Full N recovery and potable water production from urine by membrane distillation

Sebastiaan Derese[1], Arne R.D. Verliefde[2]

[1]Ghent University (Faculty of Bioscience Engineering), Coupure Links 653, Ghent, Belgium

[2] Ghent University (Faculty of Bioscience Engineering), Coupure Links 653, Ghent, Belgium

+32 9 264 99 10, +32 9 264 62 42, sebastiaan.derese@ugent.be

Abstract

Domestic wastewater is the largest point-source of plant-essential nutrients to the environment, causing eutrophication in both fresh and saline water bodies. Urine, on its own, adds 70 % of the total N content, 80% of the total K content and 50% of the total P content to domestic wastewater in a mere 1% of its volume. To compete with the Haber-Bosch process, urine nitrogen recovery should aim for an energy demand lower than 90 MJ/kg N - which is where established N recovery technologies, such as struvite precipitation and stripping/absorption, fail to make the difference (Maurer et al., 2006).

Membrane distillation is a relatively new membrane technology using vapour pressure differences to transport volatile compounds through the air-filled pores of a hydrophobic membrane. Although generally used to recover water from highly saline solutions (e.g. reverse osmosis brine) (Lawson et al., 1997), it can also be used for ammonia stripping: in this study, membrane distillation is used to selectively recover water and ammonia from both fresh and hydrolysed urine by varying operational conditions and membrane materials.

Membrane distillation experiments were run on a 125 cm^2 active membrane surface lab-scale set-up. PTFE membranes of 0.1 and 0.2 µm with a thickness of 66, 89 (no backing) and 254 µm (with polypropylene support layer) were used. Either fresh or hydrolysed human urine, collected from healthy test persons, was used at feed temperature of 40, 50 and 55 °C (permeate solution was kept at 20 °C) in DCMD. pH was either non-adjusted or increased to pH 12 (to enhance ammonia transfer) by addition of NaOH. Recirculation rate was varied from 27 to 48 L/h in the permeate and from 28 to 79 L/h in the feed. Ammonia analysis were performed by continuous flow analysis on an AA3-Autoanalyzer. Na^+ and K^+ analysis was performed on a Varian Vista-X ICP-OES.

A feed water recovery of 82% and 66 % was achieved for fresh and hydrolysed urine, respectively, without significant water permeability decrease during 24h-experiments, even though visual membrane fouling was severe (consisting of both organic fouling and scaling of P salts). Average water permeability ranged from 24.4 to 68.2 LMH/bar (fluxes of 1.7 to 5.7 LMH, respectively for a 0.06 bar vapour pressure difference using hydrolysed urine at a pH of 12 and a 254 µm thick supported membrane, and 0.08 bar vapour pressure difference using fresh urine and the 66 µm thick unsupported membrane), and rejection of both Na^+ and K^+ (major ions in human urine) was >99% in all experiments. By increasing the pH from 7 to 12 in fresh and hydrolysed urine respectively, total ammonia recovery could be increased from 19.4 to 95.6 % in only 8h-experiments. As such, membrane distillation can be seen as a selective urine recovery treatment, robust towards flux reduction through fouling.

References

1. M. Maurer, W. Pronk, T.A. Larsen. (2006) Treatment processes for source-separated urine, Water Research, 40 (17), Pages 3151–3166.

2. K.M. Lawson, D.R. Lloyd (1997). Membrane distillation, Journal of Membrane Science, 124, Pages 1-25.