Journal of Engineering Research

Volume 7
Issue 6 *Issue 6*

Article 12

2023

Enhancing the performance of conventional solar still using the Nano-doped paint (NDP) coating

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Journal of Engineering Research (ERJ
ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

Enhancing the performance of conventional solar still using Nano-doped paint (NDP) coating. An experimental study

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ABSTRACT: **Nations are throughout the entire globe continuously confronting the problem of potable water shortage. Recently, it has been thought that using solar energy to desalinate brackish water offers a practical answer to the world's water crises. The output of these stills, is meager, and academics haven't done much to boost it in any way. Solar distillers have been proposed as an efficient method to produce potable water. In recent years, saltwater has produced drinking water by various ways. The efficiency of a solar distiller is significantly influenced by various factors, most important factor of them is the absorber surface. In this research, an effort is made to increase the efficiency of a traditional solar distiller by applying a thin coating of Nano-black paint to increase the thermal conductivity of the absorber surface. The absorber significantly affects how effectively the solar still functions. In the experiment described in this article, a layer of Nano-doped black paint (NDBP) was applied on that which absorbs a standard solar still in an effort to improve the device's performance. The results showed that the nanocoating changed the condensation mechanism of all materials from film-wise to droplet-wise.It was also concluded that drip condensation at larger surface inclination angles leads to increased condensate water production.For example, the formation of condensation on the glass surface was increased by the 23rd nanocoating at a surface tilt angle of 50°.Additionally, an additional collector was used to estimate the droplet volume before and after the coating process. Also, The results indicated that, the productivity of the conventional solar still has been increased with about 25-32% when use the nano thermal coated. While the modification in design produces an average 18% improvement in fresh water productivity.**

Keywords: **Nano fluids; solar still; productivity; Nano-doped black paint water desalination.**

I. INTRODUCTION

Water scarcity is a major global issue.It is estimated that by 2025, a quarter of the world's population will be water-stressed, and two-thirds of them will suffer from water scarcity[1].

By 2030, half of the world's population will suffer from high levels of water stress.Currently, the African region suffers from high water stress, affecting up to 31% of the population, followed by Asia, America, and Europe with high water stress of 25%, 7%, and 2%, respectively[2]. Desalination is playing an increasingly important role in meeting the demand for fresh water.

Water is a natural gift that has a big impact on society progress and economic growth. Water that is clean is hard to come by[1]. Along with the quickening technological revolution, population growth is a significant factor in the sharp increase in demand for drinkable water[3, 4].

Fresh water shortage one of the most critical concerns facing the world now in recent years due to the fast expansion of industry and population. Due to the sun's plentiful energy, the most promising method of producing steam from the sun is processes for generating fresh water from seawater [5]. However, solar desalting units (SDU) provide a straightforward method for purifying water by condensing and evaporating water while utilizing a significant amount of solar energy [6]. Water for desalination can be obtained from several sources, including as seawater, saline groundwater, and even wastewater. Although among other resources, seawater made the biggest contribution [7, 8]. Desalination plants are unable to supply all the water needed in remote locations where pipeline and transportation costs are high. Portable equipment can be used in these locations to generate fresh water for long-term desalination. Solar energy is the best alternative source for supplying future energy demands. Water purification has a new beginning with the use of solar energy in portable devices. The most popular portable gadget is a solar still [9].

Based on the control of Desalination is often divided into direct and indirect processes using sun energy [10]. Desalination and solar radiation collection take place concurrently in direct mode. In the indirect method, the sun collecting component and the desalination section are separated into two components of the desalination unit. These modes include broken down into a number of strategies that form the basis for later development and adjustment [11]. Direct desalination methods. Use solar energy directly without converting it first; the hot input crosses the heated side of the membrane in this configuration. Evaporation consequently takes place on the heated side of the membrane, the vapor is forced to Condensation occurs due to the pressure, on the frigid side difference.

The flow of input is unable to pass through the membrane because of the hydrophobic specification [12].

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ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

The indirect method of solar desalination. The thermal desalination processes may use a variety of solar collector types, including as membrane distillation (MD), multistage distillation (MSD), vapor compression (VC), and multiple-effect evaporation (MED) [13].

The basic components of a solar distiller, include a tank for holding salt water (typically painted black to receive high solar radiation), an inclined crystal cover made mostly of glass, a trough for collecting clean water, insulation on all sides except glass, an intake for contaminated water, Water in the tank evaporates via convection from the top of the tank as a result of the heated water being heated by sunlight passing through a clear glass cover. The vapors accumulate at the top of the void vacuum, Condensate drops over the tilting cover and is then deposited on the distillation channel on the bottom wall of the still as the vapors are condensed into a liquid form and the heat is absorbed by the cover material. Thus, the pool's salts and other chemicals contaminants remain and can be removed later through drainage while just water evaporates, collecting incident solar radiation [14-16].

Using an energy analysis to determine the maximum quantity of energy, the second law of thermodynamics is used. that can be recovered from the total amount of energy input while still maintaining the energy's quality [17],The water in the sun still is evaporated by using absorbent materials to boost the solar still's capacity to transport heat. Wick, charcoal, baffles, gravel, sponges, fins, and other absorbing materials are among those employed [18].

Desalination of water using Nano materials, Materials with a minimum dimension of 100 nm or less are referred to as Nano materials. These materials frequently have novel, size-dependent features that set them apart from their large counterparts. Numerous of these Nano materials have been investigated and identified as potential components for water and wastewater treatment applications in adsorption, membrane filtration, photo catalysis, disinfection, and microbial control [19]. materials used as How much water a solar still produces in a certain length of time As PCMs, Nano fluids, nanoparticles, and nanostructures, energy storage for solar desalination is possible , Is increased by using various nanoparticles [20].

They are different types of Nano materials that fall within the organic and inorganic categories. It is made up of carbon-based Nano materials for organic groups such Bucky balls, grapheme, fullerene, and single-walled carbon nanotubes (CNT). How much water a solar still produces in a certain length of time The inorganics group, however, may be further broken down into metal, metal oxide, and quantum dots, Gold (Au), aluminum (Al), silver (Ag), copper (Cu), and zinc (Zn) are the most often utilized metals and metal oxide Nano materials, along with silicon oxide (SiO2), iron oxide (Fe2 O3), titanium dioxide (TiO2), and copper oxide (CuO) [16]. Solar still coated with Nano-doped paint (NDP), use of black paint that has been nanoparticle-infused. Utilizing Nano-paint has demonstrated its usefulness, particularly in solar distillers [21].

Nano-coatings are substances created by molecularly decreasing substances to create denser substances. Nanoparticles' appearance and practicality offer the paint and coating business a number of benefits and prospects. One of the first industries to utilize the possibilities of nanotechnology is coatings [22]. In summary, the productivity of single-effect solar stills ranges from 2 to 4 l/m2 days for rudimentary versions, and from 3 to 5 l/m2 for versions with improved or optimized shapes of the pool lining material. Increases to m2 days. These rather low numbers led the researchers to introduce further design changes.

II. EXPERIMENTAL SETUP

a. The experimental setup and approach.

The present experimental effort was devoted to create a new and enhanced design of solar stills. The aim of present work was to create, construct, and test a conventional and in conventional solar still on order to evaluate freshwater production using sun desalination. The present work implemented the technology of nano coated in order to enhance conventional solar desalination performance using a Nano-doped paint (NDP) coating[23].

The experimental apparatus included 5 mm thick glass was used to construct the single slope solar still [24].The area of the pool was estimated to be 45 × 45 cm2. Furthermore, the height of the front wall was 10 cm, and the heights of the back side wall were designed to be 35 cm .The slope of the condensation cover is, 30°. Table 1 shows the dimensions of the condensing surface at various surface inclination angles. Additionally, all external surfaces were well insulated with 2 cm thick polyethylene foam.

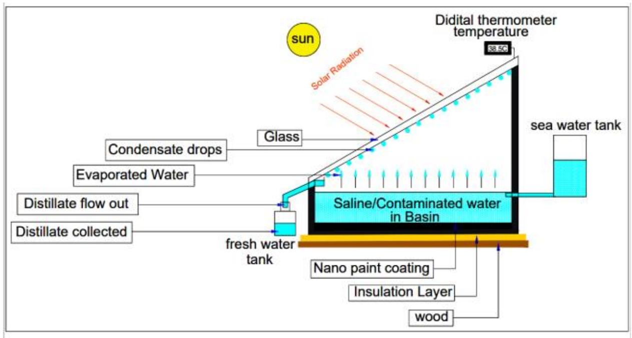

Figure.1 Sketch diagram of the experimental

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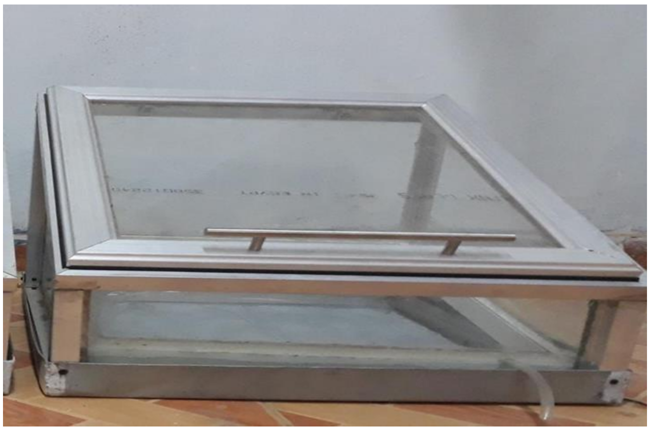

Figure.2 conventional solar still.

Figure.3 conventional solar still with nano coating.

Figure.4 conventional solar still with nano coating and heat transfer medium.

b. Experimental setup description.

As descriped in Fig.(1) to Fig. (4) ,For the testing aim, three identically constructed conventional single-slope solar stills with the designations conventional solar still and conventional solar still with black paint (CS-BP) and conventional solar still with Nano-doped black paint (CS-NDBP) and heat transfer medium were built [25]. In order to obtain a high rate of heat collection throughout the course of the available solar hours, galvanized sheet with a 0.4 mm thickness was utilized as the absorber for both stills.

Regular black paint was used to paint the top side of the absorber for the still with the designation CS-BP. While, Nano-doped black paint was used to paint the top side of the absorber for the solar still with the designation CS-NDBP [26]. Then, all absorbers had received an adequate curing The square metal basin covered by a glass panel that is 5 mm thick and has a 30° slope makes up the solar still[27]. From the lower end of the glass panel, sliding water condensate is collected using a collecting tray and placed in a graded cylinder at the interior surface of the inclined glass panel [28]. The metal bowl was rectangular in design, measuring 45 cm in length and 45 cm in breadth. Its height from the rear is 38 cm, but it drops to 12 cm at the front. To optimize the absorption of solar energy, the basin was painted a dark tone to remove the glass cover's sliding water condensate collection device; a tiny channel was built in the bottom front side of the glass panel. On the basins bottom side.

The experimentation is done in the period from 7:00 am to 7:00 pm. The amount of solar radiation, the surrounding temperature, the temperature of the glass cover, the temperature of the water in the basin, the temperature of the absorber plate, and the temperature of the distilled water are all measured for both solar stills every hour both for conventional solar stills painted in black (CS-BP) and conventional solar stills painted in black with nanoparticles (CS-NDBP). Each hour, freshwater productivity is frequently assessed. The goal of every experiment is to gauge freshwater production.

Table.1 technical description of solar stills.

No.	Items	Materials/Dimensions
		CS-NDBP
1	Basin material	Galvanized sheet
2	Absorber coating	Kemapoxy110
3	Basin Dimensions	45cmx45cm
4	Insulation	Thermal fiber
5	high wall	Glass that is transparent and 5 mm thick.
6	Side walls and the floor of the still	Glass that is transparent and 5 mm thick.
7	Top-glass cover's inclination with a horizontal	30°

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ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

III. RESULTS AND DISCUSSION

In the current experimental study, experimentation is carried out between 7:00 a.m. to 7:00 p.m. The amount of sunlight, the outside temperature, the temperature of the glass cover, and the temperature of the water in the basin, and humid air temperature are monitored every hour for traditional and modified solar stills. Each hour, the freshwater production of both standard and customized solar stills is evaluated. The purpose of every experimental measurement is to evaluate freshwater production.

Even if the redesigned system's temperature values are higher than the traditional one, it is observed that all temperatures rise about mid-day time (11:30-4:00) and start to drop following 4:00 PM due to a shift in sun radiation.

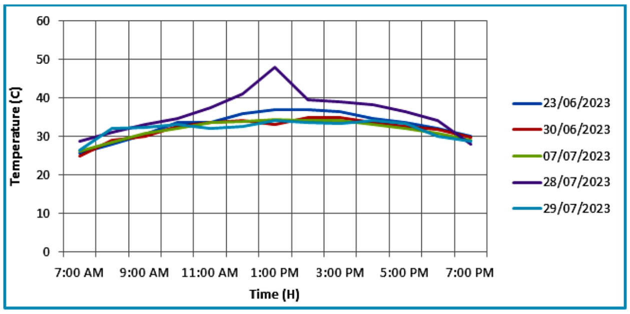

Figure .5 Differences in the ambient temperature on an hourly basis during the test days.

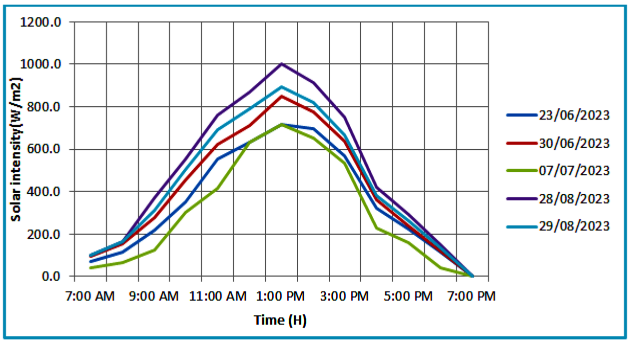

Figure.6 Solar intensity variations on an hourly basis over the test days.

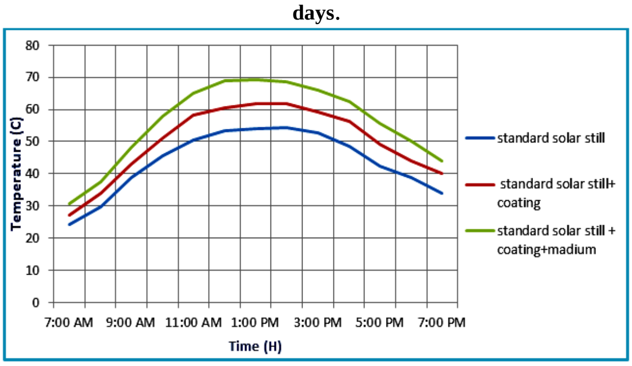

Figure.7 Basin water temperature for (conventional, conventional coating, conventional+coating+madium) solar still at the first day, the second day, the third day, the fourth day, the fifth day.

A comparison of the solar radiation and temperature with day time of the solar still shown in figures 5, 6, and 7. In other words, the results show that there is an inverse relationship between time per day and radiation and temperature .For a better evaluation, the condensate production versus wettability at different solar time. To explain a little further, as the temperature of glass increased per day the still produce more condensation than less wettable materials.

As seen in Fig.7 All throughout the day of trials illustrate the temperature variation of the basin's water with respect to time for the custom and modified solar stills. Shows how the basin's temperature changed throughout time. The highest basin water temperature was found to occur between the hours of 12 and 4.

The traditional The highest water temperature in the basin of the coating solar still is about 61.8 Co, whereas the maximum water temperature in the basin of the conventional sun still is around 54.3 Co Additionally, the Conventional Coating + medium's maximum basin water temperature is around 69.4 Co.

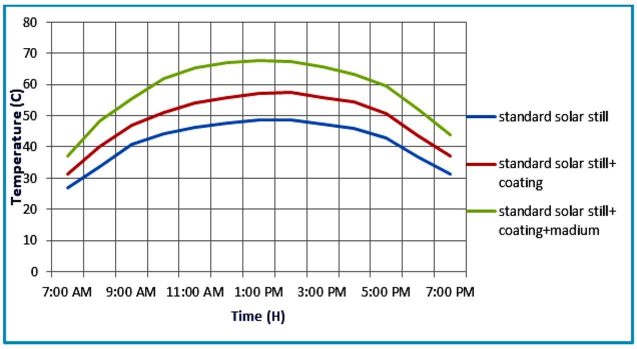

Figure.8 Humid air temperature for (conventional, conventional coating, conventional+coating+madium) solar still at the first day, the second day, the third day, the fourth day, the fifth day.

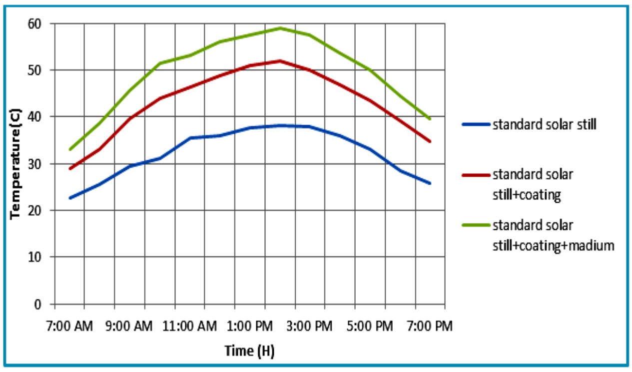

Figure.9 glass temperature for (conventional, conventional coating, conventional+coating+madium) solar still at the first day, the second day, the third day, the fourth day, the fifth day.

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ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

Fig.8 shows the results of temperature vs. different days of experiment for both traditional and modified solar stills illustrate the fluctuation in humid air temperature according to time during the whole day of testing. Shows the changing temperature of the humid air over time. It was found that between the hours of 12 and 4 pm, the air was at its most humid.

The traditional solar still's maximum humid air temperature is around 48.6 Co, whereas the conventional Coating solar still's maximum humid air temperature is approximately 57.5 Co. Additionally, the Conventional Coating with heat traansfer medium's achieves maximum humid air temperature is around 67.5 Co.

Fig.9 illustrates both traditional and modified solar stills illustrate the fluctuation in humid air temperature according to time during the whole day of testing. Shows how the temperature of the glass has changed over time. It was found that between 12 and 4 PM, the glass temperature was at its highest. The traditional Coating solar still's maximum glass temperature is roughly 51 Co, vs. the maximum of the traditional solar still glass temperature of about 38 Co.

Additionally, the Conventional Coating medium's maximum glass temperature is around 69 Co. Also, shown in figure that the productivity of water varies throughout time. The maximum water productivity was found to occur between the hours of 12 and 4 of day time. It was observed from the results that ,the traditional Coating solar still has a maximum water productivity of roughly 2715 mL as opposed the maximum water output of the traditional solar still is around 2372 mL. Additionally, the Conventional Coating with heat transfer medium have a maximum water production of roughly 3217 mL.

Experimental results also include additional illustrations. Results show the effect of an additional coating and absobation material on condensate water production from the collecting surface. We found that with the additional coating with heat transfer medium, the nanocoating on the surface and thus the droplet-like condensation produces more condensate than the film-like mode, even at a surface tilt angle of 30°.

Furthermore, it was found that with the addition of excess heat transfer medium, the amount of droplets originating from the coated surface was much higher than that originating from the uncoated surface. On the other hand, coating the surface with nanosilicon increased condensate water production. The difference between the amount of condensate when three different methods are added and the amount of condensate when no excess collectors are added indicates the displacement is described in Fig.9.

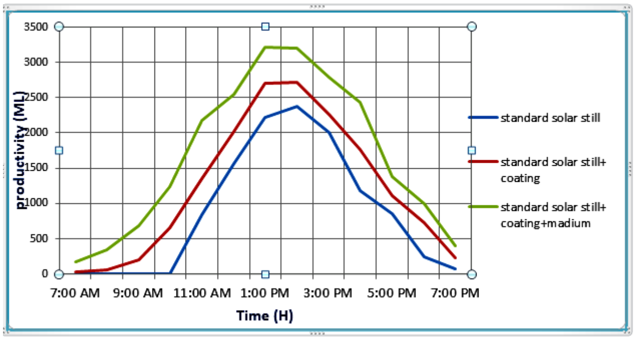

Figure.10 productivity of water for (conventional, conventional coating, conventional with coating and heat transfer me dium) solar still at different days.

a. Contribution of Nano fluids to improved moon radiation absorption:

Numerous investigations enhanced moon radiation absorption using nanoparticle suspensions over that seen for the base fluid in cases when the base fluid is clear. The characteristic wavelengths of lunar light, visible and near-infrared were particularly notable for this effect. Nano fluids can be added to the surface of the basin to increase the basin's output solar still because they increase evaporation rate and raise water temperature, heat transfer coefficient for convection and thermal conductivity. The nanoparticle suspension's infrared absorption coefficient, which accounts for the majority of the heat radiation it emits, is unchanged from that of the base fluid.

Considering this, nanoparticles can be compared as dynamic photo-thermal sites. That are capable of strongly absorbing the designated lunar radiation wavelengths and effectively converting them into heat energy.

The role of Nano fluids in enhancing the still sinks fluid's a heat transfer coefficient for internal convection and heat capacity. The thermal conductivities of every Nano fluid were found to be superior to those of their basic fluids, according to experimental results published in the literature by numerous researchers.

Metal oxides nonetheless have higher thermal conductivities than water, while having lower thermal conductivities than the respective metals. As a result, Nano fluids made of metal or nonmetal oxides suspended in water exhibited improved thermal conductivities compared to water, as is the case in the current work. In the lunar still sink containing Nano fluid, the large rise in conductivities has dynamic impacts on the main factors in heat transfer characteristics, such as the thermal boundary layer reforming and micro layer evaporation. Additionally, when the sink fluid temperature climbs until it reaches its

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ISSN: 2356-9441 Vol. 7 – No. 6, 2023 ©Tanta University, Faculty of Engineering e ISSN: 2735-4873

maximum value around noon, the expanding bubbles in the sink fluid add to turbulence in the laminar subsurface layer, which also enhances convective heat transfer in this layer and increases the vaporization from surface sub layers. In the current study when implemented the modified solar still with both nanocoating and with heat transfer medium it was observed that using Nano fluid maximizes the modified still's production gain 133.64% and 93.87% greater than that of the conventional throughout the whole day.

IV. CONCLUSION

To study the influence of wettability on the condensation yield of a single-tilt solar distiller, different materials with different wettability were used as condensation covers. It was observed that highly wettable materials such as glass for the still cover and coated basin can produce more distilled water. Additionally, we used a dip coating technique with nanocoating solution to modify the wettability of each material.

Based on experimental observations, for all materials used as condensation covers in this study, surface nanocoatings reduced the surface wettability and changed the condensation mechanism from film-based to droplet-based. Comparing the amount of condensate produced before and after surface coating, we found that more distillate was produced on the coated surface, especially when the surface tilt angle was large. However, at a 30° surface tilt, the uncoated surface formed more condensate than the coated surface. It was concluded that coating the surface leads to a significant increase in water droplets.

The results confirmed that the produced droplet volume in droplet mode was much larger than in film mode. In addition, an additional collector was used to measure the amount of dripping water before and after the coating process.

On the basis of the outcomes displayed in this context, the conclusions that can be made are as follows:

(1) By increasing the water temperature, thermal conductivity, and convective heat transfer coefficient by nanoparticles, the addition of Nano fluids to the basin's surface can increase the basin's solar still productivity accelerating heat transfer, which in turn accelerates evaporation.

(2) Using Nano fluid maximizes the modified still's production gain (133.64% and 93.87% greater than that of the conventional throughout the whole day). The improved system yields the highest water productivities.

(3) The redesigned solar desalination system is effective. According to the alteration design, there is an average 18% improvement in fresh water productivity.

V. LIST OF SYMBOLS AND ABBREVIATIONS

RE	Renewable energy
SDU	Solar desalting units
MD	Membrane desalination.
SiO_2	Silicon dioxide
Al_2O_3	Aluminum oxide
NDBP	Nano-doped black paint
I	Solar radiation
Tw	Water temperature
Ta	Ambient Temperature
Tb	Basin fluid Temperature
Tg	Glass Temperature

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