International Journal of Scientific Research in Engineering & Technology
Special Issue, Volume 4, Issue 3 (May-June 2024), PP: 84-95.
Recent Advances in Civil Engineering and Technology (REACT)-2024
www.ijsreat.com ISSN No: 2583-1240

Water Analysis and Forward Osmosis

Shereena N.P [1], Fouad Ebn Muhammad Abdulla[2]

[1] M. Tech, APJ Abdul Kalam Technological University, Department of Mechanical Engineering, Government Engineering College, Kozhikode, Kerala, India.

[2]Assistant Professor, APJ Abdul Kalam Technological University, Department of Mechanical Engineering, Government Engineering College, Kozhikode, Kerala, India.

***To Cite this Article**: Shereena N.P [1],Fouad Ebn Muhammad Abdulla[2] "Water Analysis and Forward Osmosis", International Journal of Scientific Research in Engineering & Technology Volume 04, Issue 03, May-June 2024, PP: 84-95.*

Abstract: *There-fourths of Earth's surface is covered with water, but 97.5 % of that consists of saline content, and some percent is in glacier and ice forms. Oonly 1 percent of freshwater is available for the global population for daily domestic, drinking, and irrigation purposes. The rresearchers across the world are curious to address this water scarcity problem and they are exploring sustainable solutions because non renewable energy sources are decreasing day by day, and their greenhouse emissions contribute to environmental pollution. The natural long-lasting renewable energy sources such as wind, water, and the sun are alternative solutions for this problem. Population growth and industrial waste water also affect our environmental sustainability. To solve the freshwater problem without environmental pollution, there is an urgent need for a low-cost water treatment system. In this study, an analysis of waste water and the Forward Osmosis process are introduced. The experiment provides insights into optimizing water purification conditions and underscores forward osmosis's applicability in producing high-quality water.*

Key Word: *forward osmosis, water analysis, water quality, physical parameters, chemical parameters, biological parameters,*

I.INTRODUCTION

In GCC countries desalination processes are followed for 99 percent of their daily water usage because these countries have less rainfall and more deserts, with no underground wells for freshwater. In India and other countries, we should follow their techniques for freshwater. Nowadays, Indian states like Tamil Nadu, Punjab, etc., have reported water issues. They understand and have reported saline content in underground water, as well as the effects of industrial waste water in Punjab, causing health issues and leading to cancer. Similarly, our state, Kerala, also needs a solution for freshwater because, for the past five years, Kerala has faced flood problems leading to the discharge of a large amount of waste water into open wells and other areas, causing diseases like malaria etc. In cities, people are living in congested areas, their sewage and sewerage waste is causing water pollution, it also affects well water due to tank leakage.

This report serves as the foundational work, and the Indian government must take proactive measures to address water scarcity. In the future, every state should develop water treatment plants, as the current situation poses a significant threat to all people due to the scarcity of fresh water. It is imperative to save water; doing so will safeguard our lives. Let us all understand the real meaning of this slogan.

Forward Osmosis:

Forward osmosis is a process where water moves through a semi permeable membrane from a region of lower solute concentration to a region of higher solute concentration. It's driven by osmotic pressure and has applications in water purification and industrial processes.

Water Analysis:

It's important to perform water analysis periodically to monitor water quality and address any potential issues promptly.

Aquaporin HFFO2 or FO membrane test cell:

Conducting a forward osmosis (FO) lab experiment using the Aaquaporin HFFO**2** membrane or FO membrane test cell.

Introducing Solutions to the FO Cell:

Prepare the feed solution by dissolving a known concentration of solute in distilled water. Prepare the draw solution using pure distilled water.

Peristaltic Pump:

Peristaltic pump plays a vital role in ensuring a controlled and efficient flow of the feed&draw solution during FO, Contributing to the success of the separation process.

Weighing Machine:

Weighing machines are integral in forward osmosis experiments, primarily for measuring mass changes pre- and post-osmosis. Initially, the sample, such as a solution, undergoes weighing to establish a baseline. During osmosis, water molecules move across a semi-permeable membrane from low to high solute concentration. After a set time, the sample is re-weighed to determine the mass change, indicating water movement. Calculations based on initial and final masses yield parameters like water flux or solute transport rates.

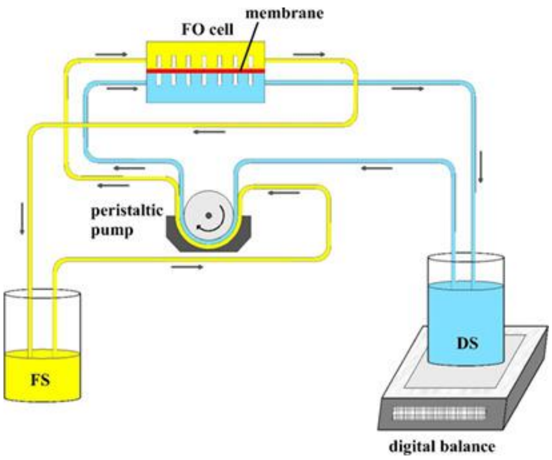

Fig 1 Laboratory scale plant for forward osmosis experiments

Tzahi Y. Cath et.al [1] This paper provides the state-of-the-art of the physical principles and applications of forward osmosis as well as their strengths and limitations. FO has garnered increased attention across various disciplines due to its versatility in applications such as water and waste water treatment, desalination, food processing, drug delivery, and power generation. Despite the current limitations in membrane robustness, ongoing basic research and exploration of new applications are driving the field's growth. A key priority for advancing FO technology lies in developing new membranes, both flat-sheet and hollow fibre, with characteristics including high water permeability, solute rejection, reduced internal concentration polarization, chemical stability, and mechanical strength. Future progress also hinges on refining high-density packing methods for flat-sheet FO membranes, as well as innovating draw solutions capable of generating high osmotic pressure. Ideally, these draw solutions should require minimal energy for regeneration, be easily separable from fresh water, possess low toxicity, and exhibit no chemical reactivity with polymeric membranes.

Sherub Phuntsho et.al [2] This study investigates the impact of temperature, particularly the temperature difference between draw solution (DS) and feed solution (FS), on Forward Osmosis (FO) performance in terms of water and solute fluxes. Results show that water flux increases by up to 1.2% per degree rise in temperature from 25°C to 35°C, and by 2.3% from 25°C to 45°C. Elevating only the DS temperature significantly enhances water flux, albeit lower than isothermal conditions. However, raising only the FS temperature doesn't notably improve water flux, though it's higher than FO at 25°C. This has significant implications as the mass of DS requiring heat energy is much lower than FS. The study also elucidates the influences of temperature on FO, including changes in thermodynamic properties and concentration polarization effects.

Ali Altaee et.al [4] emphasize the viability of combining Forward Osmosis (FO) with Reverse Osmosis (RO) for seawater desalination was assessed. RO was recommended for draw solution regeneration due to its efficiency and versatility in treating various ionic solutions. Two salts, NaCl and $MgCl_2$, were employed as draw solutions. Performance of FO and RO regeneration processes was simulated using existing software. Comparison between RO and FO-RO processes revealed lower total power consumption in RO, though the difference was negligible between RO and 0.65 mol $MgCl_2$ FO-RO processes. Power consumption in FO alone accounted for only 2%-4% of total consumption in FO-RO. However, differences in total power consumption between RO and FO-RO decreased with higher seawater salinity. In FO-RO, permeate Total Dissolved Solids (TDS) increased with draw solution concentration, with the lowest TDS achieved in the 0.65 mole $MgCl_2$ FO-RO process due to high rejection by the RO unit. The study assessed the feasibility of FO-RO for seawater desalination and compared it to RO, utilizing simulation software packages.

Kerusha Lutchmiah et.al [5] This review examines the steps needed for forward osmosis (FO) to realize its full potential in waste water treatment and water reclamation by addressing current advancements, challenges, and future prospects in the waste water sector. FO shows promise for treating waste water due to its high rejection capacity and low fouling propensity. However, challenges like ineffective membranes and reverse solute leakage persist, hindering its widespread use. Hybrid systems like FOeMD, FOeRO, and integrated approaches with seawater desalination could improve FO's commercial viability for waste water recovery. Understanding energy balances in integrated systems is crucial for assessing economic benefits. Concentrate disposal, especially with heavy metal-containing waste streams, requires careful consideration. Energy-efficient pre-treatment and organic concentration via FO could aid in energy production and nutrient recovery. With growing demand for higher-quality water, FO emerges as a cost-competitive and reliable alternative, attracting increasing interest.

Kiho Park et.al [8] This paper thoroughly analyzes a high-temperature forward osmosis(FO)/crystallization/reverse osmosis (RO) hybrid process for desalination. It suggests a process set up and draw solute options, develops a mathematical model for transport phenomena, and validates it through experiments. Suitable membrane parameters for each process are estimated from experimental data. An energy consumption model is devised and compared with conventional seawater reverse osmosis (SWRO) process. The hybrid process requires around 1.66–2.72 kWh/m^3 equivalent work, competitive with SWRO. Thermal energy accounts for 0.6–1.1 kWh/m^3, potentially lower with cheap waste heat. Experimental results determine operating temperatures and parameters for effective operation. Despite higher energy consumption, most energy is for heating, which, if utilizing waste heat, could make the hybrid process energy-efficient. The study confirms the energy feasibility of the FO/crystallization/RO hybrid process, providing insights and base data for further cost modelling.

Farrukh Arsalan Siddiqui et. al. [9] In this paper compared alginate fouling in forward osmosis (FO) and reverse osmosis (RO). Contrary to common beliefs based on water flux profiles, in experiments and membrane autopsies revealed that FO is more prone to fouling than RO. Theoretical analysis suggests that reduced internal concentration polarization during FO leads to higher fouling compared to RO. FO exhibited greater specific foulant resistance than RO, possibly due to factors like reverse solute diffusion from the draw solution. While the role of hydraulic pressure in foulant layer compaction in RO was not significant, FO showed superior water flux stability against fouling. This resilience of FO may be valuable for practical applications.

Nayla Hassan Omer [10] This review delves into the physical, chemical, and biological aspects of water quality, examining their definitions, sources, impacts, effects, and measurement techniques. Since the onset of the industrial revolution in the late 18th century, humanity has continually discovered new sources of pollution, leading to potential contamination of air and water across various environments. Despite limited knowledge of pollution rate changes, the rise in water-related diseases serves as a tangible indicator of environmental pollution levels. From an ecological standpoint, this chapter provides a comprehensive overview of water quality parameters, catering not only to human health but also to the well-being of other organisms. Water quality classification encompasses four main types, each elucidated through an exhaustive exploration of their shared characteristics, encompassing physical, chemical, and biological attributes. Through this discussion, the parameters defining water quality are examined in detail, covering their origins, impacts, effects, and methods of assessment.

Maria Salud Camilleri-Rumbau et al. [11] This study explored Aquaporin-based forward osmosis membranes for separating biogas digestate liquid fractions. Results consistently showed over 95.5% rejection of Total Ammonia-Nitrogen, regardless of draw solution or experimental conditions. High draw osmotic pressures and feed acidification reduced membrane water permeability. However, membrane rinsing effectively restored initial water flux and removed remaining foulants, confirmed by microscopy and chemical analysis. The technology demonstrated potential for high ammonia-nitrogen rejection and low fouling propensity in this application. The study assessed Aquaporin-based forward osmosis membranes using two draw solutions (NaCl and hide preservation waste water) and investigated their performance with digestate liquid fractions and feed acidification.

Ahmed F. Donia and Wael I. Mortada [14] Conflicting findings on the chemical composition of Zamzam water, particularly regarding arsenic, prompt the study's objective: to assess tap and bottled Zam zam water's composition and compare it against international drinking water standards. In this paper analysed six tap water samples and one bottled sample for various chemical constituents using standard methods (APHA). Results, compared to WHO and EPA drinking water guidelines, showed that all parameters, except TDS, were within acceptable limits ($p > 0.05$). TDS levels (averaging 814 mg/L in tap water and 812 mg/L in bottled water) exceeded EPA's non-enforceable guideline of 500 mg/L but remained below WHO's 1000 mg/L limit ($p < 0.05$). The bottled sample displayed significantly lower Na, PO43, and Cu levels compared to tap water samples ($p < 0.05$ and $p < 0.01$, respectively). In conclusion, Zam zam water generally meets quality standards, including arsenic levels, but TDS levels surpass EPA's non-enforceable guideline.

Jianlong Wang et al. [15] In this review paper summarized the recent advances of forward osmosis technology and this paper offers a succinct overview of the key areas of focus, challenges, and future prospects within forward osmosis technology. It underscores the significance of factors like membrane advancement, draw solutions, and operational parameters in driving the field forward. Furthermore, it addresses critical issues such as concentration polarization, membrane fouling, and reverse solute diffusion, highlighting their interconnectedness. Moreover, the paper stresses the importance of innovation in membrane materials, draw solutions, and energy-efficient recovery processes, aiming to broaden the commercial application of forward osmosis. By tackling these aspects, the goal is to facilitate the widespread adoption of forward osmosis across various industries.In essence, this review provides valuable insights into forward osmosis technology, offering a comprehensive understanding for researchers and engineers alike. It serves as a guiding resource for further research and development efforts, contributing to the advancement of the field.

Overall, all these papers cover various aspects of forward osmosis technology, including its applications, performance, comparisons with reverse osmosis, and its potential in water treatment and desalination processes.

1.1 Advantages

Efficiency in Treating Industrial Effluents:

Forward osmosis is highly effective in treating industrial effluents containing various contaminants. The membranes exhibit efficiency, particularly when dealing with draw effluents with moderate to low concentrations of removable agents.

Flexibility in Membrane Adaptation:

FO membranes offer flexibility by adapting to the desired quality of the product water. This adaptability is beneficial when treating effluents with varying concentrations of contaminants.

Compatibility with Other Treatment Systems:

FO systems complement other treatment systems effectively, compensating for deficiencies that may exist in those systems. This versatility is valuable in complex industrial processes where multiple treatment methods are required.

Enhanced Efficiency in Product Recovery:

FO systems play a crucial role in processes where the recovery of specific products is essential to minimize costs or improve efficiency, such as in biogas production processes.

1.2 Limitations

High Fouling Factor:

A significant drawback of FO processes is the high fouling factor they may experience, especially when treating draw effluents with high saturation. Fouling occurs when the membrane becomes obstructed, requiring the process to be halted for membrane cleaning.

Process Interruption and Cleaning:

The fouling issue leads to process interruptions and the necessity for frequent membrane cleaning. This can impact operational efficiency and increase maintenance requirements.

Challenges with Membrane Technology:

The technology associated with FO membranes is still under development. The membranes currently used are expensive and may not be highly efficient or ideal for certain functions. This limitation may lead to the preference for other, cheaper, and simpler treatment systems in some instances.

Limited Membrane Technology Advancements:

The membranes used in FO processes face challenges in terms of advancements. The technology has yet to produce membranes that are both cost-effective and highly efficient for the desired functions, limiting the widespread adoption of FO in certain applications.

II.METHODOLOGY

Experimental Set Up

Conducting a forward osmosis (FO) lab experiment using the Aquaporin HFFO2 membrane or FO membrane test cell involves a series of steps. HFFO2 is a specific Aquaporin that can be used in FO experiments. Here's a basic methodology for conducting a Forward osmosis (FO) is osmotic processes that employ a semi-permeable membrane to separate water from dissolved solutes. In FO, a net flow of water is induced through the membrane into a "draw" solution of higher concentration relative to the feed solution, driven by an osmotic pressure gradient. This effectively separates the feed water from its solutes. In contrast, reverse osmosis relies on hydraulic pressure as the driving force for separation. This pressure counteracts the osmotic pressure gradient, preventing water flux from the permeate to the feed.

Desalination is achieved by producing desalinated water from the diluted draw solution resulting from the forward osmosis process. This can be accomplished through membrane separation, thermal methods, physical separation, or a combination of these processes. Forward osmosis-based desalination plants have been deployed in various locations, with National Geographic recognizing forward osmosis as a promising technology for reducing desalination's energy requirements.

Materials and Equipment:

Aquaporin HFFO2 or FO membrane test cell, Weighing machine, Peristaltic pump,
Feed solution (higher osmotic pressure),
Draw solution (lower osmotic pressure),
Containers for holding solutions.

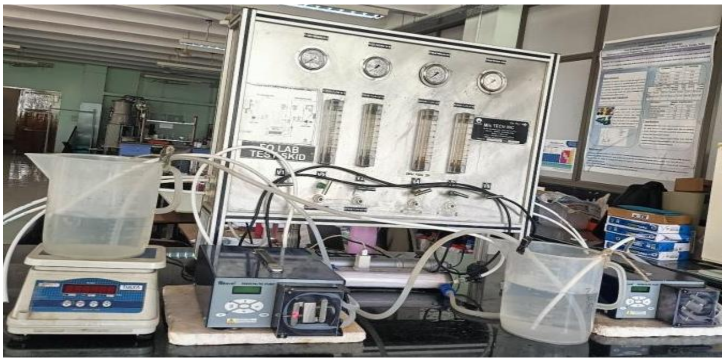

Fig 2 Experimental set up of Forward Osmosis

Experimental Steps:
Preparation of Solutions:
Prepare the feed solution by dissolving a known concentration of solute in distilled water.
Prepare the draw solution using pure distilled water.
Assembly FO cell with Aquaporin HFFO2 or FO membrane
Set up the FO cell with the Aquaporin HFFO2 or FO membrane in place.

Introducing Solutions to the FO Cell:
Fill the feed solution compartment of the FO cell with the prepared feed solution.
Fill the draw solution compartment with the prepared draw solution.

Conducting the Forward Osmosis Experiment:
Initiate the experiment by opening the valve or allowing the solutions to contact each other through the Aquaporin HFFO2 or FO membrane.
Monitor the system over time, measuring changes in volume, and any other relevant parameters.

Data Collection:
Record data at regular intervals.
Measure the volume changes.

Analysis:
Calculate the water flux and solute flux.
Analyse the efficiency of the Aquaporin HFFO2 or FO membrane in facilitating water transport.

Fig 3 Aquaporin HFFO2

2.1 Governing equations
FEED- DI water
DRAW- Waste water/NaCl/$MgCl_2$
Increase in Draw tank level= A ml
Time of Operation= B sec
Membrane Area= C cm^2
FO permeate flux= (A/1000 litres)/ (B/3600 hrs)/ (C/10000 m^2) litres/m^2/hr
Initial volume of feed=D ml
Final volume of feed =E ml
Concentration at time t=0= F mg/l
Concentration at final t=t in secs= Gmg/l
Reverse Salt Flux=(E/1000litres) x(G/1000gms/litre) -(D/1000litres) x(F/1000gms/litre) gms/m^2/hr
(Tf/3600hrs) x(C/1000x1000m^2)

III. RESULTS AND DISCUSSIONS

3.1 NaCl, MgCl2, Wastewater (Aquarium water)/DI
In the forward osmosis experiment, two jars were prepared initially. One jar was filled with a feed solution containing 2 litres of distilled water, while the other jar was filled with a draw solution(2litre) composed of NaCl. These solutions were connected through an Aquaporin module, with inlet and outlet tubes submerged in their respective solutions. The peristaltic pump was then activated, operating at a flow rate of 60 litres per hour (lph) for the feed solution and 25 lph for the draw solution. Volume measurements were taken at 15-minute intervals using a weighing machine. After 1 hour, conductivity measurements were recorded, showing a decreasing trend in draw solution conductivity over time. FO permeate flux and reverse salt flux were calculated utilizing established equations, and the results were tabulated and graphically represented. Subsequently, the draw solution was replaced with MgCl2, and the experiment was repeated following the same procedure to determine the FO permeate flux for MgCl2. The obtained values were also documented in the table. Finally, waste water samples were collected from an aquarium for initial water analysis, assessing various parameters. After treatment with the Aquaporin membrane, a post-treatment chemical analysis was conducted, revealing notable variations, particularly in the pH value, which shifted from 6.33 to 7.03. All other parameters indicated that the treated water was safe for domestic use.

3.1.1 fo permete flux
In forward osmosis, the "permeate flux" refers to the rate at which water molecules pass through a semi-permeable

membrane from the feed solution to the draw solution. This flux occurs due to the osmotic pressure gradient across the membrane, where water moves from an area of low solute concentration (the feed solution) to an area of high solute concentration (the draw solution).

3.1.2 reverse salt flux

In forward osmosis experiments, the concept of reverse salt flux involves the movement of salt ions from the draw solution into the feed solution through a semi-permeable membrane, contrary to the desired osmosis process. This phenomenon can occur due to various factors such as concentration polarization or membrane fouling. Monitoring and minimizing reverse salt flux are crucial in optimizing the efficiency of forward osmosis processes, particularly in applications like desalination and waste water treatment.

Table-1

FEED/DS	FEED WEIGHT (ml)	PERMEATE VOLUME (ml)	CONDUCTIVITY (DRAW) (µS or mS)	TIME (min)
DI/WASTE WATER	2000	2000	237.8 µS	0
	990	3010	162.4 µS	15
	546	3454	146.6 µS	30
	312	3688	142 µS	45
	233	3767	139.1 µS	60
DI/NaCl	2000	2000	92.9mS	0
	957	3043	46.8mS	15
	595	3405	44.5mS	30
	366	3634	44mS	45
	101	3899	23mS	60
DI/MgCl2	2000	2000	34.8 mS	0
	934	3066	28.4 mS	15
	509	3491	20.4 mS	30
	367	3633	14.83 mS	45
	288	3712	17.9 mS	60

Table-2

A(ml)	B(sec)	C(cm²)	FO PERMEATE FLUX (litres/m²/hr)
DI/WASTE WATER			
2020	900	23000	3.513043478
2908	900	23000	5.057391304
3376	900	23000	5.871304348
3534	900	23000	6.146086957
DI/NaCl			
2086	900	23000	3.627826087
2810	900	23000	4.886956522
3268	900	23000	5.683478261
3798	900	23000	6.605217391
DI/MgCl2			
2132	900	23000	3.707826087
2982	900	23000	5.186086957
3266	900	23000	5.68000000
3424	900	23000	5.954782609

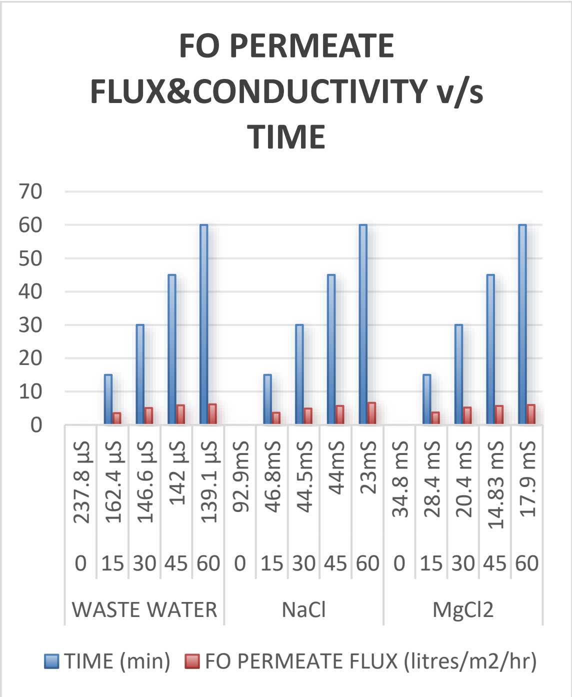

Fig 4 FO permeate flux and time graph

Table-3

FEED CONCENTRATION (g/l)	DRAW CONCENTRATION (g/l)	REVERSE SALT FLUX) (gms/m²/hr)
1M NaCl/DI		
0.00416232	0.02072304	0.1027423834
0.00737262	0.0197046	0.1090564419
0.01434672	0.0194832	0.1140018248
0.003670812	0.0101844	0.0684143

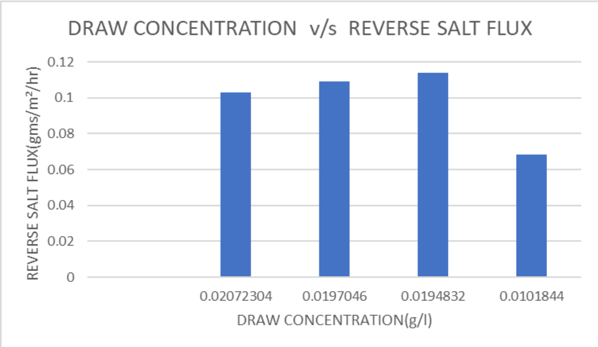

Fig 5 Draw concentration and reverse salt flux graph

3.2. Chemical Analysis

Chemical Analysis of Aquarium Waste water pH at 25 °C: 6.33. The pH of the aquarium water is slightly acidic, indicating a relatively neutral environment for aquatic life.

Colour, Hazen: 10. The slightly acidic pH is generally acceptable for freshwater aquariums, but regular monitoring is recommended to prevent significant fluctuations. The Hazen colour measurement of 10 suggests a clear appearance in the water, indicating low levels of suspended particles or organic matter.

Turbidity, NTU: 15. Turbidity at 15 NTU is within the acceptable range, signifying moderately clear water with a low concentration of suspended particles. Clear water (low Hazen colour) and moderate turbidity suggest effective filtration and low levels of suspended solids.

Total Dissolved Solids, mg/l: 244.The total dissolved solids (TDS) concentration of 244 mg/l represents the sum of inorganic and organic substances dissolved in the water.

Total Hardness as $CaCO_3$, mg/l: 55. The total hardness of 55 mg/l as $CaCO_3$ indicates moderately soft water, which is suitable for many freshwater species.

Total Alkalinity as $CaCO_3$, mg/l: 72.A total alkalinity of 72 mg/l as $CaCO_3$ suggests a stable buffering capacity, which helps resist fluctuations in pH.

Chloride as Cl-, mg/l: 24. The chloride concentration of 24 mg/l is within the acceptable range, contributing to the overall salinity and ion balance in the water.

Sulphate as SO_4^{2-}, mg/l: 2. The low sulphate concentration of 2 mg/l indicates minimal impact on water quality.

Low levels of chloride and sulphate indicate a balanced ion composition in the water.

The absence of detectable iron is positive, minimizing the risk of aesthetic and health-related issues Calcium as Ca, mg/l: 19.01. Adequate calcium levels at 19.01 mg/l support the structural integrity of aquatic organisms and contribute to water hardness.

Table-4

PARAMETERS	BEFORE TREATMENT	AFTER TREATMENT
pH at 25 °C	6.33	7.03

Colour,Hazen	10	BDL
Turbidity,NTU	15	0.5
Total Dissolved Solids,mg/l	244	305
Total Hardness as CaCO3,mg/l	55	32
Total Alkalinity as CaCO3,mg/l	72	78
Chloride as Cl-,mg/l	24	184
Sulphate as SO_4^{2-}mg/l	2	1.33
Calcium as Ca,mg/l	19.01	8
Magnesium as Mg,mg/l	1.92	2.92
Iron as Fe,mg/l	BDL	BDL
BOD,mg/l	14.4	1.28
COD	40	8

Magnesium as Mg, mg/l: 1.92. The magnesium concentration of 1.92 mg/l is at an acceptable level, supporting biological functions in aquarium organisms.

Iron as Fe, mg/l: BDL (Below Detectable Limits). The absence of detectable iron is positive, as excess iron can lead to issues such as algae growth and cloudiness.

BOD, mg/l: 14.4. The biochemical oxygen demand (BOD) of 14.4 mg/l represents the amount of oxygen required by micro-organisms to decompose organic matter. Monitoring BOD is crucial for assessing the biological load on the aquarium.

COD: 40. The chemical oxygen demand (COD) value of 40 indicates the amount of oxygen needed for chemical oxidation of pollutants. This parameter provides insights into the overall pollution level in the water.BOD and COD values provide insights into the organic load and overall water quality, indicating a moderate level of pollution.

3.3 Standards of water quality

Water, being the second most essential element for life after air, necessitates a comprehensive understanding of its quality. The widely accepted definition of water quality encompasses the physical, chemical, and biological attributes of water. Classifying water based on its source results in two primary categories: ground water and surface water, both susceptible to contamination from various sources such as agricultural, industrial, and domestic activities, leading to pollutants like heavy metals, pesticides, fertilizers, hazardous chemicals, and oils. Water quality is typically categorized into four types: potable water, palatable water, contaminated (polluted) water, and infected water. Potable water is safe for consumption, pleasant in taste, and suitable for domestic use, while palatable water is deemed safe due to the absence of chemicals posing threats to human health. Contaminated water contains undesirable substances, rendering it unfit for drinking or domestic purposes, and infected water harbours pathogenic organisms. There are three primary parameters used to assess water quality: physical, chemical, and biological. Physical parameters include turbidity, a measure of water cloudiness caused by suspended materials, and temperature, influencing various chemical reactions and biological processes. Colour, taste, and odour, influenced by organic and inorganic matter, are also considered physical parameters. Electrical conductivity (EC) measures the water's ability to conduct electrical current and is vital for determining suitability for irrigation and fire fighting. Chemical parameters include pH, indicating the acidity or basicity of water, chloride concentration, often indicative of waste water pollution, and hardness, expressing the mineral content causing scale deposits and soap-related issues. Dissolved oxygen (DO) is a critical chemical parameter in assessing water pollution; higher concentrations signify better water quality. Biological parameters involve the presence or absence of living organisms, with species diversity indexes serving as indicators of water quality. Bacteria, exhibiting various shapes and rapid reproduction, are important biological indicators. Water quality standards, established by governmental agencies, encompass in-stream, potable water, and waste water effluent criteria. The World Health Organization (WHO) has set minimum standards for drinking water that countries are encouraged to meet, underscoring the global importance of maintaining high water quality standards.

Table-5

PHYSICAL	
Temperature	10 °C to 15 . 6 °C
Odour	0 to 4 p0 value
Colour	10 to 20(platinum cobalt scale)
Turbidity	5 to 10 p.p.m..(silica scale)
Taste	No objectionable taste
CHEMICAL& BIOLOGICAL	
Total solids	Up to 500 p.p.m.
Hardness	75 p.p.m. to 115 p.p.m..(hardness expressed as CaCO3 equivalent)
Chlorides	Up to 250 p.p.m.
Iron and Manganese	Up to 0.3 p.p.m.
PH value	0.5 to 8
Lead	0.1 p.p.m.
Arsenic	0.05 p.p.m.
Sulphate	Up to 250 p.p.m.
Carbonate Alkalinity	Up to 120 p.p.m.
Dissolved oxygen	5 to 6 p.p.m.
B.O.D	Nill
B-coli	No B-coli in 100ml
Most Probable Number	1 No in 100ml
B-coli	No B-coli in 100ml

3.4 Aquaporin rejection

The investigation focused on assessing the efficacy of forward osmosis membranes incorporating Aaquaporin, utilizing draw solutions derived from waste water sourced from an aquarium. The outcomes consistently revealed rejection rates exceeding 99% across all experimental conditions. Additionally, the study demonstrated that membrane rinsing post-fouling effectively restored the initial water flux and eliminated residual foulants on the membrane surface. This finding underscores the robustness of the Aquaporin-based forward osmosis technology in achieving superior solute rejection and minimal fouling susceptibility.

IV.CONCLUSIONS

The chemical analysis reveals generally favourable water conditions for the aquarium. By addressing minor concerns and implementing recommended measures, the overall health and well-being of the aquatic environment can be sustained. Regular monitoring and proactive management will contribute to a thriving aquarium ecosystem.In conclusion, the utilization of Aquaporin-based forward osmosis membranes, coupled with draw solutions from aquarium waste water, proved highly effective with rejection rates consistently surpassing 99%. After treatment pH value varring 6.33 to 7.03. This promising outcome not only highlights the technology's efficiency in water treatment but also emphasizes its potential for sustainable and low-energy solutions in addressing water quality challenges.

REFERENCES

1. *Tzahi Y. Cath, Amy E. Childress, Menachem Elimelech. "Forward osmosis: Principles, applications, and recent developments", Journal of Membrane Science 70–87(2006).*
2. *Sherub Phuntsho, Saravanamuthu Vigneswaran , Jaya Kandasamy , Seungkwan Hong , Sangyoup Lee , Ho Kyong Shon."Influence of temperature and temperature difference in the performance of forward osmosis desalination process", Journal of Membrane Science,734–744(2012).*
3. *Shuaifei Zhao, Linda Zou, Chuyang Y. Tang, Dennis Mulchy. "Recent developments in forward osmosis: Opportunities and challenges", Journal of Membrane Science,Volume 396, , Pages 1-21(2012).*
4. *Ali Altaee, Guillermo Zaragoza, H. Rost van, Tonningen. "Comparison between Forward Osmosis-Reverse Osmosis and Reverse Osmosis processes for seawater desalination", Desalination,50-57(2014).*
5. *Kerusha Lutchmiah, A.R.D. Verliefde, K. Roest, L.C. Rietveld, E.R. Cornelissen. "Forward osmosis for application in wastewater treatment: A review'',Water research,179-197(2014).*
6. *Devin L. Shaffer, Jay R. Werber, Humberto Jaramillo, Shihong Lin, Menachem Elimelech. "Forward osmosis: Where are we now?",Desalination,Volume 356, Pages 271-284(2015).*
7. *N.S. Terefe, F. Janakievski , O. Glagovskaia , K. De Silva , M. Horne , R. Stockmann ."Forward Osmosis: A Novel Membrane Separation Technology of Relevance to Food and Related Industries",Innovative Food Processing Technologies Extraction, Separation, Component Modification and Process Intensification,Woodhead Publishing Series in Food Science, Technology and Nutrition, Pages 177-205(2016).*
8. *Kiho Park, Hwan Heo, Do Yeon Kim, Dae Ryook Yang. "Feasibility study of a forward osmosis/crystallization/reverse osmosis hybrid process with high-temperature operation: Modeling, experiments, and energy consumption'', Journal of Membrane Science (2018).*
9. *Farrukh Arsalan Siddiqui, Qianhong She, Anthony G. Fane, Robert W. Field."Exploring the Differences between Forward Osmosis and Reverse Osmosis Fouling" ,Journal of Membrane Science(2018).*
10. *Nayla Hassan Omer."Water Quality Parameters",Web Of Science, Water Quality - Science, Assessments and Policy (2019).*
11. *[11] Maria Salud Camilleri-Rumbau, Jose Luis Soler-Cabezas, Knud V. Christensen, Birgir Norddahl, Jose Antonio Mendoza-Roca, Maria Cinta Vincent-Vela."Application of aquaporin-based forward osmosis membranes for processing of digestate liquid fractions", Chemical Engineering Journal(2019) .*
12. *Wei Lun Nag, Abdul Wahab Mohammad, Daniel Johnson, Nidal Hilal. "Forward osmosis research trends in desalination and wastewater treatment: A review of research trends over the past decade", Journal of Water Process Engineering Volume 31, 100886(2019).*
13. *Wafa Suwaileh, Nirenkumar Pathak, Hokyong Shon, Nidal Hilal. "Forward osmosis membranes and processes: A comprehensive review of research trends and future outlook", Desalination, Volume 485, 1144551 (2020).*
14. *Ahmed F. Donia, Wael I. Mortada. "Chemical composition of zamzam water:A comparative study with international standards of drinking water",Helyon7,e06038(2021).*
15. *Jianlong Wang, Xiaojing Liu. "Forward osmosis technology for water treatment: Recent advances and future perspectives", Journal of Cleaner Production,124354(2021).*
16. *I.G. Wenten, K. Khoiruddin, R. Reynard, G. Lugito, H. Julian. "Advancement of forward osmosis (FO) membrane for fruit juice concentration", Journal of Food Engineering,Volume 290, 110216(2021).*
17. *Jianlong Wang, Xiaojing Liu. "Forward osmosis technology for water treatment: Recent advances and future perspectives", Journal of Cleaner Production,Volume 280, Part 1, 124354(2021).*
18. *Jaouad Eddouibi, Souad Abderafi, Sébastien Vaudreuil, Tijani Bounahmidi. "Water desalination by forward osmosis: Dynamic performance assessment and experimental validation using MgCl2 and NaCl as draw solutes", Computers & Chemical Engineering,Volume 149, 107313(2021).*
19. *Lin Wang, Tian Li, Huaqiang Chu, Wanzhu Zhang, Weiwei Huang, Bingzhi Dong, Daoji Wu, Feiyong Chen. "Natural organic matter separation by forward osmosis: Performance and mechanisms", Water Research,Volume 191, 116829(2021).*
20. *Fazeleh Khanate, Soheila Shokrollahzadeh, Yasamin Bide, Shabnam Sheshmani, Ashraf S. Shahvelayati. "High-Flux sodium alginate sulfate draw solution for water recovery from saline waters and wastewaters via forward osmosis", Chemical Engineering Journal,Volume 417, 129250(2021).*
21. *Soleyman Sahib, Mohammad Sheikhi, Mohammad Karis, Nasim Faddier, Zahra Shabani , Sanaz Ghiasi , Norollah Kasiri , Toraj Mohammadi ."Chapter 8 - Reverse and forward osmosis membrane technologies",Advancement in Polymer-Based Membranes for Water Remediation, Pages 275-309(2022).*
22. *Jiaheng Teng , Hanmin Zhang , Hongjun Lin , Junsheng Wang , Fangang Meng d, Yuezhu Wang , Mengyang Lu ."Synergistic fouling behaviors and thermodynamic mechanisms of proteins and polysaccharides in forward osmosis: The unique role of reverse solute diffusion",Desalination,Volume 536, 115850, (2022).*
23. *Chaoui , Issa Ndiaye , Jaouad Eddouibi , Souad Abderafi , Sébastien Vaudreuil , Tijani Bounahmidi ."Experimental and theoretical parametric study of forward osmosis system using NH4HCO3 and NaCl draw solutes",Chemical Engineering Research and Design,Volume 180, Pages 402-413(2022).*
24. *Satish Kumar Singh, Chhaya Sharma, Abhijit Maiti. "Modeling and experimental validation of forward osmosis process: Parameters selection, permeate flux prediction, and process optimization", Journal of Membrane Science,Volume 672, 121439(2023).*
25. *Dsilva Winfred Rufus, Ebrahim Hosseinipour , S. Arulvel , P.A. Davies ."Complete parametric investigation of a forward osmosis process using sodium chloride draw solutionn",Desalination,Volume 547, 116218(2023).*
26. *Nada Abounahia, Ibrar Ibrar , Tayma Kazwini , Ali Altaee , Akshaya K. Samal , Syed Javaid Zaidi , Alaa H. Hawari ."Desalination by*

the forward osmosis: Advancement and challenges",Science of The Total Environment,Volume 886, 163901(2023).

27. *Xinning Zhang, Paula Jungwon Choi, Noman Khalid Khanzada , Pak Wai Wong , Alicia Kyoungjin An ."Highly permeable chlorine-resistant forward osmosis membrane by grafting novel sulfonamide monomers",Desalination,Volume 564, 116754(2023).*
28. *Kuo Sun, Qiang Lyu , Xiangyong Zheng , Renlan Liu , Chuyang Y. Tang , Min Zhao , Yingchao Dong ."Enhanced water treatment performance of ceramic-based forward osmosis membranes via MOF interlayer",Water Research,Volume 254, 121395(2024).*
29. *Hao Zhang, Jingyi Liang, Zhikang Li, Feng Xiao, Yanhui Wu, Chaojie Zhang. "Preparation of Forward osmosis composite membrane with Chitosan/Tannic acid co-deposition interlayer and its fluoride removal performance", Separation and Purification Technology,Volume 330, Part A, 125300, (2024).*
30. *Satish Kumar Singh, Chhaya Sharma, Rajesh Mahadeva , Shashikant, Patole , Abhijit Maiti."Predicting forward osmosis performance with synthesized polyamide-based membrane: An integrated machine learning (MATLAB and ANN) and economic analysis framework",Journal of Cleaner Production,Volume 444, 141285(2024).*