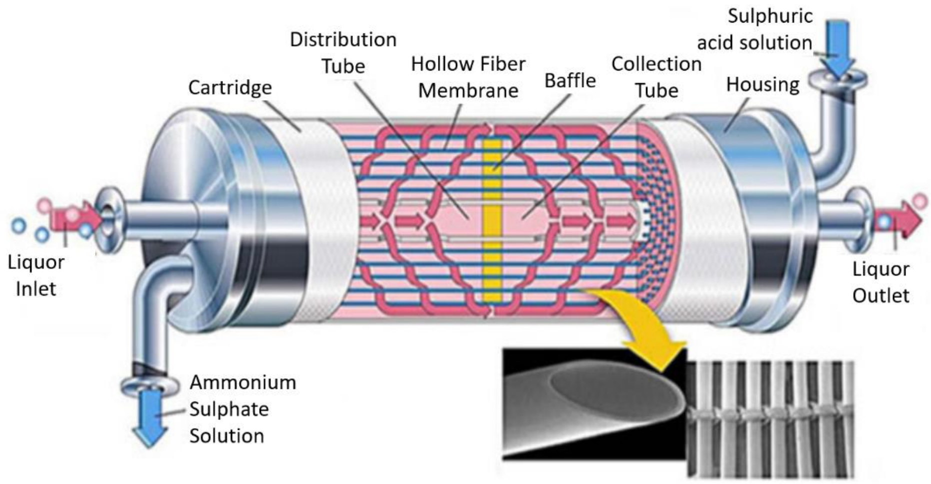
The HFMC is usually implemented at WWTPs for 100 000 population equivalents and more for a side stream treatment of sludge liquor after anaerobic digestion. Before ammonia membrane stripping can be applied, several pre-treatment steps have to be conducted in order to remove particulate matter and residual organics from the sludge liquor and to reach the required elevated pH and temperature (see **Requirements of the technology**). At higher pH and temperature, ammoniacal nitrogen is mainly present as gaseous ammonia (NH_3).

The pre-treated liquor flows through the HFMC containing hollow fibre membranes (see **Flow scheme of the technology**). Those membranes are hydrophobic and gas permeable with a pore size of between 10^{-3} and 1 µm. The HFMC has two channels: inside of the hollow fibres (lumen side) and outside of the hollow fibres (shell side). Due to differences in the ammonia partial pressure across the membrane during operation, the ammonia gas is released from the liquor at the shell side and diffuses to the lumen side. In the lumen side, it reacts with sulphuric acid to liquid ammonium sulphate.

Ammonium sulphate solution is a typical nitrogen fertiliser which can be directly used by the farmers. Typical N concentrations in the product of membrane stripping units range from 19 to 60 kg/m³ of nitrogen (Böhler et al. 2018). Due to the defined composition of the product, the relative fertilizer efficiency is similar to commercially available ammonium sulphate (Szymańska et al. 2019).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Flow scheme of the technology



From: http://powerstep.arctik.tech/nitrogen-removal.php#gal-tech-membranestrip-2

Pictures of the technology

Synergetic effects and motivation for the implementation of the technology

- ✓ **Reduction of the nitrogen return load of a WWTP**

High loads of nitrogen in sludge liquor put an additional burden on the WWTP when returned to the plant inlet ("return load"). Membrane stripping of ammonia from sludge liquor can help to reduce this return load significantly, saving on aeration energy and treatment capacity of the mainline WWTP.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

✓ **Production of a contaminant-free fertilizer**

The hollow fibre membrane contactor allows for the production of ammonium sulphate with a very high quality, resulting in a contaminant-free fertilizer. The gas-permeable membrane acts as a physical barrier for any contaminant present in the liquor.

✓ **Reduction of formation of N_2O in the biological step**

Reducing the nitrogen return load to the mainline will stabilize the nitrogen removal and helps to prevent overloads of the treatment capacity. As high nitrogen loads and high fluctuations often lead to higher emissions of N_2O from the activated sludge process, membrane stripping will also lead to a decrease in emissions of this potent greenhouse gas.

Requirements of the technology

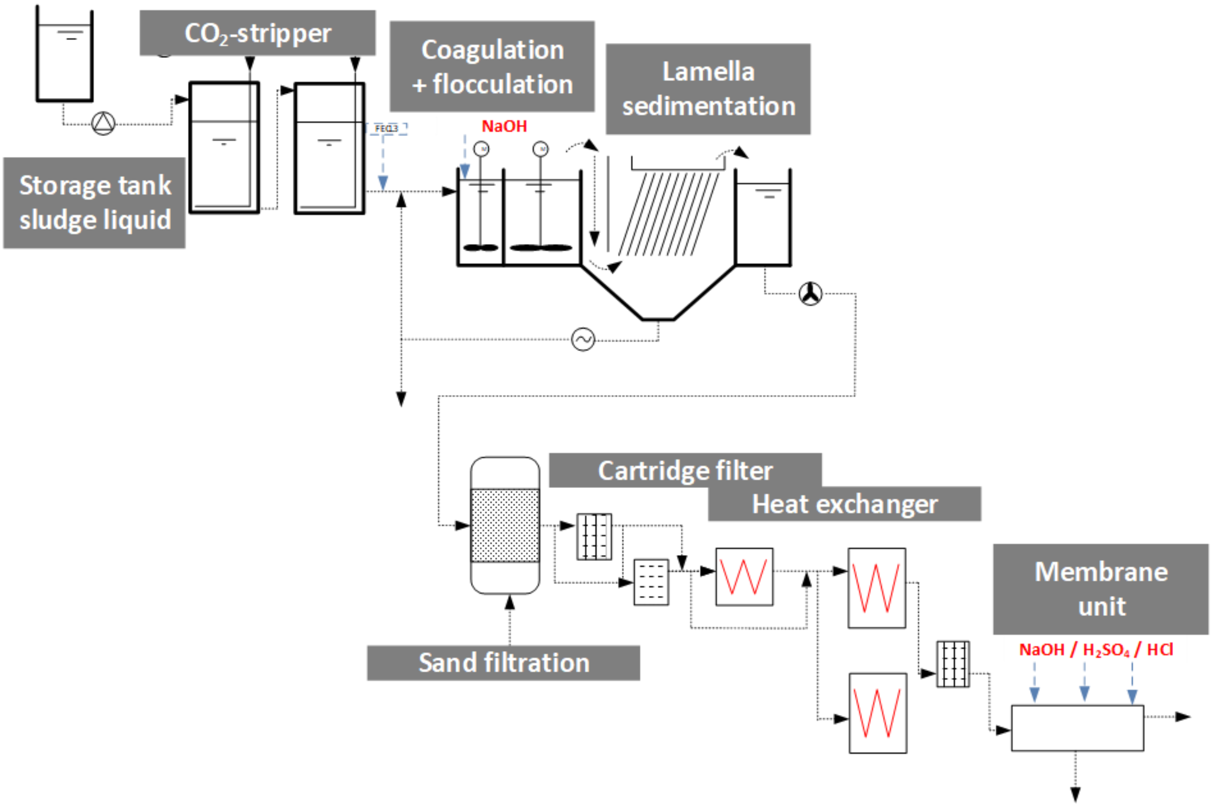
In order to reach high ammonia yields, the fraction of ammonium in relation to the total nitrogen content should be as high as possible. **Anaerobic digestion** combined with a pre-treatment of sludge such as a **thermal hydrolysis process** can help to improve degradation of organic compounds, resulting in an increase in ammonium concentrations and thus a higher recovery potential.

Several pre-treatments steps for the total removal of solids and particles are an obligatory prerequisite for the application of ammonia stripping membranes, as the membrane tolerance to particles in the influent is very low. Furthermore, temperature and pH need to be increased prior to the stripping process to shift the chemical equilibrium from ammonium (NH_4) to free ammonia (NH_3). Thus, in order to increase the pH with minimum chemical demand, CO_2 is stripped out from the liquor in a first step (see Flow scheme of the pre-treatment technologies). Depending on the chemical composition of the liquor, CO_2 stripping can increase the pH up to 0.4 units, and the buffering capacity of CO_2 is also removed (Böhler et al. 2018). The pH is then further elevated up to a pH of 10 via dosing of sodium hydroxide in order to maximize the free ammonia fraction. To prevent fouling and clogging of the membranes, the process is followed by a flocculation and sedimentation step, a sand filtration and finally a cartridge filtration step. Finally, the temperature is increased with heat exchangers. Besides the efficient design of the multi-stage pre-treatment process for particle removal, a major challenge is to find the optimum operating point with a maximised nitrogen recovery at a reasonable demand of chemicals and/or heat. Depending on the type of membrane module, the temperature of the influent liquor should be limited to prevent thermal decomposition of membrane potting. Therefore, Böhler et al. 2018 usually operated the process at 40 °C. However, according to the manufacturer a maximum temperature of 50 °C is still possible, but should not be exceeded (Membrana 2021).

Parameter	Units	Min	Max	Reference
NH_4 (influent)	mg/L	**700**	**>4000**	**Huang et al. 2020, Böhler et al. 2018, NextGen D1.5 (in prep.)**
TSS	mg/L	**0**	**1000**	**NextGen D1.5 (in prep.)**
pH	-	**9**	**10**	**Böhler et al. 2018**
Temperature	°C	**14**	**50**	**Böhler et al. 2018, Membrana 2021**
Velocity of feed streams	m/s	**0.3**	**2.0**	**NextGen, D1.5 (in prep.)**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Flow scheme of the pre-treatment technologies



Key performance indicators

Parameter	Units	Min	Max	Reference
N-recovery rate (related to the influent to the nitrogen recovery unit)	%	**70**	**99**	Böhler et al. 2018, Ashrafizadeh and Khorasani 2010
N-recovery rate (related to the influent of the WWTP)	%	**tbd**	**tbd**	

Links to related topics and similar reference projects

Ammonium sulphate production processes	Medium	Reference
with membrane stripping (HFMC)	Liquor	Case study "Altenrhein" (NextGen); Case study "Spernal" (NextGen)
with air stripping	Liquor	Case study "Braunschweig" (NextGen)
with vacuum degasification	Sludge	Circular Agronomics: D3.1, Chapter 3 (Kleyböcker et al. 2020)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N°776541

Literature

Ashrafizadeh, S., Khorasani, Z. (2010). Ammonia removal from aqueous solutions using hollow-fiber membrane contactors. Chemical Engineering Journal, 162, 1, 242-249. https://doi.org/10.1016/j.cej.2010.05.036

Böhler, M., Hernandez, A., Fleiner, J., Gruber, W., Seyfried, A. (2018). D4.3 Operation and optimization of membrane ammonia stripping. Powerstep, Deliverable 4.3, Grant Agreement Number 641661, 31 p. http://powerstep.eu/system/files/generated/files/resource/d-4-3-operation-and-optimization-of-membrane-ammonia-stripping_0.pdf

Huang, X., Guida, S., Jefferson, S., Soares, A. Economic evaluation of ion-exchange processes for nutrient removal and recovery from municipal wastewater. Clean water, 3, 7, 1-7. https://doi.org/10.1038/s41545-020-0054-x

Kleyböcker, A., Kraus, F., Moermann, W., Pudova, N., Holba, M., Dünnebeil, A. (2020). Efficient carbon, nitrogen and phosphorus cycling in the European agri-food system and related up- und down-stream processes to mitigate emissions, Circular Agronomics, Deliverable 3.1, Grant Agreement Number 773649. https://www.circularagronomics.eu/wp-content/uploads/CA-D3.1-E-0820-Classification-streams.pdf

NextGen D1.5 New approaches and best practices for closing materials cycle in the water sector (in prep.), NextGen, Deliverable D1.5, Grant Agreement Number 776541.

Membrana GmbH (2021): 3M Liqui-Cel, https://multimedia.3m.com/mws/media/1412619O/3m-liqui-cel-membrane-contactors-capturing-ammonia-in-flue-gas.pdf

Szymańska, M., Sosulski, T., Szara, E., Wąs, A., Sulewski, P., van Pruissen, G., Cornelissen, R. (2019). Ammonium sulphate from a bio-refinery system as a fertilizer - agronomic and economic effectiveness on the farm scale. Energies, 12, 4721, 1-15. https://doi.org/10.3390/en12244721

Outlook

Case study specific information will be provided, when the results of the other work packages are available:

- **Lessons learned from the case study**
- **Outcome of the assessments**
- **Legal and regulatory information concerning the whole value chain concerning the technology**
- **Business opportunities**

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement N°776541