Water Desalination using 3D-Printed Biofilms in Microbial Desalination Cells

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Introduction

- Water scarcity is a pressing global issue that currently affects 2.8 billion people. Projections suggest that by 2030, nearly half of the world's population could experience water stress (Michalak et al., 2023).
- This alarming trend arises from factors, including population growth, climate change, urbanisation, and pollution, which exacerbate the growing imbalance between the demand for and availability of freshwater (Rosińska et al., 2024).
- Desalination can augment freshwater supplies, but conventional methods e.g. Reverse Osmosis, are energy-intensive and produce polluting brine (Curto et al., 2021).
- Microbial Desalination Cells (MDCs) have gained attention as an innovative approach, utilising the metabolic processes of electroactive bacteria to treat wastewater while simultaneously generating energy (Shah, 2024).
- Despite their potential, MDCs face challenges such as membrane biofouling, which reduces their efficiency and operational lifespan. (Mpala J. *et al.*, 2023).

Aim

- To investigate the effect of immobilisation of electroactive bacteria as, 3D-printed biofilms, on water desalination in MDCs.

Methodology

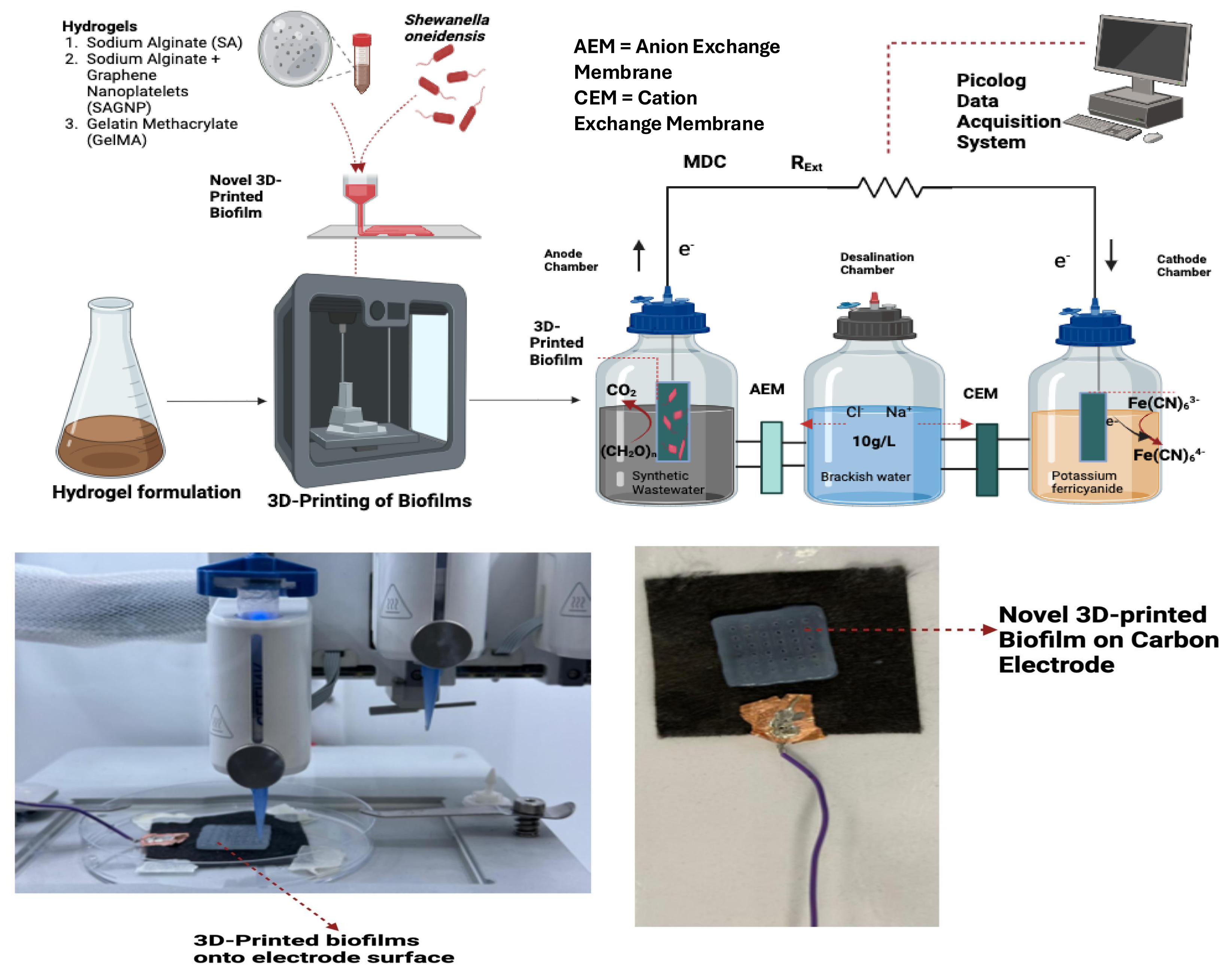

Figure 1: Schematic Diagram of the 3D-bioprinting Procedure and MDC Setup. The MDC setup involved the use of synthetic wastewater prepared by combining 10 ml of a 100X trace element solution, 10 ml of a 100X vitamin stock solution, and 980 mL of a 6.41 g/L sodium acetate solution. Additionally, 10 g/L of brackish water and 38.32 g/L of artificial seawater were utilised in the system.

Results

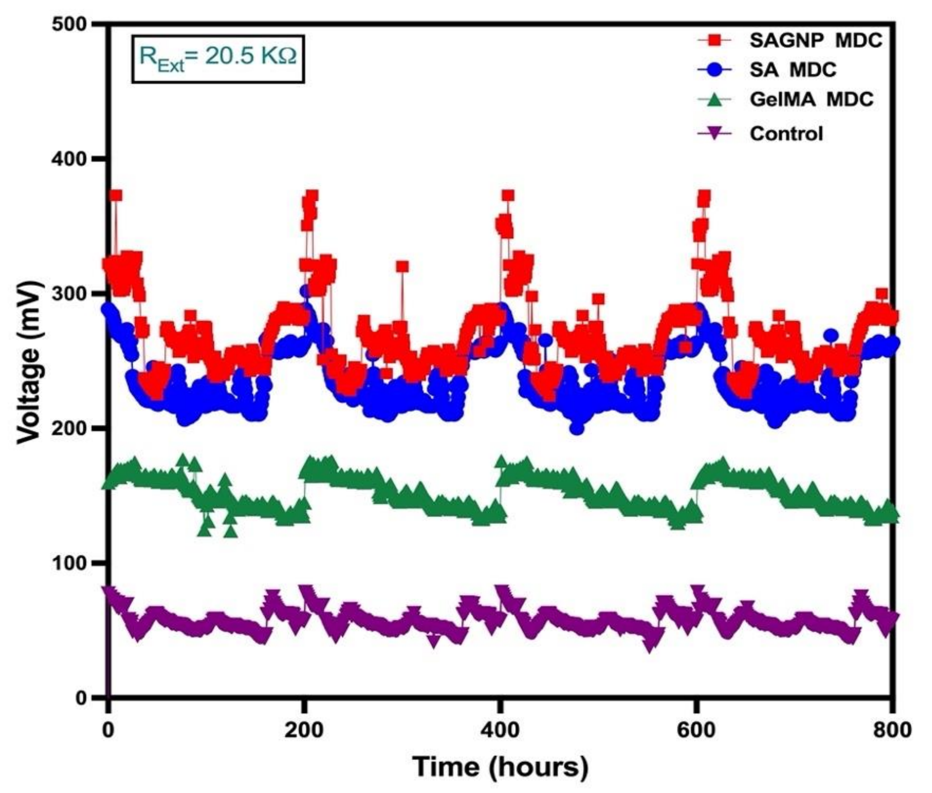

Figure 2: Voltage Profile for each 3D-Printed Biofilm. Control = suspended cells

Results Cont'd

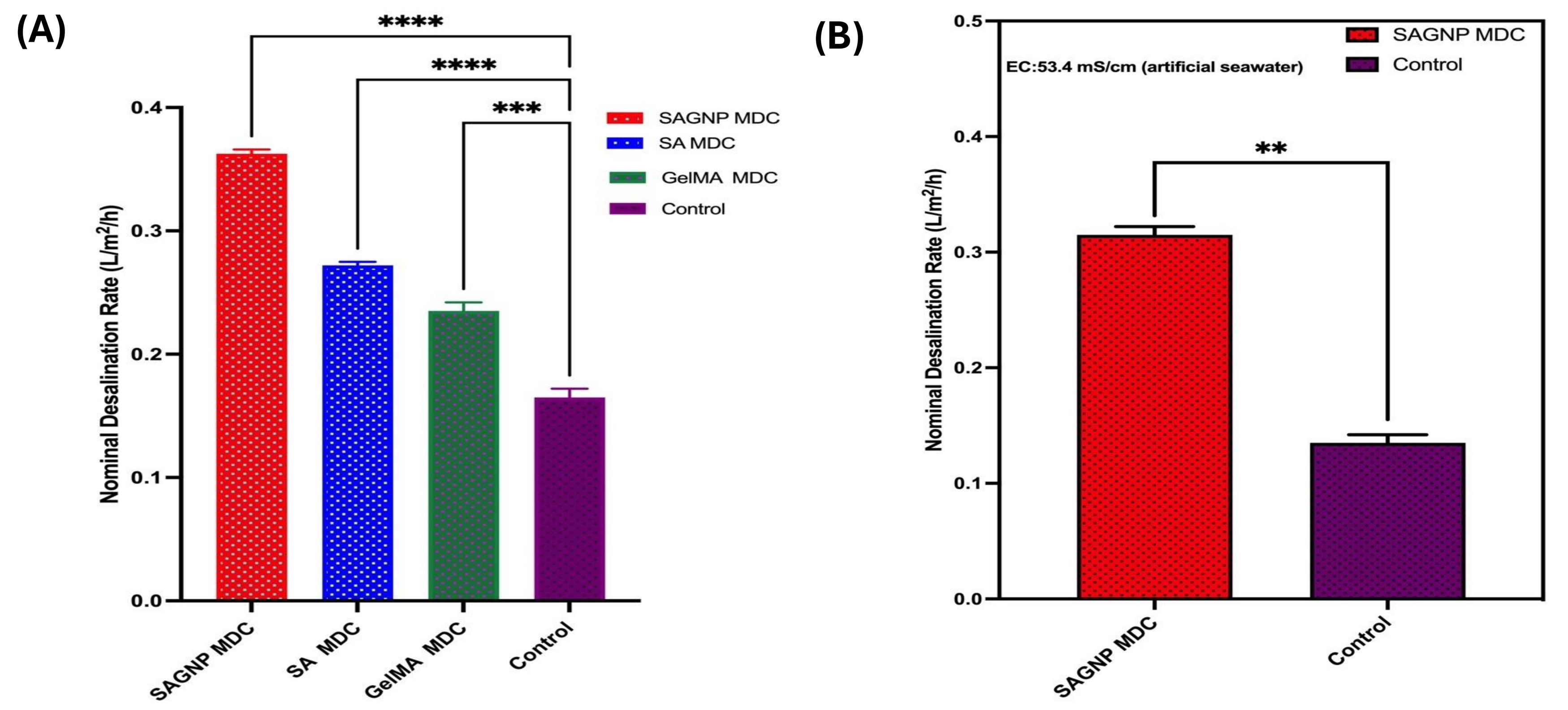

Figure 3 - Nominal Desalination Rate (NDR) (A) using brackish water and (B) using artificial seawater

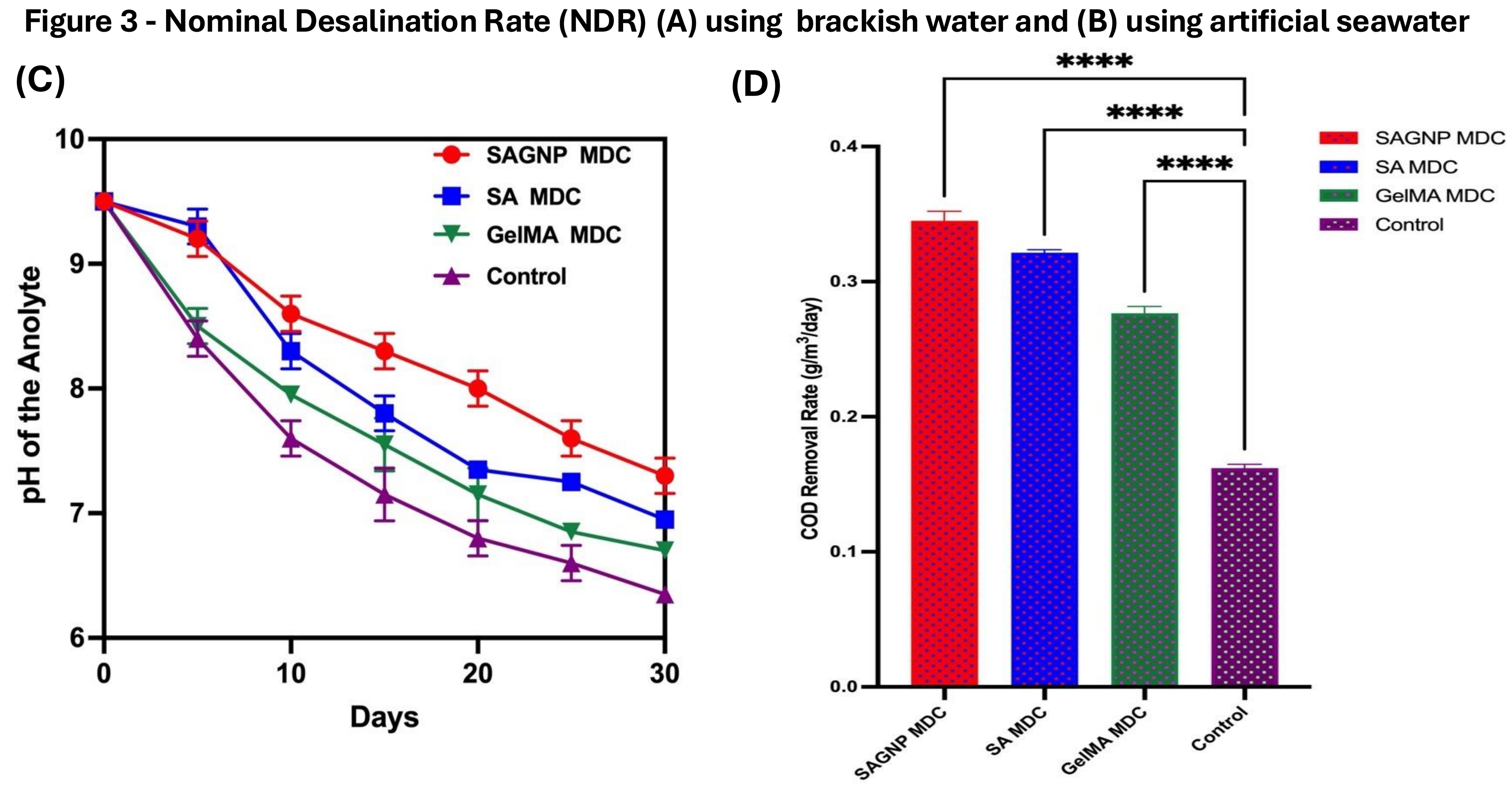

Figure 4 - (C) pH Analysis of the anode chamber and (D) COD removal of the 3D-Printed Biofilms

Discussion

- Sodium Alginate impregnated with Graphene Nanoplatelets Biofilm (SAGNP) produced the highest average voltage of 322 mV, followed by Sodium Alginate Biofilm (SA) with 289 mV and Gelatin Methacrylate (GelMA) with 170 mV (Figure 2).
- SAGNP achieved the highest NDR of 0.36 L/m²/h when desalinating brackish water. For seawater, it achieved an NDR of 0.29 L/m²/h (Figure 3).
- SAGNP shows the highest average COD removal rate of 0.36 g/m³/day with a removal efficiency of 84.4% (Figure 4D).
- The observed performance of the 3D-printed biofilm MDCs can be attributed to the biofilm optimisation, which enhanced electron transfer kinetics, resulting in an overall improvement in the desalination rate.
- These findings highlight the potential of using advanced 3D-bioprinting technology to immobilise *Shewanella oneidensis* as a 3D-printed bioelectrode for use in MDCs to accelerate desalination performance.

Conclusion

- Our results indicate that SAGNP 3D-printed Biofilms exhibited the best overall performance in terms of voltage generation, COD removal, desalination efficiency and rate, attributed to the conductive properties of graphene nanoplatelets.
- MDC performance can be optimised through the use of 3D-printed Biofilms to accelerate the desalination rate and efficiency as well as voltage generation.

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Project Impact: SDG 6