

DESIGN AND DEVELOPMENT OF A HALOPHILIC BIOFILM-BASED INTEGRATED SYSTEM FOR SEAWATER DESALINATION AND SUSTAINABLE PRODUCTION OF POTABLE WATER AND ELECTRICITY

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Keywords:

Halophilic Bacteria, Biofilm, Microbial Fuel Cell (MFC), Seawater Desalination, Anion and cation exchange Membrane (AEM/CEM), Salt Bridge, Sustainable Energy, Portable Water.

Introduction/Background:

Interest in integrated solutions that can meet both demands at once has increased as a result of the world's growing need for sustainable energy and the growing shortage of freshwater resources. Despite their effectiveness, traditional saltwater desalination methods are frequently costly and environmentally harmful. A viable substitute is provided by recent developments in microbial electrochemical technologies, which use naturally occurring biofilms to produce energy and desalinate water (Logan et al., 2006).

In this context, halophilic bacteria are particularly interesting since they can thrive in high-salinity settings. These microbes can be used to create biofilms on electrode surfaces after being isolated from hypersaline settings such as the salt pans of Sanikatta, Karnataka. These biofilms are essential to microbial desalination cells (MDCs), which desalinate seawater while facilitating electron transfer and generating energy (Shivaji & Prakash, 2009; Cheng et al., 2006).

Additionally, including organic waste—like wastewater from breweries or kitchens—into these systems might improve bioelectricity production efficiency while also aiding in waste management (Pant et al., 2012). The suggested study intends to create a sustainable, affordable solution for producing potable water and renewable energy in a single system by optimizing reactor conditions and membrane materials (Bernet et al., 2008).

Objectives:

1. To isolate halophilic bacteria from salt pan land of Sanikatta in Uttara Kannada and evaluate its potential for seawater desalination.
2. To Develop a halophilic biofilm-based integrated system for simultaneous seawater desalination and sustainable production of potable water and electricity.
3. To identify and optimize the use of suitable anion and cation exchange membranes or salt bridges for enhanced efficiency in electricity generation.
4. To evaluate the feasibility of integrating the system with kitchen waste or brewery wastewater to enhance its desalination and energy generation performance.

Methodology:

- a. To isolate halophilic bacteria from salt pan land of Sanikatta in Uttara Kannada and evaluate its potential for seawater desalination:

Soil, water, and sediment samples were collected from multiple sites using sterile tools to avoid contamination. Samples were transported at 4°C and processed within 24 hours to preserve microbial viability using the modified protocols of Gunde-Cimerman et al. (2004) and Shivaji et al. (2009).

- b. To Develop a halophilic biofilm-based integrated system for simultaneous seawater desalination and sustainable production of potable water and electricity.

A microbial desalination cell (MDC) was developed using halophilic bacteria to desalinate seawater and generate electricity. Salt-tolerant strains were cultured on NSSW and Halophilic Agar, then induced to form biofilms. The MDC comprised an anode in saline water and a cathode in low-salt water, enabling ion migration and power generation (Cheng et al., 2006).

- c. To evaluate the feasibility of integrating the system with kitchen waste or brewery wastewater to enhance its desalination and energy generation performance.

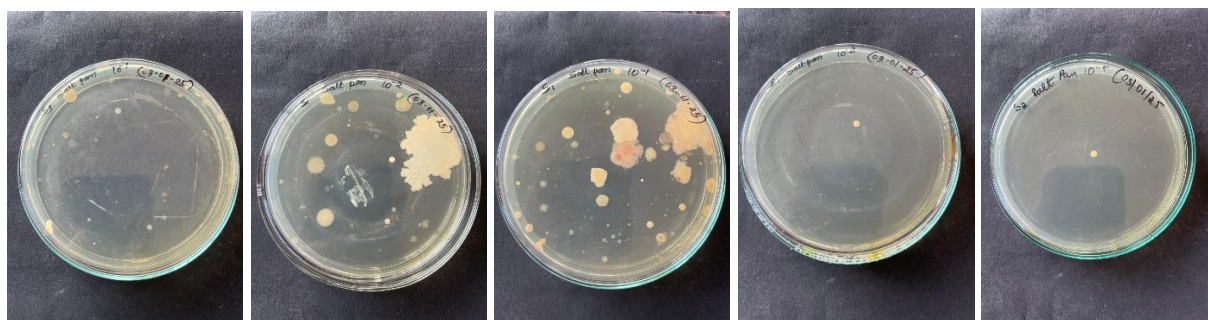
The feasibility of using organic waste as a carbon source in the MDC was evaluated. Pre-treated kitchen, sugar cane waste and brewery wastewater was used as feedstock. Desalination efficiency, power output, and organic load reduction were monitored. Water quality and power density were measured, and statistical analysis assessed treatment effectiveness (Logan et al., 2008; Pant et al., 2012).

4. Results & Conclusions (15-20 lines):

The organisms were isolated from Saltpan at Sanikatte, gokarna Rd, karnataka ,Lat 14.546983 and Long 74.345937



Soil samples from salt pan were serially diluted in different dilutions and inoculated the samples into NSSW (Natural seawater sucrose water) media. Diversity of organisms were observed in the sample at 10^{-1} and 10^{-2} dilutions. The morphological features were noted and individual colonies were isolated and inoculated in different salt concentration to see their salt tolerating ability.



All the organisms were screened to see their salt tolerating ability by increasing the salt concentration from 3.5%, 5%, 10%, 15 %, 20% and 25% in halophilic media. Out of them 4 organisms had the ability to grow in 20% of salinity.



Four of the organisms, were screened to see their desalination ability and one of the organism showed its ability to desaline salt water . that organism was sent for the identification by sequencing, by sequencing the sample organism showed 99.932% similarity to a halophilic organism, *Virgibacillus salarius* .



Phylogenetic tree of *Virgibacillus* sp.



The desalination property of the organism *Virgibacillus salarius* a novel growth medium was formulated using sugarcane waste and seawater in a 25:75 ratio, respectively. This combination offering a cost-effective and sustainable alternative to conventional media. The sugarcane waste provides essential carbon sources, while seawater contributes necessary micronutrients and maintains osmotic balance. This medium supports the growth of halotolerant or marine organisms and promotes the utilization of agricultural residues, aligning with environmentally friendly bioprocessing practices. We are standardising the media for the best result.

Project Outcome & Industry Relevance:

This project successfully aims to isolate halophilic bacterial strains capable of forming biofilms for use in microbial fuel cells (MFCs), enabling simultaneous seawater desalination and electricity generation. The designed system is expected to produce potable water while converting organic waste into bioelectricity, offering a sustainable, low-cost alternative to conventional desalination methods. Optimised use of ion exchange membranes or salt bridges will enhance system efficiency and reliability. The integration with kitchen or brewery waste improves waste valorization, promoting a circular bioeconomy model.

From an industry perspective, this dual-function system has significant relevance in wastewater treatment, desalination plants, renewable energy, and sustainable manufacturing sectors. It offers industries a way to reduce energy costs, improve effluent management, and align with environmental regulations. Scalability and adaptability make this technology suitable for remote facilities, eco-industrial parks, and smart cities, supporting green infrastructure development. This innovation contributes toward sustainable industrial practices, helping companies meet ESG (Environmental, Social, and Governance) goals and support the UN SDGs.

Working Model vs. Simulation/Study:

We have constructed a microbial desalination cell (MDC) using a PVC pipe chamber, designed to simultaneously perform desalination and generate electricity. The system utilizes *Virgibacillus salarius*, which plays a central role in the anodic chamber by breaking down organic matter and releasing electrons. These electrons travel through an external circuit to the cathode, producing electricity. Meanwhile, ion exchange

membranes separate the anodic, desalination, and cathodic chambers, facilitating the selective movement of ions to remove salts from saline water. The use of durable PVC pipe provides a cost-effective, corrosion-resistant, and easily modifiable structure for the chamber, making it suitable for laboratory-scale research and potential scalable applications. This model is under construction, ready to begin with the experiment.

Project Outcomes and Learnings:

- Identification of halophilic bacterial strains and development of a biofilm-based system for seawater desalination and potable water production.
- Optimize this system for synergistic interactions as functional microbial fuel cell capable of simultaneous desalination and electricity generation.
- Integration of the system with kitchen waste or brewery wastewater to enhance performance.

Future Scope:

This technology holds promise for scaling up to serve remote and water-scarce communities, providing them with clean, drinkable water and renewable electricity simultaneously. In coastal and island regions, such systems could reduce dependence on costly and energy-intensive desalination plants, making freshwater access more affordable and sustainable.

The use of halophilic bacteria offers resilience in extreme saline conditions, which makes the system ideal for deployment in harsh environments. By integrating with organic waste streams, such as kitchen or brewery effluents, the system can serve as a waste-to-resource model, reducing environmental pollution and improving sanitation.

Industries could benefit by reducing wastewater treatment costs and generating part of their electricity requirements internally, supporting their transition to green technologies.

Further research could focus on genetically enhancing halophilic strains for better biofilm formation, electron transfer efficiency, and desalination performance.

Development of hybrid systems combining MFCs with solar or wind power could create energy-autonomous water treatment units.