

Evaluation of different adsorbents for ammonia recovery in suspended gas permeable membrane systems

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SUPPLEMENTARY MATERIALS

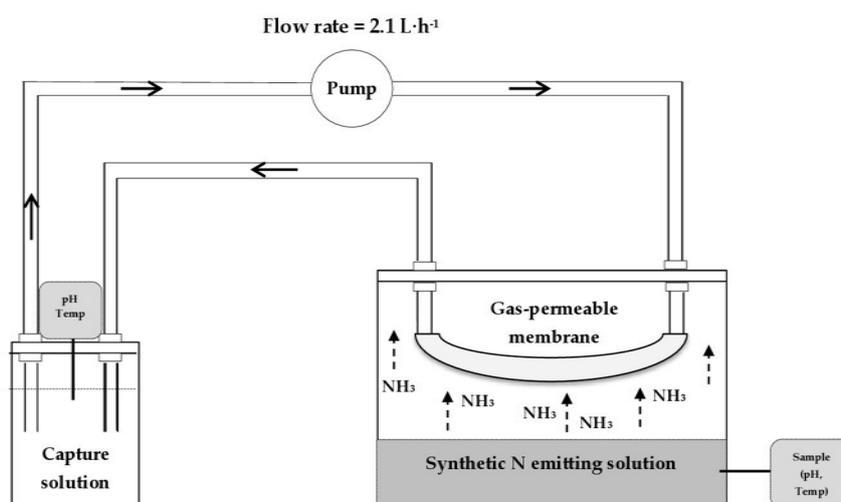


Figure S1. Scheme of the NH_3 capture process by the suspended gas-permeable membrane system in a closed circuit using different trapping solutions at 25°C . Reproduced from [Membranes, 2021, 11(7):538; DOI: 10.3390/membranes11070538] under CC BY 4.0 license.

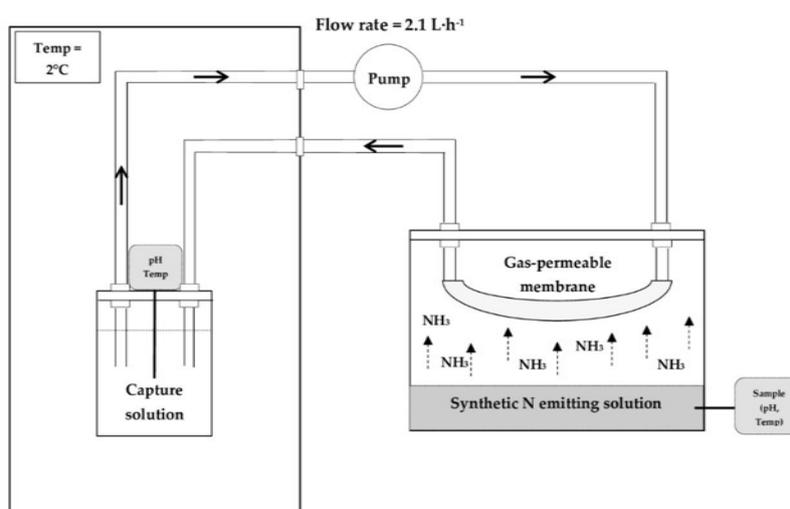


Figure S2. Scheme of the NH_3 capture process by the suspended gas-permeable membrane system in a closed circuit using different trapping solutions at 2°C . Adapted from [Membranes, 2021, 11(7):538; DOI: 10.3390/membranes11070538] under CC BY 4.0 license.

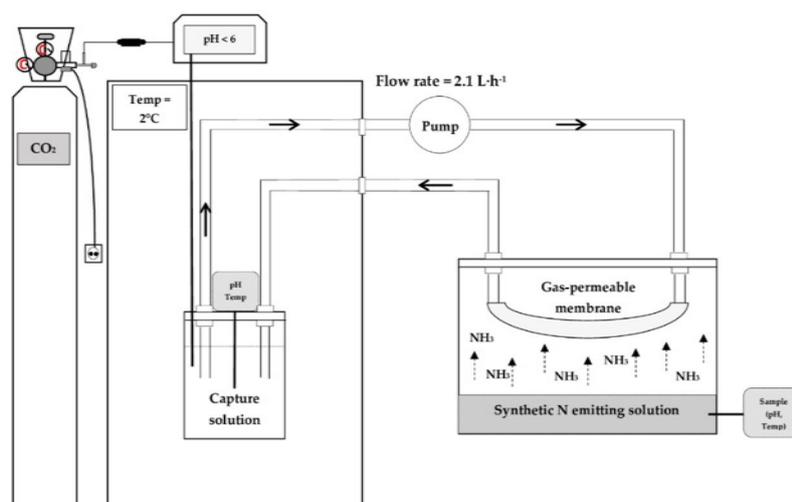


Figure S3. Scheme of the NH_3 capture process by the suspended gas-permeable membrane system in a closed circuit using carbonic acid as the ammonia trapping solution at 2 °C. Reproduced from [Membranes, 2021, 11(7):538; DOI: 10.3390/membranes11070538] under CC BY 4.0 license.

Table S1. Characteristics of the e-PTFE membrane used in the experiments.

| | |
|---|----------------|
| Length (cm) | 100 |
| Outer diameter (mm) | 5.2 |
| Width of the wall (mm) | 0.64 |
| Polymer density (g/cm^3) | 0.95 |
| Porosity (%) | < 60 |
| Average pore size length (μm)* | 12.7 ± 5.9 |
| Average pore size width (μm)* | 1.3 ± 0.9 |
| Absorption surface (cm^2) | 163.4 |

* Pore sizes are average values across 10 membrane samples characterized by Scanning Electron Microscopy (SEM).

Table S2. Summary of operation and chemical costs, as well as end-product market prices, for the eight ammonia trapping solutions under analysis.

| Operation costs | |
|--|---------------------|
| <i>Pumpdrive 5001 peristaltic pump</i> | |
| Electrical consumption (kWh) | 0.1 |
| Cost (€/kWh) | 0.3 |
| Weekly electrical consumption (kW/7d) | 16.8 |
| Weekly cost (€/7d) | 5.0 |
| Chemical costs | |
| <i>Acid consumption</i> | |
| Sulphuric acid (g) | 51.3 |
| Phosphoric acid (g) | 38.3 |
| Nitric acid (g) | 96.6 |
| Carbonic acid (g) | 59.1 |
| Acetic acid (g) | 60.1 |
| Citric acid (g) | 64.0 |
| Maleic acid (g) | 58.6 |
| <i>Acid cost</i> | |
| Sulphuric acid (€/L) / (€/kg) | 47.6 / 87.1 |
| Phosphoric acid (€/L) / (€/kg) | 44.9 / 80.4 |
| Nitric acid (€/L) / (€/kg) | 37.4 / 52.0 |
| Carbonic acid (€/L) / (€/kg) | - / 89.5 |
| Acetic acid (€/L) / (€/kg) | 46.4 / 48.7 |
| Citric acid (€/kg) | - / 81.2 |
| Maleic acid (€/Kg) | - / 105.8 |
| Fertilizer bulk prices | |
| Ammonium sulphate 21% (€/kg) | 0.69 ^[1] |
| Diammonium Phosphate (DAP) 18-46-0 (€/kg) | 1.09 ^[1] |
| Ammonium nitrate 34,5% (€/kg) | 1.08 ^[2] |
| Ammonium bicarbonate 99-100% (€/kg) | 0.93 ^[3] |
| Ammonium acetate 99% (€/kg) | 1.11 ^[3] |
| Ammonium citrate > 90% (€/kg) | 1.06 ^[3] |
| Ammonium maleate (€/Kg) | 2.76 ^[4] |
| NH ₃ -H ₂ O 25% (€/kg) | 1.30 ^[3] |

The prices of the end products have been obtained from the suppliers listed below:

¹ North Carolina Dept of Ag-USDA Market News Service, 2022. Available online at:

https://mymarketnews.ams.usda.gov/filerepo/sites/default/files/3159/2022-04-14/579600/ams_3159_00112.txt (accessed 14 April 2022).

² Almacenes Antonio Guerrero. Agricultura y Ganadería-Convencional y Ecológica, 2022. Available online at: <https://www.almacenesantonioguerrero.es/productos/nitrato-345-25kg/%0A.Best-price-In-stock/2051660.html> (accessed 16 April 2022).

³ Various suppliers, 2022. Available online: <https://www.made-in-china.com/> (accessed 14 April 2022).

⁴ Hangzhou LookChem Network Technology Co. Ltd. Available online at: https://www.lookchem.com/product_Ammonium-hydrogen-maleate-Manufacturer-High-quality-Best-price-In-stock/2051660.html (accessed 16 April 2022).