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Membrane distillation (MD) of digestate reject (process) water for performance optimization of a biogas plant in Sweden

INTRODUCTION

Recovery and reuse of resources from waste and wastewater streams has been identified as key to achieving the main objectives and essential preconditions for sustainable development. The reject water from an anaerobic co-digestion (AD) process typically contains high concentrations of dissolved ammonium nitrogen (NH_4-N), TS, phosphorus. The approach of recycling reject water back into the main flow line of the AD plant leads to gradual build-up of nutrients in the digester, which may cause process instability and inhibition of the AD process.

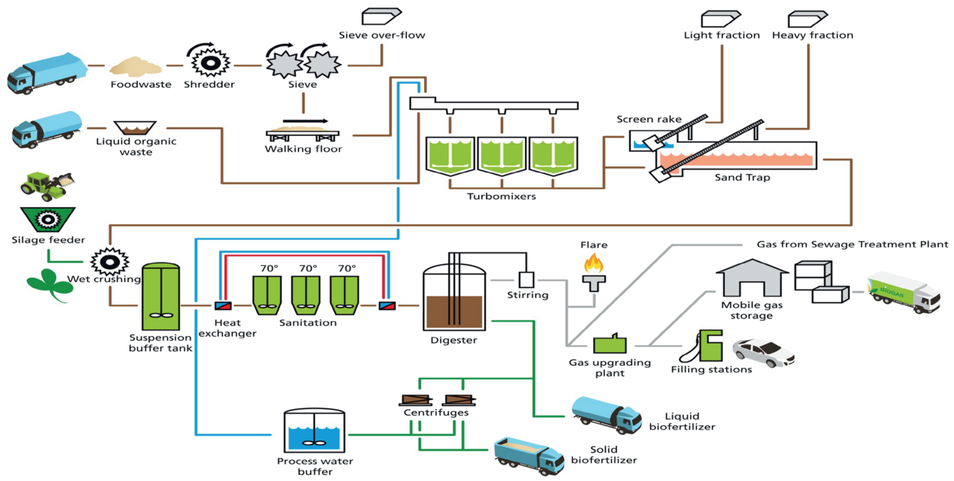
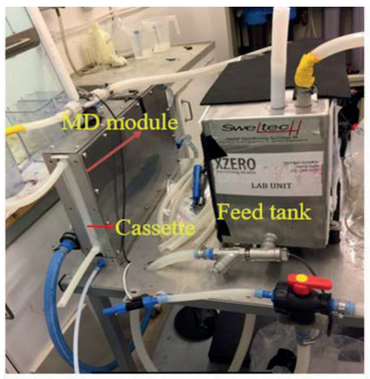


Fig. 1: Vafab Miljö Biogas Plant, Sweden.

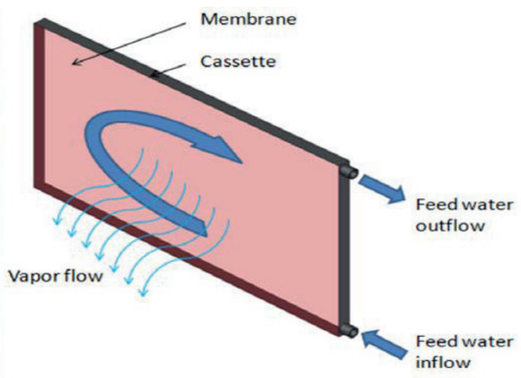
- Very complex characteristics of digestate reject water
- It is very difficult to handle, recover water, and concentrate the nutrients
- Need energy and cost effective technology with high separation efficiency.

Air-gap membrane distillation (AGMD) is a thermally driven separation/purification process where water vapor is transported through a hydrophobic microporous membrane by temperature gradient-induced vapor pressure. No comprehensive study has been done with reject water separation and AGMD. Research to date indicates that AGMD could be a promising technological option for handling digestate sludge reject water. But further research is required to firmly quantify actual performance of MD.

METHODOLOGY



(a) AGMD lab unit



(b) Membrane cassette [14]

Fig. 2: (a) AGMD lab unit facility and (b) Membrane cassette.

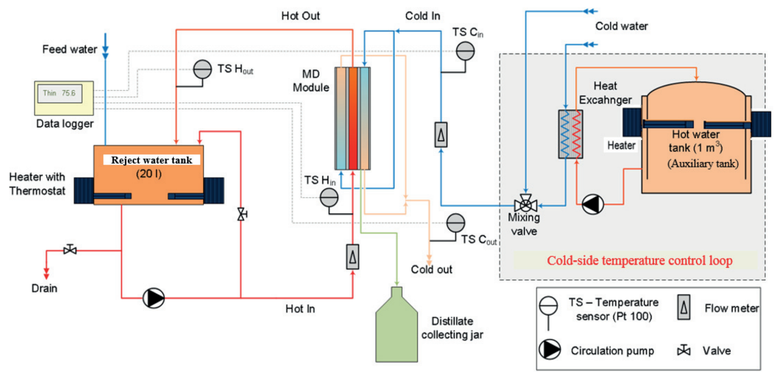


Fig. 3: Detailed schematic diagram of the laboratory-scale MD.

PROJECT OUTLINE

INPUT DATA
- Biogas plant data
- Reject water collection
- MD lab unit experimental setup

EVALUATING
- Characterization of digestate reject water
- Membrane distillation overall performance

FOCUS ON
- Separation efficiency
- Product water quality
- Permeate water production rate
- Thermal energy demand

METHODS
- Biogas plant survey
- Experimental tests
- Techno-economic analysis

RESULTS

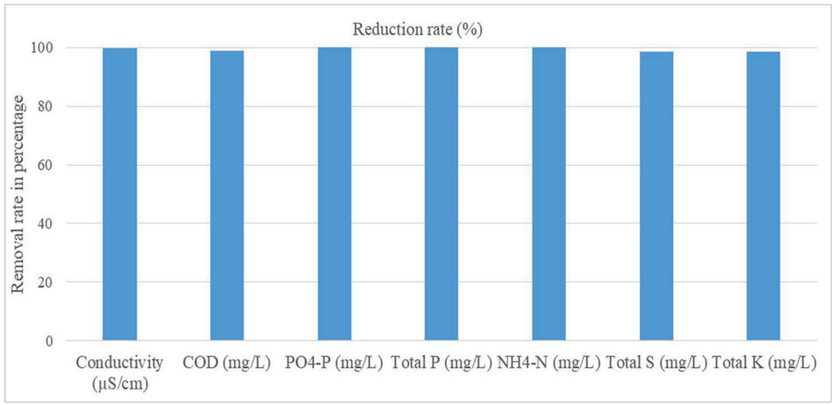


Fig. 4: Percentage removal rate of components in AGMD product water.

The results showed that the removal rate of COD, P, S, and K was > 98% and the removal rate of total ammonia nitrogen (TAN) reached nearly 100%.

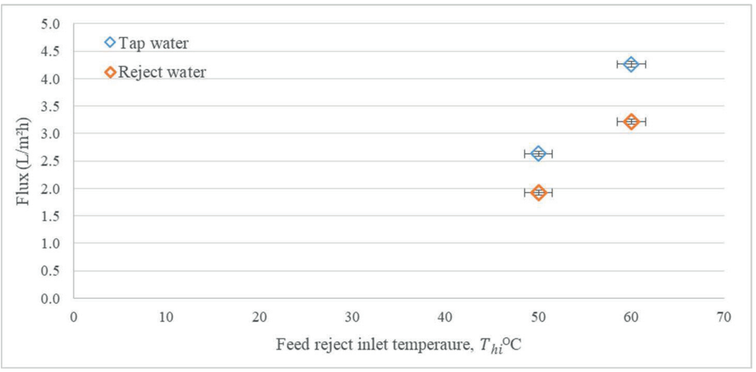


Fig. 5: AGMD product water (flux) as a function of feed inlet temperature.

The flux was 3.3 L/(m²h) at 60°C inlet temperature and showed a 28% decline by the end of the experiment. The corresponding yield of recovered permeate water was >56%.

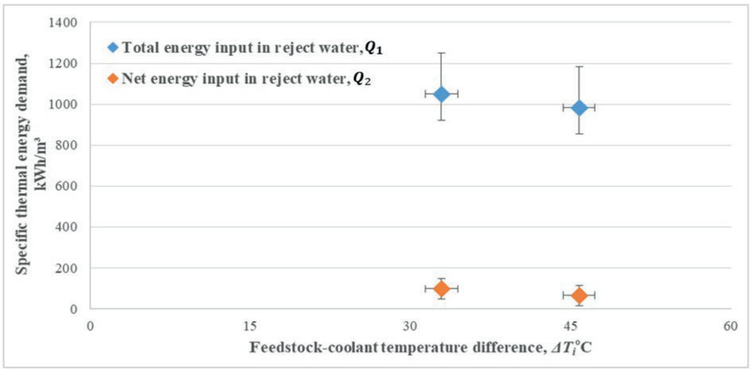


Fig. 6: Specific thermal energy consumption by the AGMD module.

Specific heat demand for AGMD ranged from 900 to 1300 kWh/m³ without heat recovery and was as low as 66-170 kWh/m³ with heat recovery.

CONCLUSIONS

- In this study, we assessed the potential of integrating AGMD in laboratory scale technology for digestate reject water to recover concentrated nutrients and product water suitable for recycling.
- The technology was evaluated in terms of separation efficiency, nutrient recovery, water flux dynamics, and specific thermal energy demand.
- The AGMD prototype tested here is capable of achieving excellent separation efficiency, as the product water samples showed a high purity level.
- After three consecutive days of AGMD operation, there was no leaking, wetting, or fouling of the membrane, but some permeate flux reduction was observed, as expected,

Reference: Khan EU and Nordberg Å, Membrane distillation process for concentration of nutrients and water recovery from digestate reject water, *Separation and Purification Technology*, 206 (2018) (90-98).