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Thermal Analysis of Sea Water Hybrid Solar Desalination System - An Experimental Approach

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ABSTRACT

The primary environmental impacts of seawater desalination are salty, hot, and chemical pollution induced by the direct release of concentrated brine from various desalination processes. The primary goal of this research is to conduct experimental thermal analyses of seawater in a hybrid solar desalination system. It uses solar energy to heat seawater, which is then fed via copper tubes. Hybrid solar desalination systems make use of evacuated tube collectors (ETC) and compound parabolic concentrators (CPCs). Sea water evaporates due to the intensity of sun radiation, resulting in steam. Steam is condensed, and the resulting potable water is stored in an airtight container. Groundwater, saline water, and saltwater were used as inputs, yielding 2.5, 1.5, and 2 litres of drinkable water.

1. INTRODUCTION

Freshwater is the world's most precious resource and crucial for all human as well as ecological functions [1]. The increase in population, agricultural activities, industrial growth, and global warming has widened the gap between freshwater resources and conventional water supply, turning it into a global issue [2, 3]. Desalinating brackish and saltwater, building new dams, treating wastewater, and moving surplus water to drought-affected areas are all potential answers to the global water dilemma. Traditional fossil fuel energy sources have been demonstrated to be environmentally harmful. Solar energy provides a practical and sustainable way to desalinate water [4, 5]. Solar power is a plentiful, renewable energy source. One of its most intriguing features is the ability to replace fossil fuels. Solar energy has a variety of uses, including space heating [6-8], household hot water production [9-12], power generation [13], freshwater production [14], and drying agricultural goods [15]. As the need for drinkable water in coastal areas grows, desalinating salty water is increasingly thought to be a reliable and practical solution [16]. This is because salty water is the most plentiful water source and is still primarily pollution-free, with a few notable exceptions. Desalination systems can be categorized into membrane, distillation, RO, MED, and MSF systems. All these technologies require fossil fuels and electricity. Two basic kinds of technology are employed over the globe for desalination [17]. For either to work, some kind of energy input is required to turn salty water into drinkable water. There are more subdivisions within these two major classes (processes). Whether salt is removed from seawater throughout the process is a key consideration for such methods. Some examples of these processes are desalinization and evaporation. In salt extraction methods, the water is first treated to remove salts and then reused as fresh water. With the alternative method, the water is extracted first, leaving behind the salty brine. Multi-effect distillation, Multistage flash, freezing procedures, Mechanical Vapor Compression, Membrane Distillation, and sun stills are all examples of phase change desalination. Even though MED and MSF have been demonstrated as trustworthy and mature, they are best suited for large-scale units. Several researchers have also investigated the outcomes of hybridizing MVCs with MSF and MED [18-21]. Without the need for harmful or expensive fossil fuels, solar desalination technologies will provide effective solutions in and around the world [22, 23]. Therefore, using solar energy for desalination is a viable method of resolving water scarcity issues, particularly in dry places [24]. In the last ten years, various desalination techniques have been developed [25-27]. However, the most popular solar desalination method is the use of solar stills [28]. Clean drinking water may be made using solar stills, which are powered by the sun. Their fundamental operating concept involves water evaporation from the basins and condensation on the glass overhead.

For higher efficiency of a solar desalination system is advised to use it with other devices, like a concentrator, solar collector, or reflector [29, 30]. Concentrator technology was adopted by many scholars for higher thermal efficiency in desalination systems. Omara et al. [31] performed experiments on modified stepped solar still. Authors found stepped solar still with internal reflectors can make it 75% more productive than a regular solar still. Tiwari and Suneja [32] came up with an idea for a solar still with an inverted reflector and did a numerical analysis of it. Omara et al. [33] looked at how the reflectors (external and internal) affected the stepped solar desalination system. Based on the tests, the modified stepped solar still having reflectors (external and internal) gives about 125% more than the standard solar desalination system. Tanaka [34] made a solar still with external and internal reflectors and tested it in the lab. The study revealed that increasing the number of reflectors used in solar stills might boost daily production by as much as 70 to 100 percent during the winter months.

Combining different concentrators with solar desalination systems has been suggested and deliberated previously as a way to make solar desalination systems work better. Gorjian et al. [35] came up with, built, and tested a parabolic solar desalination system to remove salt from seawater. The results show that the solar desalination systems had a maximum daily yield of 5.12 kg/m^2 and a maximum efficiency of 36.7%. Parabolic concentrator-based solar desalination equipment was suggested by Chaochi et al. [36]. They came up with a theoretical model to figure out how solar radiation affected the temperature of the absorber and the flow rate of the distillate. The theoretical model gave a flow rate that was off by an average of 42%, according to the results. Researchers have thought of different ways to connect solar desalination systems to other solar collectors [37]. Malaeb et al. [38] proposed integrating a slowly rotating drum inside the still. This would cause thin water films to form over the drum and increase the amount of water that evaporates. Arunkumar et al. [39] made 4 non-concentrating solar desalination systems and 3 concentrating solar desalination systems and tested how well they worked. Their research focuses mainly on a hybrid solar desalination system and a compound parabolic collector. Kedar et al. [40, 41] primarily worked on solar desalination systems using evacuated tube collectors. Their results show that 25-27 litres of soft water per day can be useful for drinking and industrial applications. A compound parabolic concentrator was developed and studied for the effect of reflecting material on CPC-ETC hybrid solar desalination system The effectiveness of the single-effect boiling approach was demonstrated for solar desalination in rural areas therefrom [42-46]. Saxena and Gaur [47] studied exergy analysis of evacuated tube solar collectors whereas Jiang et al. [48] mainly reviewed compound parabolic tubular absorbers.

El-Sebaey et al. [49] evaluated thermal and economic analysis for modifications in the cylindrical sector and double slope single basin solar still. He argued that double slope single basin solar still most applicable for urban communities. Their results showed that the most work could be done with a hybrid solar desalination system and a compound parabolic collector. Whereas Arunkumar et al. [50] studied the productivity enhancement of solar still by using porous absorbers with bubble wrap insulation. Their study shows for enhancing productivity, porous absorbers are required for solar still. Agrawal and Rana [51] studied theoretical and experimental performance evaluation of single slope single basin solar still with multiple V-shaped floating whereas Kaushal et al. [52] experimentally studied flowing weak basin type vertical multiple effect diffusion solar still with waste heat recovery. Haddad et al. [53] studied basin-type solar still using a vertical rotating wick. Whereas Sellami et al. [54] studied the experimental performance of solar stills by covering absorbers for different layers of sponge. Shalaby et al. [55] had studied experimentally absorber single basin solar still with PCM. He had used paraffin wax acts as a PCM for their experimentation. Some of the researchers had studied single basin solar still and they had improved their performance with absorber material [56, 57]. Goosen et al. [58] reviewed recent developments in the environment considering the desalination aspect. Their study shows a great need for desalination in seawater areas. Whereas Wang et al. [59] studied an integrated approach for solar desalination applications. Al-Addous et al. [60] reviewed innovations in solar-powered desalination whereas Huang et al. [61] studied the most effective key pathways for solar desalination. Tiwari et al. [62] reviewed recent developments in solar-driven desalination systems.

Portable desalination systems are very important, and using exergy analysis to look at these systems can be a great way to make more fresh water while using less energy. This study is intended to determine experimentally the effect of a single evacuated tube collector (ETC) with a Compound Parabolic Collector (CPC) for desalination. Out of all the different types of concentrators, CPC is the best and most efficient. To make CPC work better, materials that reflect light are used. Also, the effect of seawater on a hybrid solar desalination system and the effectiveness of reflective coating materials on CPC to improve the thermal performance of a hybrid solar desalination system were studied. Different raw water sources such as groundwater, saline water, and seawater are used in the said experimental set-up. The main benefit of this system for desalinating water is that it uses less thermal energy than other systems. Results show that a combined CPC-ETC configuration is capable of delivering an average water throughput of 5.6 kg/m^2-day for groundwater, 3.75 kg/m^2-day for saline water, and 5 kg/m^2-day for seawater which is better in comparison to single basin solar stills. Water sample tests proved that the said methodology is an effective means for good desalination.

The literature review reveals that most studies focused on analytical, experimental, and numerical investigations. Experimental thermal analyses of seawater in a hybrid solar desalination system using ETC and CPC are not found in the literature. The proposed work aims to maximize the production of soft water from seawater using single-effect boiling in a solar desalination system that incorporates both an evacuated tube collector and a compound parabolic concentrator. To achieve maximum soft water production through condensation, it is crucial to understand the heat transfer process from the evacuated outer surface of the tube to the inner surface, leading to the generation of soft water. The experimental studies were conducted in Pune city to consider various factors such as high heat rate, improved water flow rate, and temperature distribution under various environmental and climatic circumstances. Under the drinking water standard (IS-10500:2012), a chemical analysis of the intake seawater and output freshwater samples was conducted.

According to the chemical analysis of water samples, the distillate falls well below the drinking water specification limit.

2. MATERIALS AND METHODS

2.1 Experimental setup and procedure

The experimental set-up mainly consists of an evacuated tube collector used for the desalination of seawater. The ETC tubes made of borosilicate glass act as an absorber. It is a tube-in-tube structure. Solar radiation is absorbed by these tubes. As shown in Figure 1, seawater is stored in a barrel at a height to provide the required head. Two pipes are used in the system. One pipe is attached to the input, ETC and another pipe starts from ETC to collecting jar. The desalinated water is collected in a clear air-tight collecting jar to prevent steam from escaping. A stand to attain the height of CPC is used on which the water barrel is placed. The CPC stand can be rotated as per the latitude and longitude. As the water flows through the tube, heat due to solar radiation is transferred by the tubes to the water which results in the formation of steam. Salts and contaminants settle down at the surface of the tube during conversion from water to steam. As the flow rate of this steam is very low there is no need for a condenser in the system. However, when a multistage system is used, a condenser is required due to a higher rate of steam being generated [49]. A possible solution for raising the amount of heat transfer is the use of a parabolic concentrator which has high reflectivity. The concentrator reflects the rays passing through the gap of tubes. So, heat is also provided to the tubes through the lower end. This increases soft water conversion and thereby increases the efficiency of the experimental setup. Figure 1 mainly indicates the actual experimental setup with Teflon coating on CPC.

For carrying out the tests different water samples are required. Groundwater is collected from a campus of Cummins Engineering College for Women, Pune, MH, India, saline water is made by mixing salt into groundwater, and seawater from the Arabian Sea is used. Various experiments were carried out in March 2022 on the premises of MKSSS's Cummins College of Engineering for Women in Pune, Maharashtra, India. Table 1 shows the various instrumentation used while experimenting. Experiments were carried out using the three types of water as input viz. groundwater, saline water, and seawater. While performing the experimentation, the thickness of the Teflon layer was varied from 1 to 3 mm for groundwater and 3 mm for saline water and seawater. Table 2 shows the experimentation chart by varying the water type with the thickness of the Teflon layer.

Figure 1. Experimental setup with Teflon coating on CPC

The experimental procedure steps are as follows:

1) Fill the hard water tank until it reaches the operating level.
2) Adjust the test case parameters (temperature, flow rate).
3) Compound parabolic concentrator placed below set of evacuated tube collector.
4) All measuring instruments will be ready for measurements of various parameters such as Intensity of solar radiation, wind velocity, thermometer, flow rate etc.
5) Open the non-return valve through which hard water flows entirely through copper tubes in the evacuated tube collector.
6) Set and adjust the opening and closing timing of valves according to the water flow rate.
7) In the actual operation water is heated inside copper tubes for the formation of steam.
8) The valve is adjusted to another point of a copper tube through which steam passes through the condenser.
9) The steam stop valve is adjusted for a smooth flow of steam passing to the surface condenser.
10) After condensation of steam, jar saline/soft water is collected.
11) Steps no. 4 to 9 should be repeated for different flow rates and different distances between ETC and CPC and accordingly various experiments are conducted.

2.2 Components used in the experiment

Single-ended ETC with a double-pipe copper tube is used in the experiment as a main component [40]. The inner tube which is also called the absorber is covered with a coating. This coating absorbs solar energy efficiently and prevents radioactive heat loss. Air is present in the space of ETC. This air has to be removed to form a vacuum. Otherwise, if air is present, it increases conductive and convective heat loss. They are suitable for cold ambient temperatures. They are also suitable for many industrial applications. To be economically efficient high temperatures of water and steam should be generated. The ETCs are built to have a cold-water inlet and when solar radiations fall on it, the water gets heated. The heated water moves up as its density decreases and is stored in the insulated tank and the freshwater goes to the solar collector by natural thermosiphon (natural flow). ETC can be classified into different types. The ETCs available can be categorized into two groups. They are named single-walled glass evacuated tubes and the Dewar tube. The ETC used in our experiment heats up and condenses input water with the help of solar radiation. It is cylindrical having a length of 1500 mm. A copper tube is present in the Evacuated Tube Collector through which water flows and gets heated and steam comes out from the other side. Using a copper tube can increase the rate of heat transfer. Aluminium, silver, and steel can be used for the same purpose [41]. Figure 2 shows the schematic sketch of ETC and separated Cu Tube. Specifications of the evacuated tube collector include the inner diameter and outer diameter of tubes 47 and 65 mm respectively. The length of the tube is 1500 mm and the internal surface between the tubes is 116 mm. Along with a glass thickness of 1.6 mm and an absorber area of 1.6 m^2. Experimental parameters selected water flow rate, intensity of solar radiation, temperature and wind velocity. Table 1 lists the specifications of the instrumentation used in the experimental setup.

Table 1. Instruments used in the experiment

Instrumentation System	Range	Model / Type	Variable
Water flow meter	0.01 - 100 lpm	STD	Flow rate of water
Solar power meter	0 - 2000 W/m^2	KM-SPM-530	Intensity of solar radiation
Infrared thermometer	−50°C to 380°C	IRL -380	Temperature
Anemometer	KM-910	0-45 m/s	Wind velocity

Table 2. Experimentation with types of water

Type of Input Water	Thickness of Teflon Layer (mm)	No. of Days Experimented	Date
Ground water	1 2 3	1 1 2	04/03/2022 05/03/2022 05/03/2022 06/03/2022
Saline water	3	1	12/03/2022
Sea water	3	7	13/02/2022 to 20/02/2022

The second important component is the CPC which is placed below the ETC. CPC is non-imaging like a flat plate collector which is used to focus beam radiation coming from the sun on a central receiver tube. Figure 3 shows the schematic sketch of CPC, with a length of 1800 mm, absorber area of 0.4 m^2 focal length of 150 mm. Jiang et al. [48] performed in-depth review of the CPC collector concept which is made of an absorber and two parabolas. CPC has elements known as receiver and reflector. These elements reflect the beam radiation coming from the sun so as to concentrate it on the receiver tube. The profile of the CPC has a specific geometry which is dependent on the type of receiver and is located such that it coincides with the focal point of the system. In the present study, the ETC is placed on the focus of the CPC [42]. Different materials which have high reflectance are used as a coating material on the CPC [43-46].

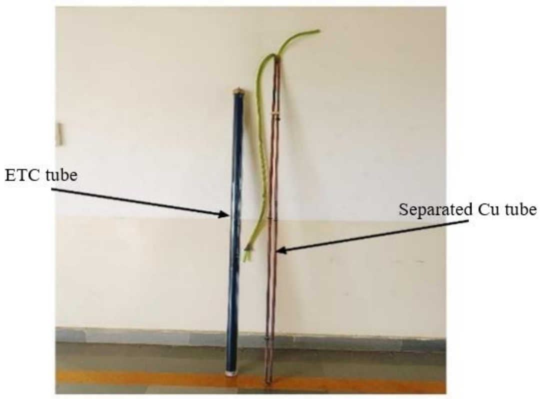

Figure 2. ETC and separated Cu tube

Thermocouples are deployed to record the temperature at various points. The temperature readings were taken for inside and outside water originating from ETC, the temperature of the system, and the surrounding temperature using infrared temperature sensors (gun type). Solar radiation was measured with the help of handheld solar radiation (pyranometer) while the water flow rate was measured by using a magnetic-type water flow meter (Figure 4). While performing the experimentation thickness of the Teflon layer was varied from 1 to 3 mm for groundwater and 3 mm for saline water and seawater. Table 2 shows the experimentation chart by varying the water type thickness of the Teflon layer. Observations obtained from the experimental procedure were recorded. This is presented in the subsequent sections.

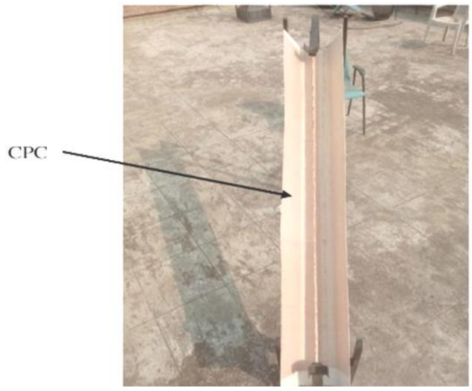

Figure 3. Pictorial view of the CPC

(a)

(b)

Figure 4. (a) Water flow meter; (b) Solar radiation - pyranometer

3. RESULTS AND DISCUSSIONS

The results and discussion section mainly include results of the experiments of the hybrid solar desalination system and accordingly discussions are presented in this section.

3.1 Result of experimentation

The testing was done for one complete day (morning to evening) 7.00 am to 6.00 pm. Output water quantity depends on various parameters. These parameters are studied during the experiment. The variation of solar radiation and ambient temperature is presented in Figure 5. The intensity of solar radiation increases gradually, and so does the quantity of potable water obtain from the setup. The largest quantity of soft water is obtained in the afternoon, in an airtight jar, which increases productivity. The wind flow rate does not affect the water output. The temperature in the Pune region ranges from 23 to 36°C. The temperature changes throughout the day, from sunrise to dusk. Ambient temperature increases from morning to evening according to weather conditions on that day. During morning time very few drops of water are collected in a jar. The collection of water drops rises during the afternoon time. Solar radiation intensity slowly increases from 700- 930 W/m^2 with collector outlet temperature varying from 71-85°C as presented in Figure 6. As a result, the temperature of the collector water output rises steadily from morning to afternoon. The maximum outlet temperature of the collector was 85°C, and the solar radiation intensity was 930 W/m^2. As outlet temperature increases, the amount of soft water output also increases. The distance between ETC and CPC also plays a crucial role. If this distance increases, less amount of soft water is obtained as it takes a relatively higher heating time to heat the evacuated tube. As the heat is transported through conduction and radiation, the solar desalination system's radiation and conduction losses may be higher. It is recommended that an ideal distance of 20 mm be maintained to reduce losses and improve the efficiency of the solar desalination system. The variation of solar radiation and ambient temperature is presented in Figure 5. It is noted that the peak global solar radiation of about 900 W/m^2 is received for two hours while the total horizontal surface radiation of about 6.2 kWh/m^2-day was received. The atmospheric temperature ranged from 22 to 34°C on the test days which is typical during the summer month of March when the experimentation was done.

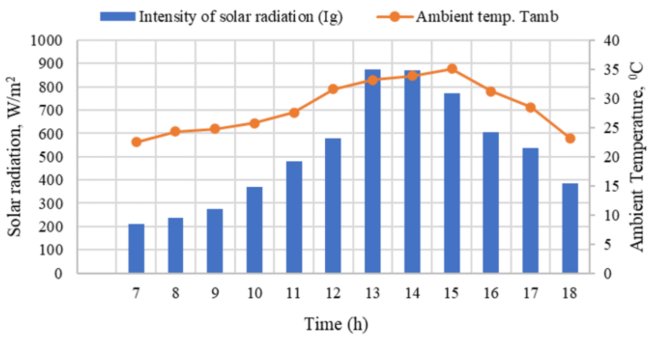

Figure 5. Variation of intensity solar radiation and ambient temperature

In Figure 7, experimentation results for groundwater for 3 mm thickness of Teflon are presented. The rate of water output and effectiveness of a solar desalination system are closely connected to the quantity of solar radiation hitting the system and the ambient temperature. The maximum value of solar radiation and ambient temperature was 930 W/m^2 and 35.2°C respectively. The average value of solar radiation and ambient temperature for the day was noted as 530.66 W/m^2 and 28.7°C respectively.

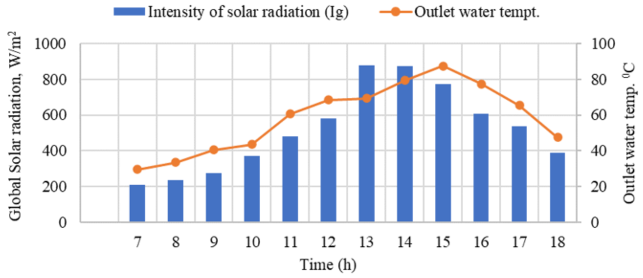

Figure 6. Variation of outlet water temperature with solar radiation

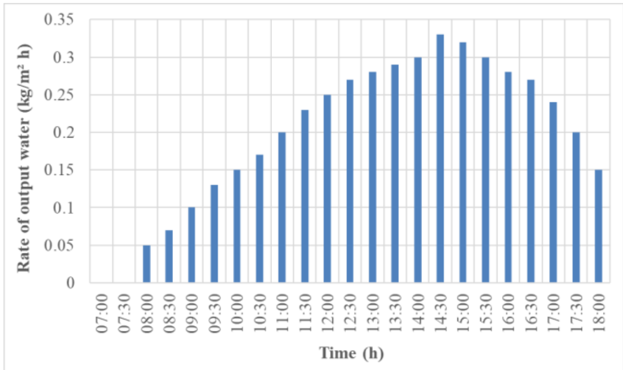

Figure 7. Rate of output for groundwater by using 3 mm thickness of Teflon

From Figure 7, it can be seen that the rate of output for groundwater increased gradually from 0.05 kg/m^2 h with an increase in solar radiation. The maximum output rate for groundwater obtained was 0.35 kg/m^2 h at the local time of 3.00 pm of the day. The maximum output rate was obtained when the value of solar radiation and ambient temperature were maximum. After achieving the maximum output, solar radiation and ambient temperature decrease gradually which further results in a decrease in the rate of output for ground water.

Results from experimental investigations for saline water for 3 mm thickness of Teflon are presented. The maximum value of solar radiation and ambient temperature was 900 W/m^2 and 35°C respectively. The average value of solar radiation and ambient temperature for the day was noted as 510.75 W/m^2 and 27.7°C, respectively. The rate of water output and effectiveness of a solar desalination system are closely connected to the quantity of solar radiation hitting the system and the ambient temperature.

From Figure 8, it can be seen that the rate of output for saline water increased gradually from 0.03 kg/m^2 h with the rise in solar radiation. The maximum output rate was obtained when the value of solar radiation and ambient temperature were maximum. The maximum output rate for saline water obtained was 0.32 kg/m^2 h at the local time of 3.00 pm of the day. After achieving the maximum output, solar radiation and ambient temperature decrease gradually which further results in a decrease in the rate of output for saline water as is evident from the downward slope of Figure 8.

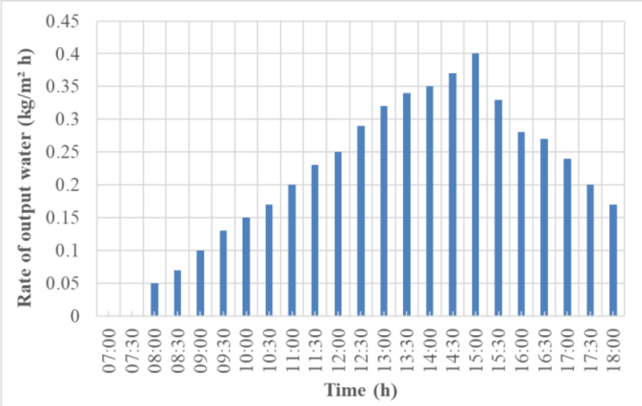

Figure 8. Rate of output for saline water by using 3 mm thickness of Teflon

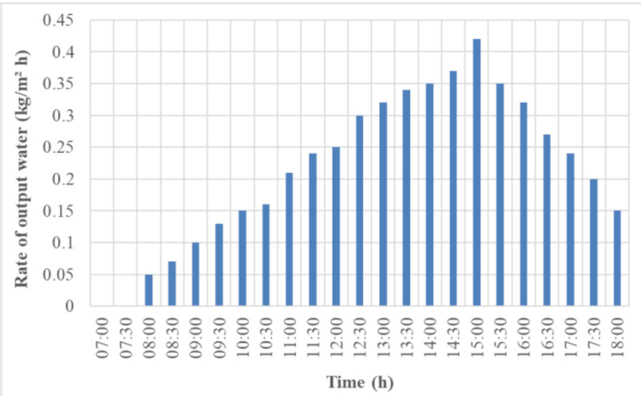

Figure 9. Rate of output for seawater by using 3 mm thickness of Teflon

Experimental results for seawater for 3 mm thickness of Teflon are presented in Figure 9. The maximum value of solar radiation and ambient temperature was 900 W/m^2 and 35.0°C, respectively. The average value of solar radiation and ambient temperature for the day was noted as 507.33 W/m^2 and 27.52°C, respectively. The rate of water output and effectiveness of a solar desalination system are closely connected to the quantity of solar radiation hitting the system and the ambient temperature. Figure 9 shows that the rate of output for seawater increased gradually from 0.03 kg/m^2 h with higher solar radiation. The maximum output rate was obtained when the value of solar radiation and ambient temperature were maximum. The maximum output rate for seawater obtained was 0.37 kg/m^2 h at a local time of 3.00 pm of the day. After achieving the maximum output, solar radiation and ambient temperature decrease gradually which further results in a decrease in the rate of output for seawater.

Figure 10 shows the comparative bar chart experimentation result for ground, saline, and seawater for 3 mm thickness of Teflon. It can be seen that the trend for the rate of output for ground, saline, and seawater was found similar in all three cases i.e. after achieving the maximum output, solar radiation and ambient temperature decrease gradually which further results in a decrease in the rate of output for seawater. The maximum rate of output was obtained for the seawater followed by groundwater and saline water. Though the boiling point of water increases with increasing salinity, its specific heat reduces. The reduction of specific heat dominates the increase in boiling point, justifying the observation. The maximum rate of output obtained for the seawater, groundwater, and saline water were 0.37 kg/m^2 h, 0.35 kg/m^2 h, and 0.32 kg/m^2 h respectively. Typically, in all three cases, the maximum output rate was obtained when higher intensity of solar radiation and ambient temperature.

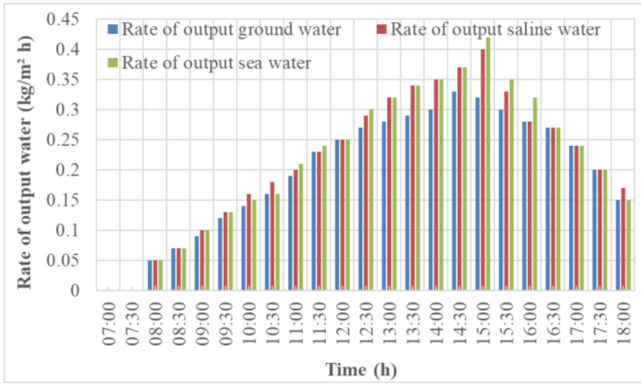

Figure 10. Comparison between rate of output for ground, saline and seawater by using 3 mm thickness of Teflon

The output water quantity collected according to ground, saline, and seawater as input water is shown in Table 3. The average output water quantity collected was 2 liters, 2.2 liters, and 2.5 liters for groundwater with CPC having a thickness of Teflon layer as 1 mm, 2 mm, and 3 mm respectively. Since 3 mm Teflon coating yielded the best results, the rest of the experiments with seawater and saline water were conducted employing the same Teflon thickness. In the case of saline and seawater, the average output water quantity collected was 1.5 liters, and 2 liters respectively. Maximum water collection of 2.5 liters/day was found in groundwater having a thickness of Teflon layer of 3 mm whereas least water collection of 1.5 liters/day was found in saline water having a thickness of Teflon layer of 3 mm.

Table 3. Output water quantity collected according to the type of input water

Type of Input Water	Thickness of Teflon Layer (mm)	No. of Days Experimented	Output Water Quantity (L/ day)	Output Water Quantity (kg/m^2-day)
	1	1	2	5
Groundwater	2	1	2.2	5.5
	3	2	2.5	6.25
Saline Water	3	1	1.5	3.75
Sea Water	3	7	2	5

Table 4. Comparison of chemical components of water after and before purification with allowable limits

Parameters	Water Sample at the Inlet	Water at the Outlet	Acceptable Limits* (IS 10500:2012)
pH	8.24	7.09	6.5 - 8.5
Turbidity, NTU	2.00	Nil	1 (Max)
Total Alkalinity, mg/l	255.00	10.00	200 (Max)
Total Hardness, mg/l	4575.00	15.00	200 (Max)
Chlorides, mg/l	23751	10.63	250 (Max)
Total Dissolved Solids	31000.00	40.00	500(Max)
Iron, mg/l	0.34	Nil	0.3 (Max)
Sulphates, mg/l	1920.00	Nil	200(Max)
Nitrates, mg/l	4.55	Nil	45 (Max)
Fluorides, mg/l	3,44	Nil	1(Max)
Calcium, mg/l	1000.00	4.00	75(Max)
Magnesium, mg/l	504.22	1.21	30 (Max)
Coliform MPN	50	Nil	Nil
E.Coli	Absent	Absent	Absent

*Acceptable Limits** -These limits are according to ISO10500: 2012

3.2 Results for inlet and outlet water properties

The water from the Arabian Sea is used as a sample, and it is then analyzed chemically. Standard methods are used to test both samples of water coming in and samples of water going out. In the Table, you can see the results. The chemical makeup of the samples of water coming in and going out is compared to the Indian standard drinking water specifications (IS 10500:2012). Table 4 presents a comparison of the allowable chemical components that apply to the water's composition both before and after the purification process. Water production is influenced by several resources, including groundwater, saline water, and seawater. The testing findings show that a Teflon thickness of 3 mm yields an output water amount of 2 L/day. Compared to saline water, seawater produces superior outcomes.

Water quality parameters are essential indicators used to evaluate the sustainability and safety of water. These parameters mainly include temperature, pH, turbidity, total alkalinity, hardness, chlorides, total dissolved solids etc. The pH level of water indicates whether it is acidic or alkaline. pH affects chemical reactions, mineral solubility, and the efficacy of water treatment methods. pH values outside the permissible range can be harmful to aquatic life and water treatment systems. The total dissolved solids (TDS) are the sum of the inorganic and organic components in water. It contains minerals, salts, metals, and other dissolved particles. High TDS levels might impair the flavour and appropriateness of water for drinking.

Water bodies with high turbidity levels can limit photosynthesis and oxygen production. It can also impair the visibility of aquatic creatures and interfere with their feeding and reproductive activities. Water temperature influences a variety of biological, chemical, and physical processes in aquatic habitats. It has the potential to impact gas solubility, metabolic rates of aquatic organisms, and species dispersion. Temperature measurements help to comprehend the thermal properties of water bodies and how they may affect aquatic life. The presence of certain cations causes water to become hard. Hardness is the concentration of divalent or multivalent cations, typically calcium and magnesium, represented as calcium carbonate.

As per the result presented in Table 4, it proves that the system successfully removed chemical contaminants present in the hard water sample. The values of the outlet water sample prove that the chemical parameters are within the limit as per IS 10500:2012, thereby making the output water potable.

3.3 Environmental benefits

Desalination can also generate freshwater from high salt concentrations and other pollutants. This can help individuals meet their fundamental needs, grow food, and support their livelihood. The conversion of seawater into freshwater has environmental benefits for human civilization. Desalination, when done correctly, is a proven process for providing safe, usable water for large populations. More usable water indicates that we can eliminate the problem in the food supply chain. A famine may devastate major population centres. It causes malnutrition, chronic hunger, high mortality rates, and an urgent need for aid. Minimizing saltwater pollution indirectly lowers carbon emissions in the environment. Using renewable energy leaves a minimal carbon footprint. Access to desalination technologies may not cure all of these problems overnight, but it will help households survive till the next day. Another environmental benefit is the preservation of fresh water for future generations to use.

Our world experiences regular weather cycles. Some years may experience a lot of snow or rain. Other years may have relatively little precipitation useful for agriculture or drinking water. We have the opportunity to construct freshwater reserves through the desalination process, which will be used when access to new water rations becomes limited.

The existence of desalination facilities supports a wide range of businesses. The salt collected from water during the desalination process is extremely concentrated and hazardous if dumped into the environment carelessly. It may also be employed in several industries and applications. De-icing agents can be manufactured from sodium-containing materials. Ice is effectively removed from transportation networks with aqueous brine solutions.

4. CONCLUSIONS

Desalination using solar hybrid systems shows promise for producing fresh water in remote areas with limited access to electricity. There is a need for portable, low-energy devices that can operate independently. In this study, a compound parabolic concentrator with an evacuated tube collector is suggested as a method for producing drinkable water. A single CTC-ETC combination was designed and implemented at Cummins College of Engineering for Women in Pune, India. The conclusion drawn is based on various experiments and the aforementioned discussions.

The freshwater output was determined through experimental runs that explored various sources including groundwater, saline water, and seawater. The experimental findings revealed that the 3 mm Teflon coating yielded the highest water output. Results of the experiments indicated that groundwater, saline water, and seawater produced water outputs of 6.25, 3.75, and 5 kg/m^2-day, respectively. The higher output with seawater, as opposed to saline water, can be attributed to the relatively higher salt concentration, which reduces the specific heat of water and consequently leads to a faster evaporation rate. This research determined freshwater production by conducting experimental trials using various sources such as groundwater, saline water, and seawater.

Ongoing research is aimed to find an improved reflecting material for the CPC, such as Titanium Dioxide paint, and to analyse the exergy efficiency of these systems to reduce losses.

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