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Integration of Enhanced Direct Contact Membrane Distillation and Parabolic Trough Reflector: A Sustainable Solution for Water Quality Issues in Bangladesh

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I. Abstract

Bangladesh faces significant challenges related to water quality. This research addresses Bangladesh's water crisis, characterized by increasing salinity, contamination from heavy metals (especially arsenic), pathogens, and other pollutants. Leveraging the country's abundant solar potential, we present a self-sufficient, reliable and sustainable method to purify water, ensuring safe drinking access.

We propose the combination of pre-existing **Direct Contact Membrane Distillation (DCMD)** with few modifications, which include: employment of superhydrophobic coating of fluorinated silicon nanoparticles (SiF-NPs) on the surface of 1-Hexene grafted Polypropylene (PP) membrane. Moreover, efficient vortex generators were included for increasing the turbulence. These modifications address current limitations, such as: membrane fouling, membrane wetting, temperature and concentration polarization, and the proposed model results in increased permeate flux, increased Water Contact Angle (WCA), increased vapor passage and increased salt rejection rates. Furthermore, pre-filtration, inclusion of chemical cleaning of the membrane enhances the life span of the DCMD membrane which is very crucial for a developing country like Bangladesh.

For heating the water required for DCMD, **Parabolic Trough Reflector (PTR)**, utilizing the metallic wastes, were introduced. The modified PTR with optimized geometry, Heat Transfer Fluid (HTF), solar tracking ability, and improved heat transfer texture makes it an ideal choice as the supplier of heat for the feed solution in DCMD. A self-sufficient system using Photovoltaic (PV) cells, used to power the tools, suits the rural economy of Bangladesh. Our integrated approach ensures safe drinking water for an average village, even amidst elevated salt concentration and heavy contaminants.

If commercially implemented according to our proposed model, each person within the water plant range will daily receive an average of five liters of safe distilled water for culinary use and drinking as a part of our integrated solution for drinking water problems.

II. Table of Contents

Unless otherwise noted, all images were made by the student researchers.

III. Key words

Direct Contact Membrane Distillation, Parabolic Trough Reflector, Superhydrophobic nanoparticle, Polypropylene membrane, Temperature Polarization, Concentration Polarization, Membrane Fouling, Membrane Wetting, Desalination, Water purification, Sustainable system, Heavy Metal Contamination, Arsenic removal, Water Independence, Reusing metallic waste.

IV. Abbreviations and Acronyms

DCMD	Direct Contact Membrane Distillation	**PP**	Polypropylene
PTR	Parabolic Trough Reflector	**SiF-NPs**	Fluorinated Silicon Nanoparticles
MD	Membrane Distillation	**KW**	Kilowatt

V. Acknowledgements

With profound gratitude, we acknowledge the invaluable mentorship of Mr. Abdul Khaleque throughout the course of this research project. His extensive experience and wisdom in the field proved to be an indispensable resource, and his insightful directives consistently steered us towards the most productive avenues of inquiry. Mr. Khaleque's unwavering support and encouragement, particularly during moments of challenge, were instrumental in ensuring the smooth and efficient execution of this research. We are deeply indebted to his dedication and commitment to our success, and we recognize that the successful completion of this project would not have been possible without his guidance.

VI. Biography:

Rafsan Jani, currently enrolled in the eleventh class at Rajshahi Cadet College, is an emerging student researcher dedicated to harnessing engineering principles to address pressing global challenges. With a particular focus on power generation, Rafsan seeks to devise innovative strategies to surmount existing barriers in this vital sector. His commitment is further intensified by his profound concern for environmental sustainability. Rafsan posits that breakthroughs in power generation technology are essential for forging a path towards a more sustainable future. This dedication was prominently displayed when he participated in a campus creativity exhibition in 2022, presenting his project “HAYTHAM X ONE”. The project garnered the top award for its insightful, sustainable, and eco-friendly concept to mitigating Bangladesh's prevailing acute power shortages. Since this accolade, Rafsan has continued to actively conceptualize and refine solutions to real-world issues. In addition, he consistently participates in various national Olympiads and has achieved commendable success in several of them.

Zarif Hasan Mahmud Alvi, also a Class 11 student at Rajshahi Cadet College, possesses an unwavering passion for learning and an innovative mindset specifically geared toward the field of science. As a true science enthusiast, he has demonstrated proficiency in verbal communication. Notably, he actively contributed to project “HAYTHAM X ONE”, where he played a pivotal role in devising an integrated approach for renewable energy. With a resolute determination, Zarif aspires to transform his passion into a fulfilling career. His commitment to scientific exploration and sustainable solutions is commendable and promises a bright future ahead.

1. Introduction

1.1 Problem

Having access to safe and clean drinking water is essential to human survival. But for a variety of reasons, a significant amount of the population in Bangladesh is deprived of this fundamental necessity. Bangladesh, a nation intersected by numerous rivers and situated on the world's largest delta, ironically grapples with severe water-related issues. Despite its abundant water resources, the populace of Bangladesh confronts water scarcity and pollution on a regular basis. As per a study by Water Org, an estimated 40% of the population lacks access to clean drinking water, and 11.8% are exposed to polluted water sources. In Bangladesh, waterborne diseases have severe consequences, affecting health and well-being. Diarrhea, gastrointestinal illnesses, and skin infections are prevalent, emphasizing the need for water management and sanitation efforts.

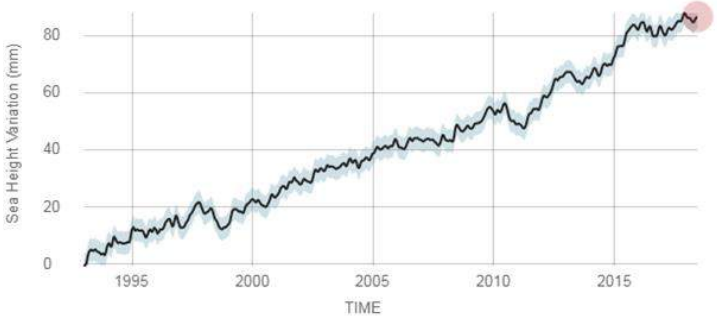


Image 1: Satellite sea level observations (Courtesy: NASA Goddard Space Flight Center)

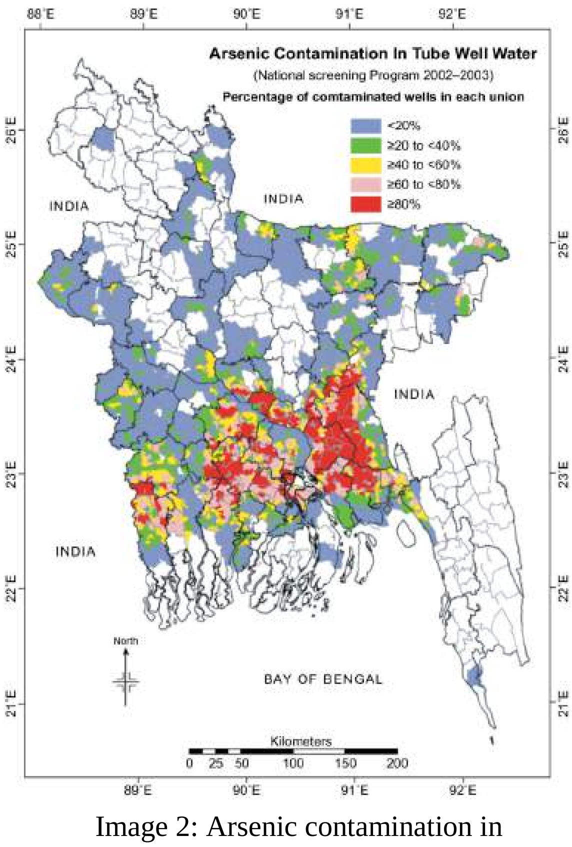


Image 2: Arsenic contamination in underground water in Bangladesh (Courtesy: ResearchGate)

Furthermore, Bangladesh ranks among the nations most susceptible to the repercussions of climate change. The rising sea levels and increased salinity attributed to climate change pose a substantial risk to human health. When saline water seeps into freshwater sources, the water becomes unsuitable for drinking. Unfortunately, many people in Bangladesh, particularly those in coastal areas, are forced to drink water with high salinity levels. This saline water can have a number of negative health consequences, including: High Blood Pressure, Pregnancy Complications, and Digestive Issues. According to The Financial Express, climate change could potentially affect the country's agricultural land, thereby threatening the livelihoods of millions.

Arsenic poisoning from contaminated drinking water is a major issue to be addressed in Bangladesh. The World Health Organization recommends a maximum arsenic level of 10 micrograms per liter (µg/L), but Bangladesh's standard is 50 µg/L due to the widespread contamination. Studies indicate roughly 57 million Bangladeshis are at risk, with estimates suggesting 35-77 million consuming water exceeding even the relaxed national limit. Arsenicosis is a crippling illness that can result from prolonged exposure and cause internal malignancies, cutaneous sores, and even death.

For all these reasons the most fundamental human need—clean drinking water—becomes a continual source of concern.

So, considering the increasing trash generation, water pollution, and resource depletion we propose a solution to all of these problems. This very waste could be the path to a more promising future. Although they are essential for solar thermal energy systems, parabolic trough reflectors (PTRs) can be costly due to their traditional materials. The metalized plastics that are thrown in Bangladesh hold a startling solution. Even if they're not ideal, these plastics have a reflecting quality that could be used. This invention addresses two issues at once: reuse of trash and the development of a less expensive solar energy substitute. Widespread adoption could reduce reliance on fossil fuels, improve Bangladesh's access to renewable energy, and pave the way for a more sustainable future.

1.2 Engineering Goal

The main goal of this research is to provide a PV powered sustainable, efficient, and cost-effective method of obtaining fresh drinking and cooking water from contaminated and salty water by combining activated charcoal, redesigned DCMD, and improved PTR. Unlike current DCMD and PTR methods, the proposed devices specifically target the removal of minerals, arsenic, heavy metals, pathogens, organic wastes, etc. from water while simultaneously lowering the ecological footprint of waste, which will be used in the production of PTR. The devices are intended to be practically applicable and meaningful in their implementation.

1.3 Materials

For pre-filtration, proposed materials are:

- Activated charcoal

The materials proposed for producing the membrane base [1] and coating [2] include:

- Flat polypropylene membrane with 0.0073 m^2 surface area (A), 0.45 μm pore size, 114 μm thickness, and 84.6% porosity
- 1-hexene (97%);
- Benzophenone (98.5%);
- Acetone (99.5%); and sodium chloride ACS reagent
- Poly vinylidene fluoride-co-hexafluoropropylene,
- PVDF–HFP, (average Mw ∼ 455 000, Mn ∼ 110 000)

PTR can be made from Recycled materials, such as:

- Stainless Steel or Aluminum Sheets
- Plywood and conventional wood
- Steel Tubes
- Copper Tubes
- Mylar, Vinyl, Reflective Aluminum with a PVD Protective Coating

For Chemical Cleaning, materials proposed are:

- <3% citric acid
- <0.3% NaOCl
- 0.3% Ethylenediaminetetraacetic Acid (EDTA)
- 3% hydrochloric acid (HCl)

1.4 Principal Objective

This research suggests an innovative solution in light of the growing issue of a shortage of clean drinking water, especially in rural Bangladesh where groundwater sources are contaminated. Our goal is to create an independent water treatment plant that is especially made to help these underprivileged communities. The objective are cited below:

1. Efficient and All-Inclusive Water Purification:

- Ultrafiltration for Comprehensive Purification: To remove a wide range of contaminants the system will use a modified Direct Contact Membrane Distillation (DCMD) technique. The World Health Organization (WHO) requirements are met when clean, safe drinking water is produced using this ultrafiltration method.
- Accessibility for All: By establishing a centralized facility, all local households will have easy access to the treated water, greatly enhancing public health and wellbeing.

2. Renewable and Sustainable Energy Source:

- Grid Independence and Lower Burden: Using Parabolic Trough Reflector (PTR) fueled by plentiful solar energy, the suggested system places a high priority on self-sufficiency further complemented by Photovoltaic Module. By doing this, reliance on the national grid is eliminated, relieving pressure on the current power infrastructure and guaranteeing continuous functioning.
- Net-Zero Carbon Impact and Financial Gains: Utilizing solar energy as the facility's main power source reduces its environmental effect and helps create a cleaner future for the community. Furthermore, this strategy supports a sustainable and resource-efficient economy, which is in line with Bangladesh's developmental objectives.

3. Ecologically safe and sound:

- Safe Water Waste Management: For the concentrated brine generated during the DCMD process, the system integrates a sustainable waste management plan. This could entail exploring possible prospects for resource recovery or even safe disposal techniques.
- Cooperation for UN Sustainable Goals: The Sustainable Development Goals (SDGs) of the United Nations, especially those pertaining to clean water, safe drinking water, and responsible consumption and production, will be closely followed in the facility's design and operation.

4. Driving Innovation for Impactful Solutions:

- Combining Promising Technologies: This project champions innovation by integrating a modified DCMD system with a solar-powered PTR. This novel approach optimizes the efficiency and effectiveness of water treatment while minimizing energy consumption.
- Smart Solutions for Pressing Issues: The project addresses the critical issue of water scarcity in rural Bangladesh with a well-researched and strategically designed solution, offering a sustainable path towards a healthier future for these communities.

2. Pre filtration for boosting the efficiency of modified DCMD

Pre-filtration will primarily be used to reduce membrane fouling in the DCMD membrane as well as wear and tear and obstruction throughout the entire system, guaranteeing smooth conduction. The primary component of this unit will be activated charcoal; the purified water process only takes a few minutes as water passes through an activated carbon filter. Compared to conventional filtration methods, which might take several hours, this takes a lot less time [3]. A different tank will be used to hold this water. The pre-filtration unit is not too precious at filtering water as DCMD is used for that purpose.

3. Modified DCMD in action

3.1 DCMD

Direct Contact Membrane Distillation (DCMD) is a configuration of membrane distillation (MD), a thermally driven separation process. In DCMD, both the feed and permeate solutions are in direct contact with a hydrophobic porous membrane. The water vapor transferred across the membrane is directly condensed in a cold permeate inside the membrane module. [4]

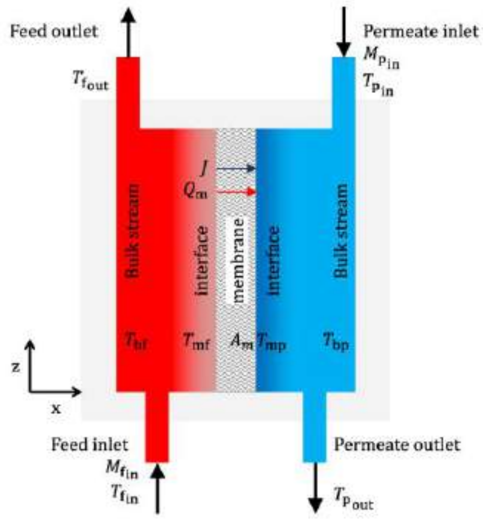


Image 3: Principle of DCMD (Courtesy: ScienceDirect)

The nature of DCMD's thermal driving force causes nonvolatile solutes such as salts, colloids, and macromolecules to be almost completely retained by the membrane. (Direct Contact Membrane Distillation (DCMD) Applications, First Online: 01 January 2015). [4] The salt rejection of an efficient DCMD membrane is up to 99.98%. So, the water which is contaminated by impurities such as salt, colloids, macromolecules, organic impurities (bacteria and pathogens), sediments and other chemical impurities. But the major problems of the prevailing DCMD is the requirement of high temperature feed water, temperature polarization, concentration polarization, membrane fouling and membrane wetting. [5]

Temperature Polarization refers to the temperature difference between the bulk feed and permeate solutions and their corresponding temperatures at the membrane/solution interface in DCMD, which often limits mass transfer in DCMD. **Concentration Polarization** is a phenomenon where the concentration of solutes at the membrane surface is higher than in the bulk of the solution. In DCMD, it can reduce mass flux by nearly 10%. **Membrane Fouling** is the accumulation of unwanted materials on the surface or in the pores of the membrane, leading to a decrease in performance. **Membrane Wetting** occurs when the pores of the hydrophobic membrane fill with liquid, reducing the performance of the DCMD process. Wetting is more significant at high feed temperatures, and salts in the feed can promote it. [5]

3.2 Modification

We intend to overcome the limitations of the prevailing DCMD in the following ways:

First off, the proposed DCMD membrane is a 1- Hexene Grafted Polypropylene membrane, which has demonstrated potential advantages in terms of enhanced mass and heat transfer coefficients, higher flux of vapor permeate, etc. Grafting 1-Hexene, which has non-polar characteristics and is reasonably inexpensive, further enhances PP's low surface energy, high mechanical capabilities, and chemical durability. 1-Hexene causes a more than 10% rise in the membrane's vapor flux as well as a 15.2% increase in the heat transfer coefficient overall. However, the grafting reduces the hydrophobicity of the membrane. (ACS Omega 2022, 7, 44903−44911) [1]

Therefore, in order to resolve the problems and also enhance effectiveness, superhydrophobic coating of fluorinated silicon nanoparticles (SiF-NPs) had been used at a thickness of 15 micrometers (optimal thickness, since an increase in thickness can reduce the permeability flux) to address membrane wetting. The Surface Energy (SFE) calculation revealed that, as a result of flourosilanization, the coating considerably reduces the membrane's SFE from 5.46 to 0.3 mJ m^2, preventing membrane wetting. [2] Furthermore, the addition of a superhydrophobic particle layer changed the interface between water and the polymer matrix, increasing the vapor/membrane surface area and lowering the temperature and concentration polarization. This resulted in a flux of 17 liters per square meter per hour (LMH) in the modified membrane, which is nearly three times higher. Consequently, they lessen membrane fouling as they lessen the absorption of organic molecules. The net gain in permeate flux was 40%. [2]

Thirdly, we embed vortex generators in the opposite side of the membrane in the wall of the flow field. The fundamental characteristics of turbulent flow are that it is dissipative and diffusive; it spontaneously spreads heat energy as well as concentration of impurities in the feed solution. All previous studies done in this sector acknowledged the importance of turbulence in reducing temperature and concentration polarization. But they proposed using spaces on the membrane which reduces the surface of absorption flux, reducing the benefit of spacers. That is why we embed vortex generators on the wall of flow field so that the surface area is not reduced but turbulence is generated. Excessive turbulence can also exert compressive pressure on the membrane surface, especially when using a compressible membrane. But 1-Hexene graft increases structural rigidity hence the effect is minimized.

Computational fluid dynamics (CFD) simulations were used by El Kadi et al. (2020) to assess spacer-filled DCMD modules. They discovered that, in comparison to spacer-free modules, conductive spacers enhance DCMD performance [6]. To be more precise:

i) Concentration polarization was reduced;
ii) Mass flux increased by 35%;
iii) Heat flux improved by 31%;
iv) Thermal efficiency increased by 1%; and
v) Heat transfer coefficients on membrane surfaces were enhanced.

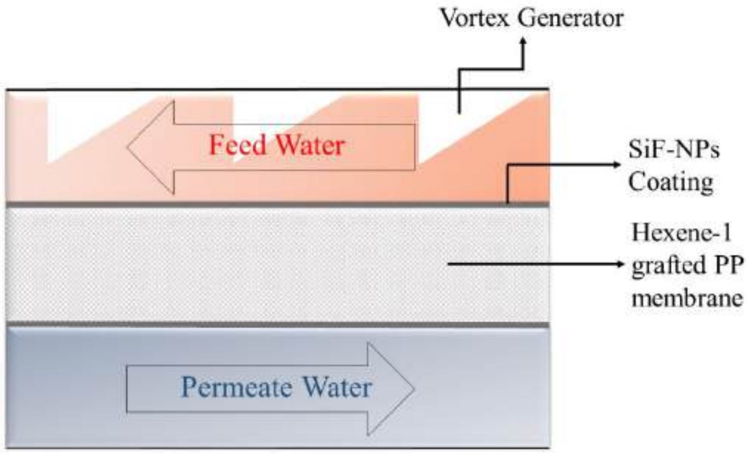


Image 4: Modified DCMD

3.3 Chemical and Vibration Cleaning of the Membrane

The four basic forms of fouling that limit membrane flux are colloidal, organic, inorganic, and biological [7].Chemical cleaning, an effective way to reduce fouling, will successfully remove four different kinds of pollutants. The effectiveness of several agents, including citric acid, sodium hypochlorite (NaOCl), and ethylenediaminetetraacetic acid (EDTA). One can utilize a variety of cleaning solutions, such as sodium dodecyl sulfate (SDS) cleaning, citric acid, EDTA-NaOH, hydrogen chloride (HCl)-sodium hydroxide (NaOH), and so on.

In our case, Permeate flux recovery increased in the following order, according to the results: <3% citric acid <0.3% NaOCl ≈ 0.3% EDTA 2. Up to 70–85% of the permeate flux (flow) was restored by combining NaOCl conditioning with 3% hydrochloric acid (HCl) cleaning of the membrane afterward [8].Together, they produce a chelating agent to reestablish the flow, a sanitizing agent, and a detergent agent.

Vibration cleaning is another method used to control membrane fouling. The application of mechanical vibration has been explored as a low-cost alternative to reduce harmful heavy chemicals. The vibration reduces the contaminated layer by utilizing the shear force exerted on the feed side of the membrane by the air bubbles. The combination of both the chemical and vibration process ensure the membrane stays in peak performance for extended period.

3.4 Calculations

Membrane Porosity (ε): This is the fraction of the membrane volume that is void or, in other words, the fraction of the volume that is not occupied by the membrane material. In this case, ε = 84.6% or 0.846.

Pore Size (R): The diameter of the pores in the membrane. Here, r = 0.5 micrometers or 0.5×10^{-6} meters.

Membrane Thickness (δ): The thickness of the membrane. Here, δ = 130 micrometers or 130×10^{-6} meters.
Target Water Outflow (Q): The desired volume of water to be filtered per unit time. Here, Q = 30 liters per minute or 30×10^{-3} m^3/min or 0.5×10^{-3} m^3/sec.

Optimal Pressure (ΔP): The pressure difference across the membrane required to achieve the most efficient filtration. The optimal pressure can vary depending on the specific membrane and system, but for the purpose of these calculations, we’ll assume that we’re operating at this optimal pressure.

Effective Membrane Area (A): This is the total area of the membrane that is available for filtration. It can be calculated from the target water outflow (Q), membrane porosity (ε), pore size (R), membrane thickness (δ), and optimal pressure (ΔP) using the Hagen-Poiseuille equation for flow through a cylindrical pore:

$$A = \frac{8 \cdot Q \cdot \mu \cdot \delta}{\pi \cdot \varepsilon \cdot \Delta P \cdot r^2}$$

Where μ is the dynamic viscosity of water. At room temperature (20°C), μ ≈ 1 x 10^-3 Pa·s.

Flux per Unit Time (J): This is the volume of water that passes through a unit area of the membrane per unit time. It can be calculated as:

$$J = \frac{Q}{A}$$

Water Velocity (v): This is the velocity of the water passing through the pores of the membrane. It can be calculated as:

$$v = \frac{J}{\varepsilon}$$

Mass Flow Rate (ṁ): This is the mass of water that passes through the membrane per unit time. It can be calculated from the volumetric flow rate (Q) and the density of water (ρ), as follows:

$$\dot{m} = Q \cdot \rho$$

Where ρ is the density of water. At room temperature (20°C), ρ ≈ 1000 kg/m³.

Permeate Flux (J): This is the volume of water that passes through a unit area of the membrane per unit time. It can be calculated from the volumetric flow rate (Q) and the effective membrane area (A), as follows:

$$J = \frac{Q}{A}$$

Transmembrane Pressure (ΔP): This is the difference in pressure between the feed and permeate sides of the membrane. In DCMD, this is typically the vapor pressure difference across the membrane, which can be calculated from the temperatures of the hot feed (T_h) and cold permeate (T_c) using the Antoine equation for the vapor pressure of water:

$$\Delta P = P_{\text{sat}}(T_h) - P_{\text{sat}}(T_c)$$

Heat Transfer Coefficient (U): This is a measure of the heat transfer efficiency of the membrane. It can be calculated from the heat transfer rate ($\dot{Q}$), the effective membrane area (A), and the temperature difference between the hot feed and cold permeate (ΔT), as follows:

$$U = \frac{\dot{Q}}{A \cdot \Delta T}$$

Heat Transfer Rate ($\dot{Q}$): This is the rate at which heat is transferred from the hot feed to the cold permeate. It can be calculated from the mass flow rate ($\dot{m}$), the specific heat capacity of water (c_p), and the temperature difference between the hot feed and cold permeate (ΔT), as follows:

$$\dot{Q} = \dot{m} \cdot c_p \cdot \Delta T$$

Where c_p is the specific heat capacity of water. At room temperature (20°C), $c_p \approx 4186$ J/(kg·K).

4. Improved PTR for thermal support

4.1 Potential of PTR

Given its energy potential, the Parabolic Trough Reflector (PTR) is a great option for providing heat energy to the DCMD feed solution, particularly in Bangladesh, a subtropical nation that receives 4.36 kWh/m^2 of solar radiation per day with a maximum of 6.5 kWh/m^2 [9]. A parabolic trough reflector is a kind of solar thermal collector that has a reflective metal mirror through it. It is straight in one dimension and curves like a parabola in the other two. Heat transfer fluid (HTF) that is meant to be heated is positioned at the focal line, which is where the energy of sunlight entering the mirror parallel to its plane of symmetry is concentrated. After being exposed to solar radiation, the HTF will transmit the heat to the feed water. The efficiency of PTR depends on materials used to make it, specific geometry, orientation and HTF.

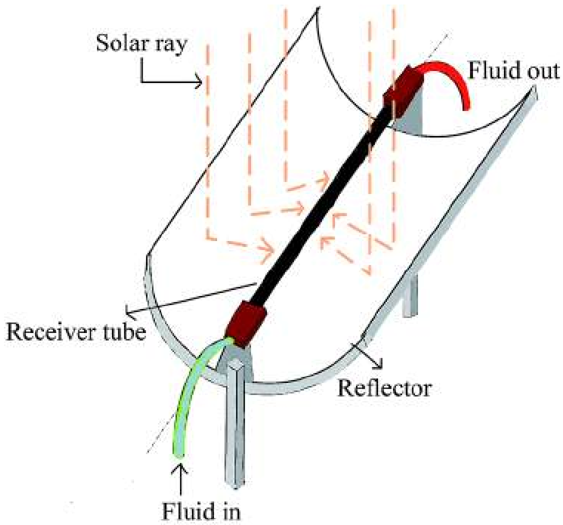


Image 5: Working Principle of PTR (Courtesy: ResearchGate)

4.2 Optimal Design for PTR

Our proposed PTR double envelope design is most suitable as a receiving tube with a diameter of 0.027 meters, which is the most favorable design. Furthermore, the PTR's 80 degree rim angle and 5.7-meter parabolic aperture produce the maximum energy and exergy ("usable work potential" of energy) efficiency, at 45.9% and 79.4%, respectively. Based on the study by Thappa, S., Chauhan, A., Anand, Y. et al. [10]

The best option for HTF is using nanofluid; Cu with CuO as a nanoparticle presented a notable increase in heat transfer coefficient [11]. These chemicals are also simpler to operate with and to make. By increasing the receiving tube's capacity to absorb heat, the use of metal foam in a parabolic trough solar collector resulted in a 4% increase in thermal efficiency. [12] The boundary layer effect can be disrupted and the heat transmission tube can be further optimized by inserting turbulators that are specifically intended to create turbulence in the flow. The fluid that flows through the steel pipe is required to be coated with borosilicate glass [13]. Using borosilicate glass covers has the following benefits:

1. Low coefficient of thermal expansion: Because boron trioxide is a component of borosilicate glass, it has a very low coefficient of thermal expansion and reduces heat loss.
2. Thermal Shock Resistance: Compared to conventional soda-lime glass, borosilicate glass has a substantially lower Coefficient of Linear Thermal Expansion. Lastly,
3. Extreme durability and chemical resistance: Nuclear waste is even stored in borate glass due to its exceptional chemical resistance; the boron content makes it less soluble, preventing unwanted materials from leaching into or out of the glass.

The orientation and solar tracking ability will further enhance the operating output of PTR. Typically oriented north–south to ensure the highest possible efficiency [14], also with the help of optical sensors the mirrors will rotate along the axis for optimal angle with indecent rays.

4.3 Calculation

Geometry of the Parabola: A parabola is described by the equation:

$$y^2 = 4fx$$

Where f is the focal length

Focal Point: By definition of the focal point of the parabola, all incoming rays parallel to the axis of the parabola are reflected through the focus

Design Parameters: The design of the parabolic reflector takes into account the available aperture size (a), focus location (f - i.e., where receiver would be placed), and height of the reflector (h). These parameters are interrelated via the equation:

$$h = \frac{a^2}{16f}$$

Rim Angle: The “flatness” of the shape of a finite parabola is typically characterized by the rim angle (ϕ). When rim angle increases (within the same aperture), the parabola becomes more curved, and the focal distance shortens.

4.4 Production from Metallic Wastes

The desired process would follow the procedure to utilize the metallic wastes in the production of PTR thus:

In the process of constructing a parabolic trough reflector, various recycled materials are utilized. These materials include stainless steel or aluminum sheets, plywood, steel tubes, copper tubes, and reflective materials such as Mylar, vinyl, or reflective aluminum with a Physical Vapor Deposition (PVD) protective coating.

The first step involves the collection of all necessary recycled materials. The stainless steel or aluminum sheets are then cut into the desired size of the parabolic trough, the dimensions of which are dependent on the intended application of the reflector. These cut metal sheets are subsequently bent into a parabolic shape using a suitable mold or form.

The structure of the parabolic trough is constructed using recycled plywood. This material choice ensures that the structure remains lightweight and easy to handle. To enhance the stability and durability of the structure, recycled steel tubes are used for reinforcements.

A recycled copper tube is attached at the focus of the parabolic trough, serving as the collector tube where the reflected sunlight will be concentrated. If metal sheets are not being used as the reflective surface, a reflective material such as Mylar, vinyl, or reflective aluminum with a PVD protective coating is applied to the parabolic trough.

The final assembly ensures that the reflective surface is smooth and clean, and the collector tube is properly positioned at the focus of the parabola. It is important to note that safety should be prioritized when handling these materials and tools. Appropriate protective gear should be worn, and work should be conducted in a well-ventilated area.

5. Overall System

5.1 Navigating the System

1. Prior to the contaminated water being pumped into the facility, a pre-filtration unit will filter out organic contaminants (pathogens, pesticides, herbicides, and other synthetic compounds) and chemical contaminants (mainly oil, Perfluorooctanesulfonic Acid, lead, mercury, and copper).

2. Parabolic Trough Reflectors with specifications and orientation stated above will start heating the HTF using solar irradiation. We recommended operating hours from 9 am to 2 pm because on average our country gets 5 hours of effective solar irradiation. The HTF will carry the heat and exchange the heat in the heat exchanging unit, warming the feed water to 90 degree Celsius. The HTF will be diverted into the radiator to be used again in the loop.

3. The primary distillation process will take place utilizing countercurrent flow across the DCMD membrane, which will be accomplished by transporting the hot feed water to the DCMD unit and using thermal driving force to distill it. Meanwhile, cooler distilled permeate from the reservoir will also be carried to the DCMD unit.

4. The concentrated feed solution that is completely saturated with contaminants and is no longer suitable for use will be kept in a different reservoir. The fact that DCMD leaves far less leftover than other distillation methods is one of its advantages. The leftover solution will be employed for additional filler utilizing carbon block-equipped ceramic filtration, which may reduce harmful pollutants and heavy metals like arsenic, barium, cadmium, chromium, iron, lead, mercury, and selenium to a safe level to be expelled to the environment. [15]

5. To distribute the generated water, the distilled water will be kept in several protected water tanks. In Bangladesh, the average village has about 1500 residents, and each person needs 3.5 liters of water per day for drinking and 1.5 liters for cooking [16]. With the added benefit that every ten days of production, our planned facility will generate enough water for two days' worth of use, producing five liters of water in five hours for 1500 people every day. In wet or foggy days, solar radiation may not be enough, and the plant requires maintenance. Therefore, 9000 liters of water will be produced daily at the rate of 30 liters of

distilled water per minute, with 7500 liters going toward distribution and 1500 liters toward storage. For this purpose, different water reserves might be utilized.

6. Since PTR is being used to heat the feed solution, which accounts for the majority of DCMD's power consumption, the process as a whole will need a lot less energy to run the plant. Water independence will be achieved by using efficient photovoltaic modules to power the entire system, ensuring that it is self-sufficient and not dependent on non-renewable power sources.

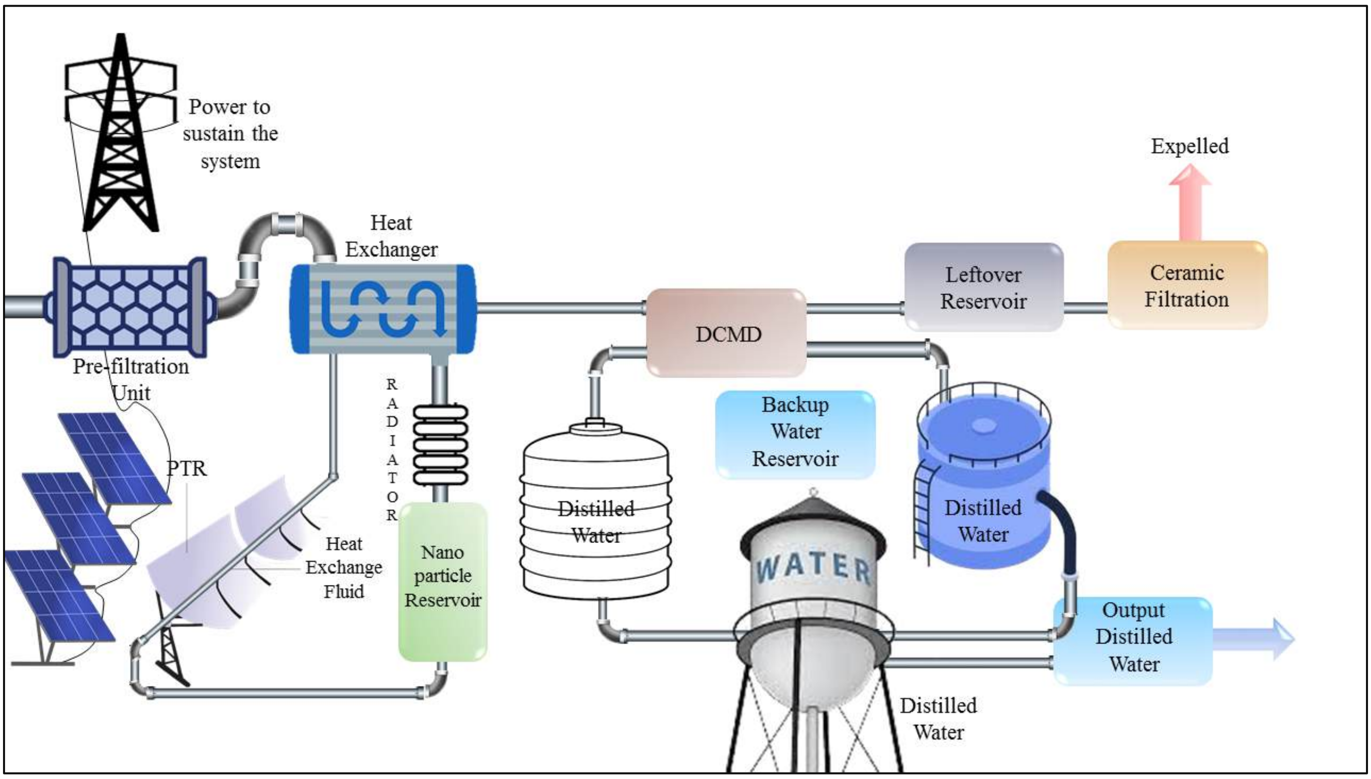


Image 6: Overall Diagram

5.2 Overall Calculation

To calculate the energy needed to heat 30 liters of water per minute is 4.36 KWh/m^2; after the employed modifications we expect to see a rise in the efficiency. Currently, using 80.26% ≈ 80% efficiency:

The energy required to hat 30 liters of water from 25° (room temperature) to 90° C,

=8170500 Joule [Using Omni Calculator]

Again, the power required to heat the desired amount of water in 1 minute:

=170218.75 Watt [Using Omni Calculator]

=17.21875 KW

Area require to carry out the desired result: $\frac{Energy\ Required}{Energy\ Available}$

$$= \frac{170.21875}{4.36}$$

$$= 39.049977 \text{ m}^2$$

6. Result and Conclusion

Summarizing our research we get the following findings:

Category	Common Findings
Membrane Grafting	Grafted membranes enhance performance by improving hydrophobicity and selectivity.
Model Performance	Higher flux achieved with optimized membrane properties and operating conditions.
Effect of Feed Temperature	Feed temperature impacts flux and energy efficiency; higher temperatures often yield better performance. The most efficient difference is around 50 degree Celsius.
Influence of Membrane Properties	Membrane thickness, pore size, and surface roughness affect flux and fouling behavior.
Effect of Superhydrophobic coating	Membrane wetting is greatly reduced as the coating prevents water from leaking
Vortex Generators	Brings the benefits of using spacers to induce turbulence as well as does not reduce performance by lessening the area of absorption
Permeate Characteristics	High-quality permeate with low salt content and minimal fouling.
Energy Efficiency	DCMD can be energy-efficient due to low temperature differentials and latent heat utilization.

Table 1: Common Findings of our developed DCMD

Moreover, if we compare our proposed work with other literatures, we will observe various developments. The developments will contribute to enhance the efficiency of our proposed integrated system, which in turn will result in a reliable outcomes. The table of comparison is as follows:

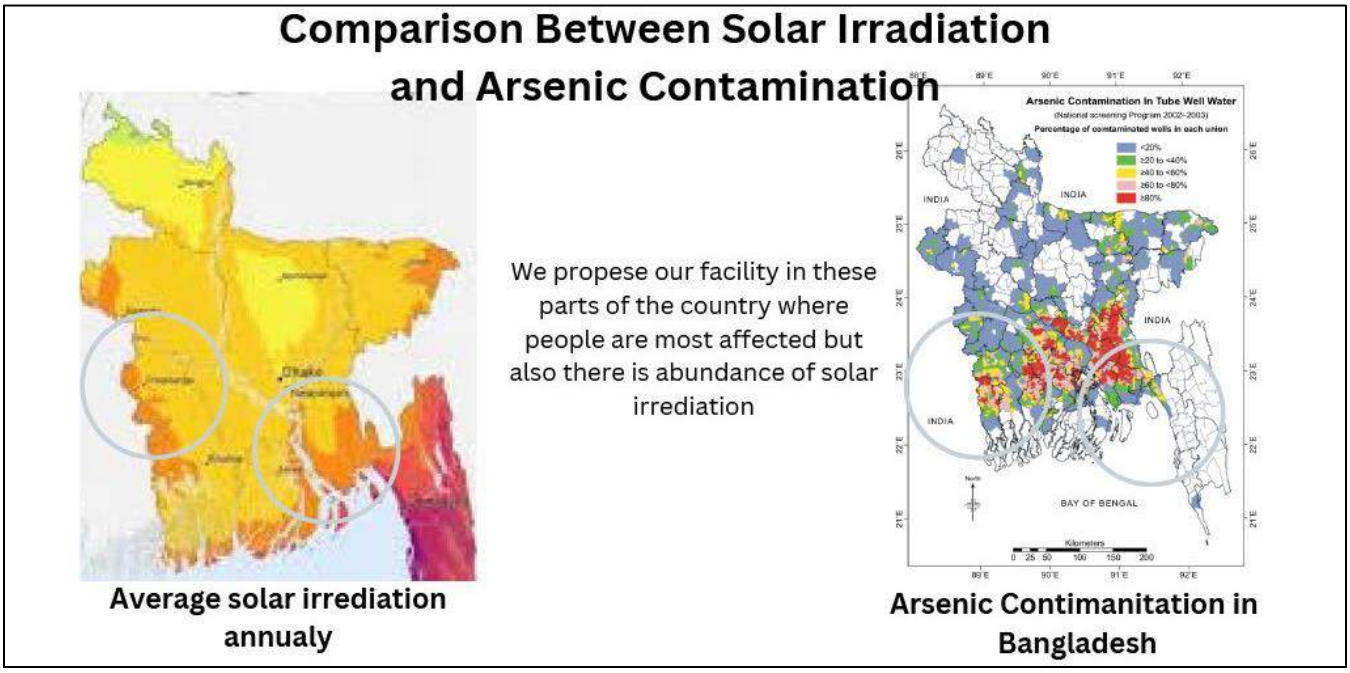
Aspects	Ansari et. al. [17]	Kamaz M et. al. [18]	Our Proposal
Membrane Grafting	Improved DCMD model by coupling continuity, momentum, and energy equations. Grafted membrane using Nusselt correlations.	Focused on PVDF membranes. Surface modification critical to reduce adsorption of dissolved organic species and mineral salts.	Grafting 1-Hexene, which has non-polar characteristics and is reasonably inexpensive, further enhances PP's low surface energy, high mechanical capabilities, and chemical durability
Membrane Composition	Not specified	Polyvinylidene fluoride (PVDF)	Polypropene (PP)

Influence of Membrane Properties	Membrane properties (thickness, porosity) significantly affected DCMD performance.	Focused on PVDF membrane surface modification.	The most optimized and efficient perimeters will be used
Application Context	Not specified	Hydraulic fracturing-produced water treatment using PVDF membranes.	Purification of water from any contaminated sources
Model Performance	Good agreement with experimental results (<7% deviation). Analyzed water flux, temperature, concentration polarization coefficient, and thermal efficiency.	Not explicitly discussed in this paper.	Our assumption suggests increased flux rate with decreased polarization, fouling and wetting.

Table 2: Comparison with other literature

Our proposed system is especially designed considering the rural economy of Bangladesh. This work, if implemented, on the one hand, will provide culinary and drinking water for the rural people. On the other hand, this project will try to reduce the metallic waste which are harming the environment by the utilization of them in the production of Parabolic Trough Reflector (PTR). So, to put it together, one problem is solution to another problem. And when one is solved, the other one is also solved.

Again, if we consider the arsenic prone regions and regions with higher solar irradiation, we will find similarities in their location. The following comparison between the maps will make it clear to understand:



For Bangladesh, a densely populated country vulnerable to water crisis, water distillation from various contaminated sources will be a requirement for sustainability in the future. DCMD is the most promising choice for that for its effectiveness, simplicity and flexibility. As DCMD can purify water from any contaminated sources. The modified DCMD membrane will last long and be effective for a long time. Our modified plant is capable of sustaining the water demand for the average village in our country, especially in the region prone to salinity and arsenic contamination. As our plant is incorporated with PTR and photovoltaic cells, the initial cost might be higher but the only cost will be in installation and after some years of continuous supply the benefit will outweigh the investment cost and will be profitable. Also, the implementation does not require much area. Furthermore, out plant assembles all the technological breakthroughs in DCMD and PTR and modifies it for the country so the highest gain is possible. So, if our system is implemented in the arsenic prone and salinity prone regions, the water independence of thousands will be ensured and hence upgrade the life standard of them along with maintaining the sustainability of the environment.

7. References

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