Electrochemical Membrane Stripping System for Total Ammonia Nitrogen Removal in Recirculating Aquaculture Systems

Yuliana Pullas, Dina Zilberg, and Avner Ronen

The Jacob Blaustein Institutes for Desert Research, Ben Gurion University of The Negev, Israel.

1. INTRODUCTION

Recirculating aquaculture systems (RAS) are land-based, water-efficient solution to global food security challenges. Protein catabolism in fish generates total ammonia nitrogen (TAN), of which unionized ammonia (NH_3) is toxic to fish[1] (Fig. 1). Nitrification converts TAN to nitrate but requires periodic water exchange, while denitrification converts it to nitrogen gas, causing irreversible nutrient loss[2] and precluding resource recovery. Therefore, we developed an Electrochemical Membrane Stripping **(EMS)** system that removes TAN from RAS water and recovers it as liquid fertilizer.



Fig 1. 60 – 75% of the fish feed is excreted as residues including toxic ammonia, which affects the fish's biological systems.

2. MEMBRANE PREPARATION AND EXPERIMENTAL SET-UP

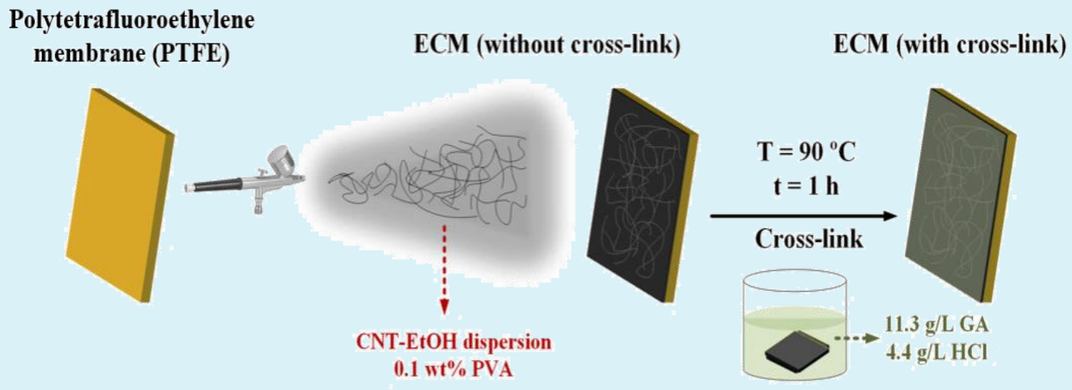


Fig 2: Preparation of the electroconductive membranes (ECM).

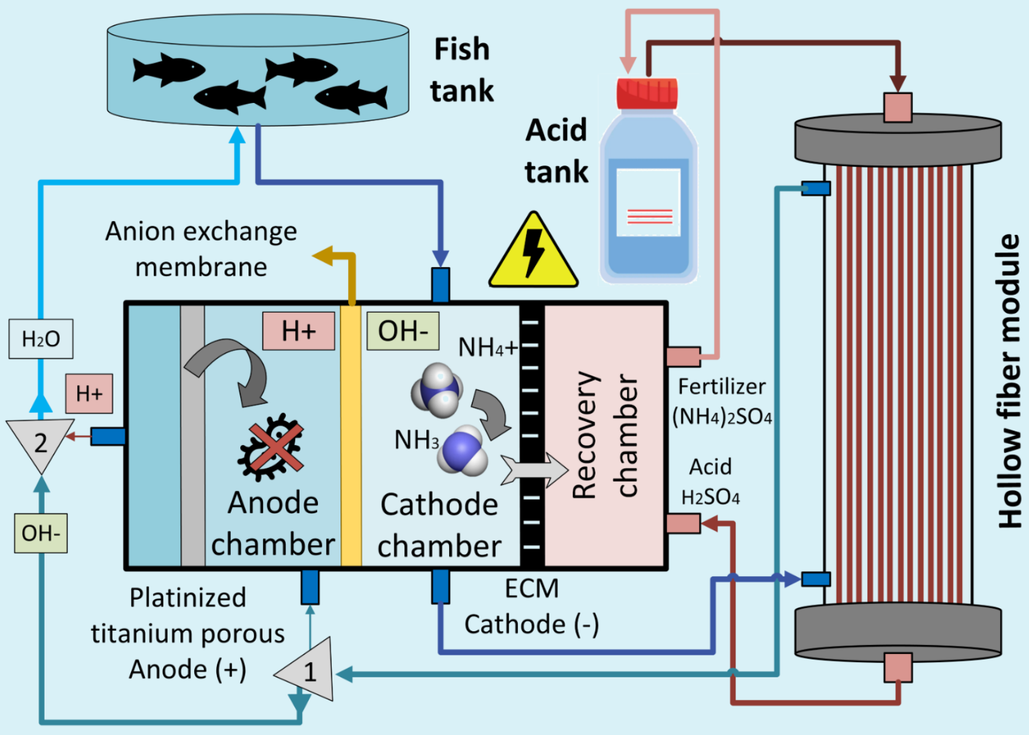


Fig 3: Experimental set-up of the EMS to remove TAN from RAS.

Electroconductive membranes **(ECM)** are fabricated by spray coating carbon nanotubes **(CNT)** (Fig. 2). Under an applied negative potential, NH_4^+ migrates towards the ECM by electromigration while water reduction generates OH^-, raising local pH and converting NH_4^+ to free NH_3, which is stripped through the hollow fiber module and absorbed in sulfuric acid to yield $(NH_4)_2SO_4$, a fertilizer.

4. CONCLUSIONS

- An AC waveform of -2.0 V for 15 seconds and +0.5 V for 2.5 seconds maximizes cathodic pH while minimizing energy input.
- Optimal AC achieved a of 55.6 % TAN removal in real RAS water and reduced H_2O_2 production by 95 %.
- Long-term recovery efficiency was 42.4±5.3%, demonstrating the feasibility of nitrogen recovery as liquid fertilizer.

5. REFERENCES

[1] Zhang, R., et al., *Sustain. Prod. Consum.*, Oct. 2023
[2] Edwards, T., et al., Science of The Total Environment, Jan. 2024
[3] Qi, S., et al., J. Memb. Sci., May 2025.

3. RESULTS AND DISCUSSION

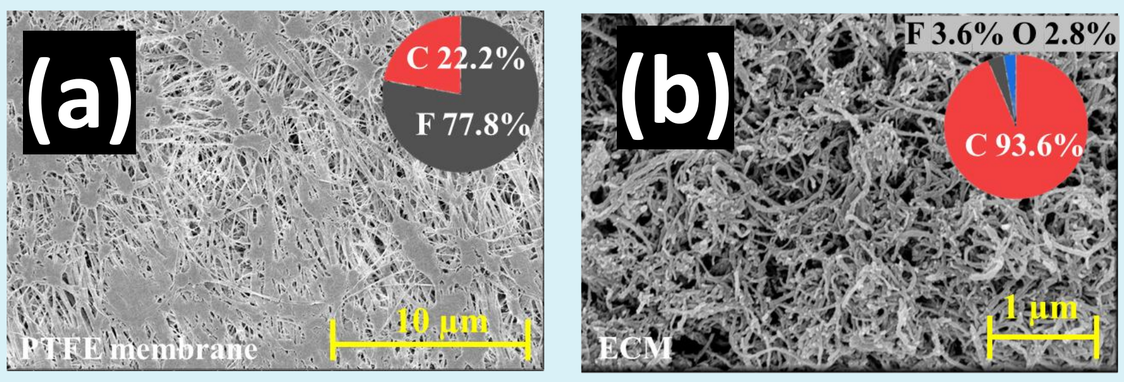


Fig 4. Scanning Electron Microscopy-Energy Dispersive X-ray Spectroscopy **(SEM-EDS)** for the pristine polytetrafluoroethylene **(PTFE)** membrane (a) and ECM (b) .[3]

SEM-EDS analysis (Fig. 4) confirms successful CNT coating: the pristine PTFE membrane is composed predominantly of carbon and fluorine (C 22.2%, F 77.8%), whereas the ECM displays over 93% carbon with the emergence of an oxygen signal, consistent with carboxyl CNT functionalization.

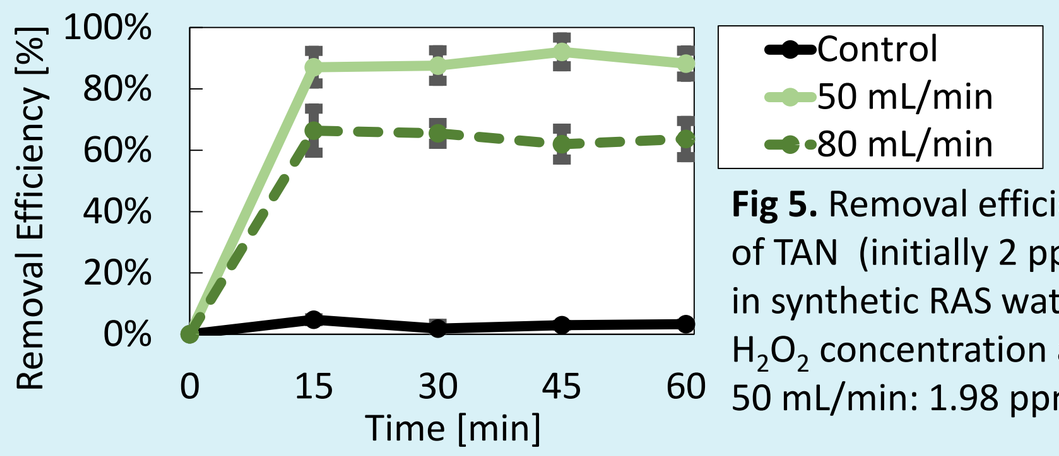


Fig 5. Removal efficiency of TAN (initially 2 ppm) in synthetic RAS water. H_2O_2 concentration at 50 mL/min: 1.98 ppm.

At 50 mL/min and -1.0 v (Direct current - **DC**), TAN removal reached 89% (Fig. 5), driven by elevated pH in the hollow fiber module, favoring the un-ionized NH_3 fraction. Yet, the H_2O_2 concentration (1.98 ppm) exceeded safe aquaculture thresholds, motivating a shift to alternating current **(AC).**

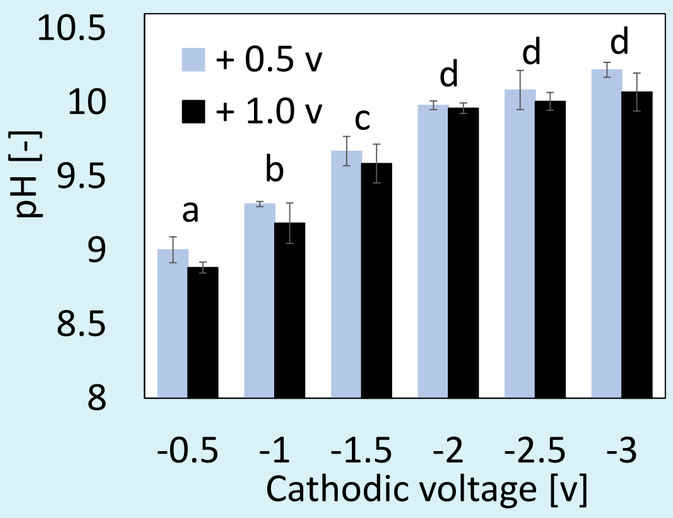


Fig 6. Cathodic and anodic voltage optimization with synthetic RAS water.

AC parameters were optimized to maximize cathodic pH (Fig. 6). The voltage -2.0 v is the least energy-intensive within the highest statistically equivalent pH group. Therefore, the optimal waveform is -2.0 V for 15 seconds and +0.5 V for 2.5 seconds.

Optimal AC (-2.0/+0.5 V), reached a 55.6±1.8% TAN removal in real RAS water (Table 1), while hydrogen peroxide had a 95% reduction in concentration relative to DC. The lower H_2O_2 levels ensure its safe accumulation in water for fish farming.

Long-term TAN recovery efficiency in the acid was 42.4±5.3%.

Table 1. TAN removal efficiency using RAS water (TAN = 2ppm) for DC and AC at 50 mL/min.

Voltage [v]	TAN removal [%]	H_2O_2 [ppm]
Cont. (0)	15.1±1.9	0.02±0.01
-1.0	71.2±3.9	2.6±0.4
-2.0 & +0.5	55.6±1.8	0.12±0.02

Ben-Gurion University of the Negev

BIDR The Jacob Blaustein Institutes for Desert Research

Goldman Sonnenfeldt School of Sustainability and Climate Change
Ben-Gurion University of the Negev

RONEN Laboratory
Water Treatment