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Practical investigation of zinc oxide nano plate effects on the performance of closed solarpowered still

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ABSTRACT

Brackish wastewater is mostly discharged to the sea or desert, which put the environment and ecosystem on the danger and result in significant problems.

In order to reuse brackish wastewater of Mobin petrochemical complex and to produce sweet water, a closed solar powered still is set up. Obviously, the increase in brackish water temperature increases the average daily production of solar desalination still, considerably. So, the nano plate and vacuum pump are added to augment the evaporation rate. Experiments are held to find the effect of nano plate and vacuum pump on solar energy adsorption. The vacuum pump pulls out the water vapor slightly from the solar box and improves the vaporization.

Results indicate that nano plate augments evaporation rate; thus it produces more sweet water and saves more energy in contrary to the solar powered still without nano plate.

KEYWORDS

Zinc oxide;
Solar powered still;
Nano plate;
Evaporation.

INTRODUCTION

Obviously, the mankind life is dependent on sea, rivers, underground water, raining for continuing the life. The problem of shortage of potable water is dramatically soring. It has been estimated that about97% of the earth wateris saline and just approximately 3%of earth water is drinkable[1]. The rapid growth ofthe clean water consumption due to sever increase in population and industrialization is becoming more unbearable. In spite of this, water pollution is alarmingly dangerous for ecosystem. In order to solve these problems, zero discharge desalination procedure has been introduced as the best solution. Today, there are some oil-based technologies such asmulti-effect distillation, MED, multistage flash, MSF, that can solve the problem of drinkable water scarcity. But, it is not defined as a good and sustainable way because the availability of fossil fuels in the whole universe is very limited and burning of the fossil fuels emit many hazardous gases which is not environmentally friendly[2-3]. Thus, the use of solar energy for the production of fresh water seems to be an excellent choice due to many significant advantages. It is the most environmentally friendly, pollution-free, self-contained, reliable,

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quiet, long-term, maintenance-free, year-round continuous and unlimited operation at moderate costs form of all energies that can be used for desalination.

Zero discharge desalination process is remarkable since itdecreases or removes the biological problems, which are resultant of concentrated brine wastewaters drainage into sea ecosystem. Scholars mostly, have fulfilled their investigation of the technical feasibility of solar stills during 1986 to 1995[4,5]. After that till to 2000, the focus has gone on the development of solar still. Since 2000, economics and thermodynamic efficiency factors have been investigated in order to make it more economically and competitive with other desalination techniques such as RO, multistage flash (MSF), multi effect distillation (MED), ED, etc., which some of them (i.e. MED and MSF) employ with direct use of fuel energies[6-7].

In this experimental work, several effective parameters of closed solar powered still, which is applied to desalination unit, are surveyed. Evaluation of insolation rate in during the day (hourly), annual ambient temperature, and daily insolation rate are studied.

In addition, temperature gradient, evaporation rate, amounts of highest and lowest production, electricity generation and density are investigated in this closed solar powered-still during a year. Additionally, the effect of nano plate, which is directly influence on efficiency, is surveyed

MATERIALS AND METHODS

Experimental setup

The thermal desalination solar still used in this work is composed of a metallic basin and a glass roof.

The thickness of glass roofs and walls is 4 mm to enhance transmissivity coefficient. The floor of solar-powered still is made of zinc oxide nano plate. The net evaporation rate area of solar desalination still is $1\,m^2$, facing south with an inclination of 35.7° (the latitude of Tehran City) to achieve the most solar radiation. Insolation rate is the amount of radiant energy from the Sun which impacts upon a unit surface area. This depends upon the angle of the Sun with respect to the vertical over the surface. According to the literatures the maximum amount of insolation rate is received when the inclination of the glass roof equals to the latitude of area. So, the inclination of glass roof for this experiment is chosen 35.7° with respect to the latitude of Tehran City. Also, the surface of solar still bottom is dyed black. The solar still area consists of 3 parts, which are separated by means of 2 long rectangles. The middle part is filled with the concentrated brine wastewater and its level is 100 cm. So, the maximum amount of solar insolation rate is absorbed in these conditions. The feed is conveyed into the still through a 2cm diameter hole, the distillate is collected into avessel and concentrated brine wastewater is

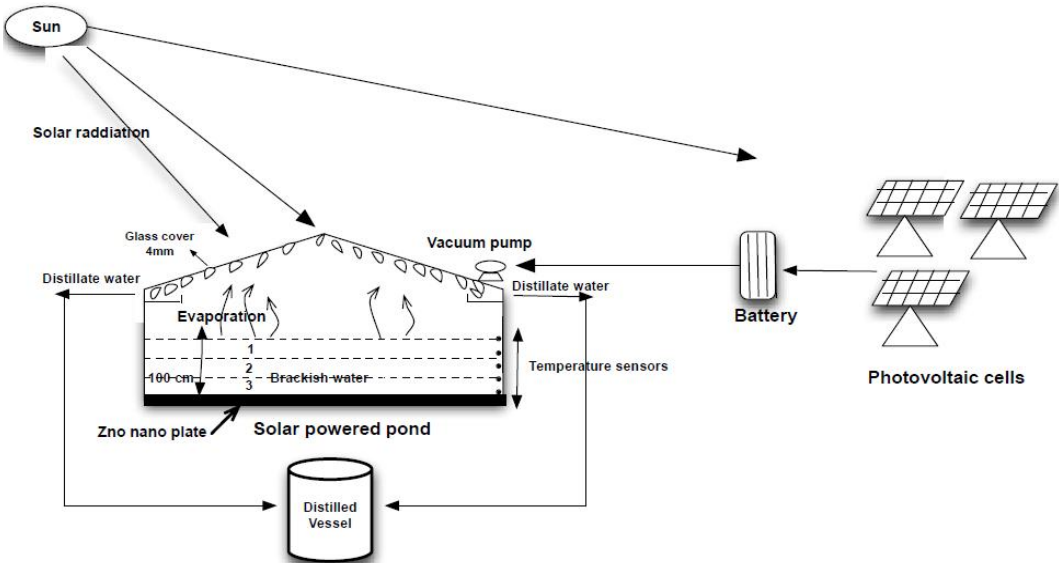

Figure 1 : The schematic of the used solar powered desalination still

drained through another 2 cm diameter hole. A schematic of the used solar desalination still is shown in Figure 1.

Methods

This solar still operates on the same principle as rainwater: evaporation rate and condensation[10, 11, 12]. The water from the oceans evaporates, only to cool, condense, and return to earth as rain[13, 14]. When the water evaporates, it removes only pure water and leaves all contaminants behind. This solar still mimics this natural process. This solar still has a top cover made of glass. The glass cover allows the solar radiation (short-wave) to pass into the still, which is mostly absorbed by the blackened base. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The base also radiates energy in the infrared region (long-wave), which is reflected back into the still by the glass cover, trapping the solar energy inside the still (the "greenhouse" effect). The floor of used solar still is situated a nano plate. This floor is black and is made from nano particles of zinc oxide. This choice is helped to enhance the trapped thermal energy. So, the evaporation rate will be enhanced and lead to the higher amount of drinking water comparing with the current solar still. The heated water vapor evaporates from the basin and condenses on the corner of the solar still. In this process, the salts and microbes that were in the original water are left behind.

Generally, the evaporation rate is defined as the amount of liquid evaporates per square meter per day. The properties of air such as moisture content and temperature, insolation rate and wind velocity affect on this rate.

Distilled water is accumulated in side parts of the solar still and is drained into collector vessels ultimately. The produced water is generally potable; the quality of the distillate is very high because all the salts, inorganic and organic components are left behind in the still. Initial volume and initial salinity percentage of feed of solar still are 1000 liter and 5.45%, respectively. The height of brine wastewater in solar still is divided to 5 parts therefore the height of each part is 20 cm. The specific gravity and temperature are evaluated in each part of the solar still. Also, evaporation rate, average ambient temperature, density, viscosity, average temperature of different layers, insolation rate, maximum and minimum value of production rate is measured in this work. Specific gravity of the layers is calculated by weight-volume method. Distillate exit from two sides of still continuously so system remains under non-equilibrium condition. Residence time of solar still affects the performance time of zero discharge desalination process. So, concentrated wastewater is drained from solar still when the concentration reaches 20% according to the local operating conditions of the experiments such as Insolation rate, evaporation rate. In the proposed next stage, saline water will be saturated in forced circulation crystallizer. Solar desalination still is recharged with wastewater that contains 5.45% of salinity. The schematic of the used solar desalination still process is shown in Figure 2. In this work the amount of insolation rates, I , are used according to the Tehran latitude which depends on the 12 monthly mean temperatures.

RESULTS AND DISCUSSION

Experiments are held to find the effect of nano plate in solar energy adsorption, rate of water production and amount of energy saving in the proposed solar powered desalination still. The vacuum pump pulls out the water vapor slightly from the solar box and improves the vaporization. So, the effect of weather moisture and wind velocity on the vaporization may be minor comparing with the effect of insolation rate.

Zinc oxide nano plate of proposed solar still

The nano plate is situated under the proposed solar still as floor. The used material for making this plate is zinc oxide nano particles.

Zinc oxide nano particles

Zinc oxide nano particle is a common ingredient and has a huge variety of applications. Zinc is an essential mineral and is non-toxic in low concentration[8].

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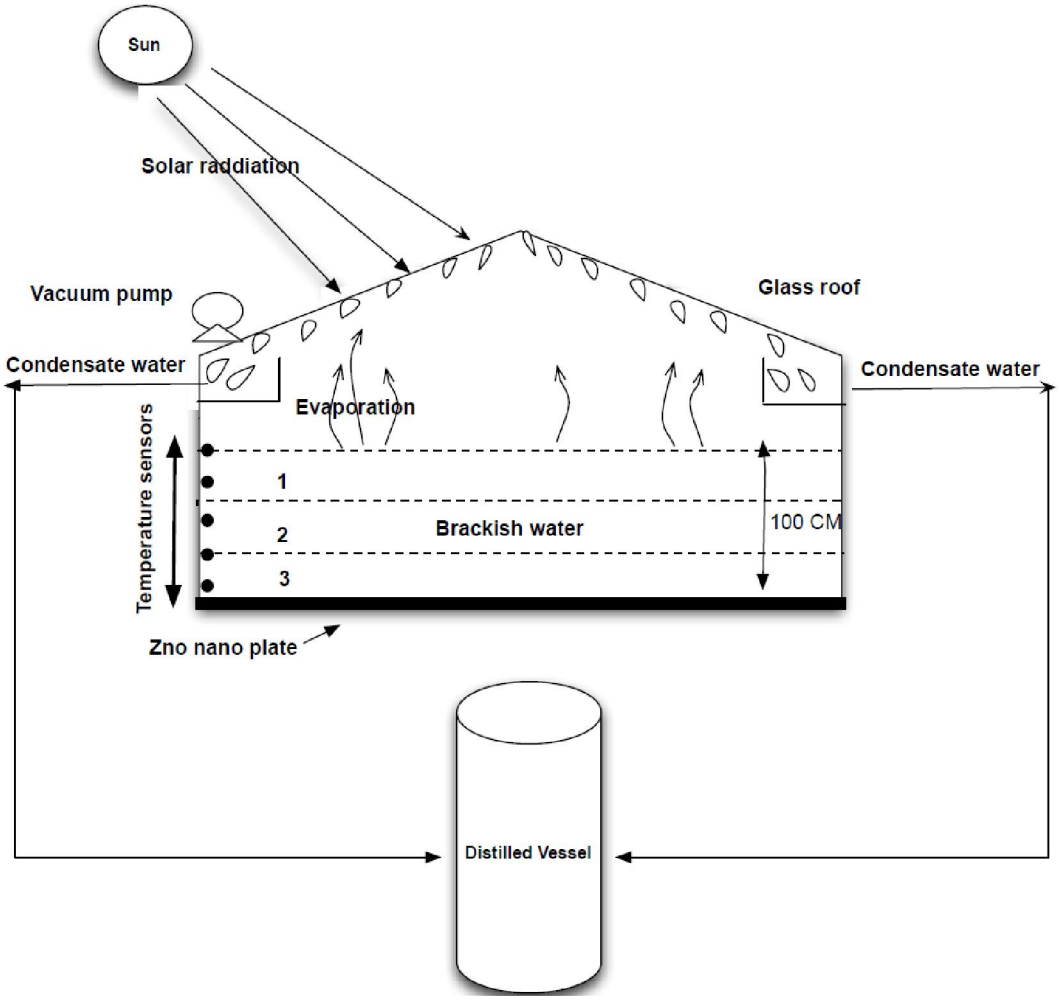

Figure 2 : The schematic of the used solar desalination still process

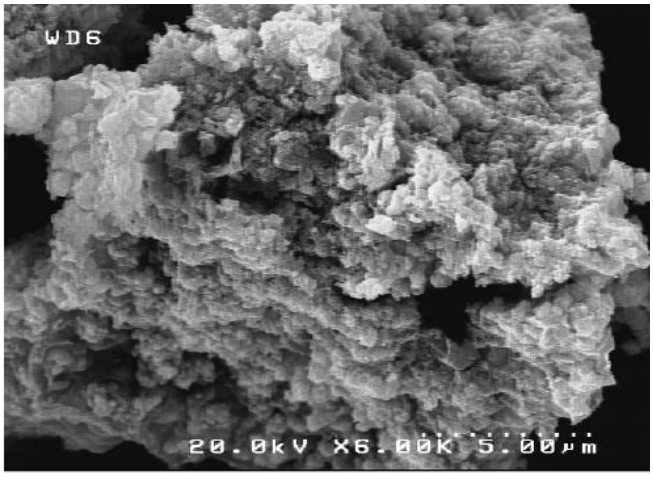

Figure 3 : The SEM of zinc oxide nano particles (5 μm)

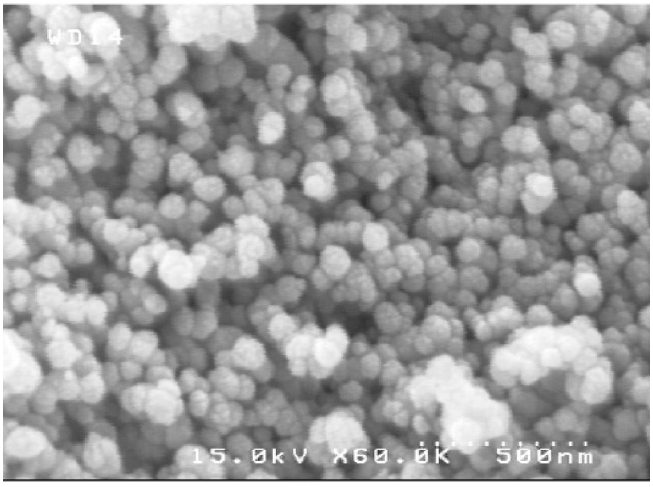

Figure 4 : The SEM of zinc oxide nano particles (500 nm)

Synthesis method of nano-sized ZnO

Zinc metal is used to make a solution containing one molar Zn^{2+} ion. At first, this solution is purified, and then a type of surface-active reagent (zinc acetate dehydrate) 0.05 M is added. At the next step, approximately, 10% of ethanol is added under the ultrasonic conditions. The produced solution is agitated for 25 to 30 minutes. The obtained solution

will be homogenised after this time interval. Same reagents are added to Na_2CO_3, 1M solution under the same conditions. Then another surface active reagent (folic acid) is added. The solution is agitated for 30 min again. In the nest step, filtering and washing of the solution is done several times by ethanol and distilled water alternately under the ultrasonic action. The produced substance is prepared to dry for fifty minutes at $80\,°C$. Then it roasted at $450\,°C$ for forty fifty minutes to obtain zinc oxide nano particles. The obtained produced substance haslight yellow colour, and can been characterized by XRD and TEM. Produced spherical particles with the average diameter of 35 -55 nm in size areobserved approximately and finally the crystal is pure zinc oxide with hexahedral structure[9]. Figure 3 and Figure 4 show SEM photos of nano particles in two different visions in the scale of 5 μm and in the scale of 500 nm respectively. The nano plate, which is situated as floor of solar still is made of zinc oxide nano particles.

Figure 5. shows the values of evaporation rate and ambient temperature in different months during 2013. The increase in the ambient temperature values shows the increase in the amount of evaporation. As mentioned, this solar still is a pool of saltwater which acts like collector with integral heat storage for supplying thermal energy. So, solar

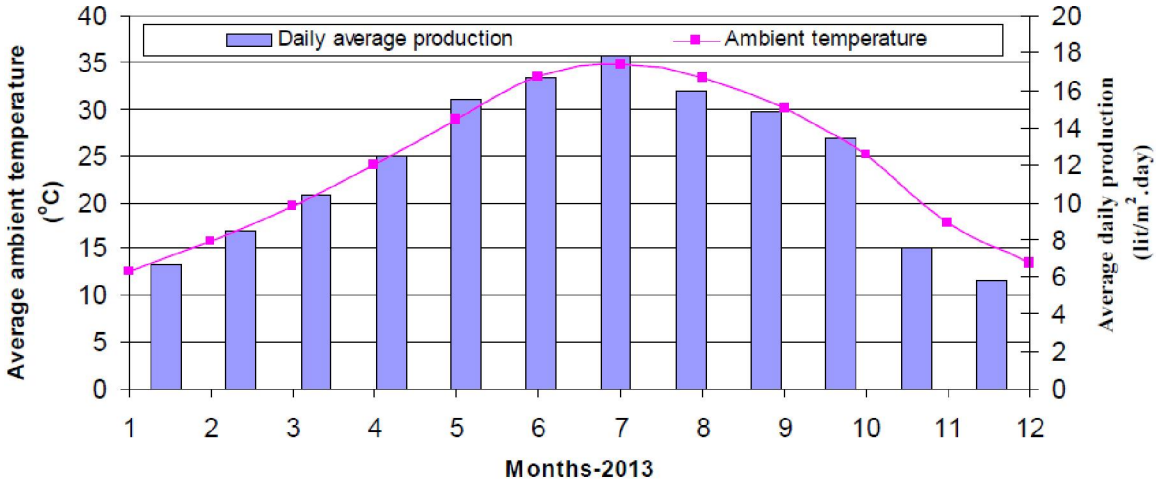

Figure 5 : The evaluation of average daily production and ambient temperature during 2013

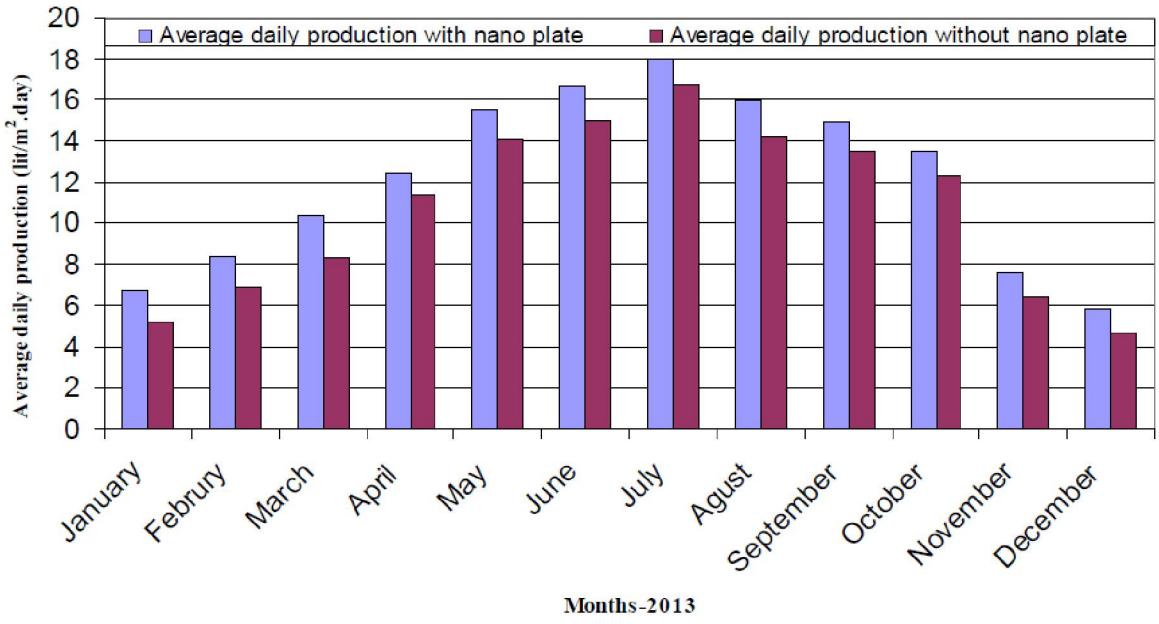

Figure 6 : Comparison between equipped solar powered still and usual solar powered still

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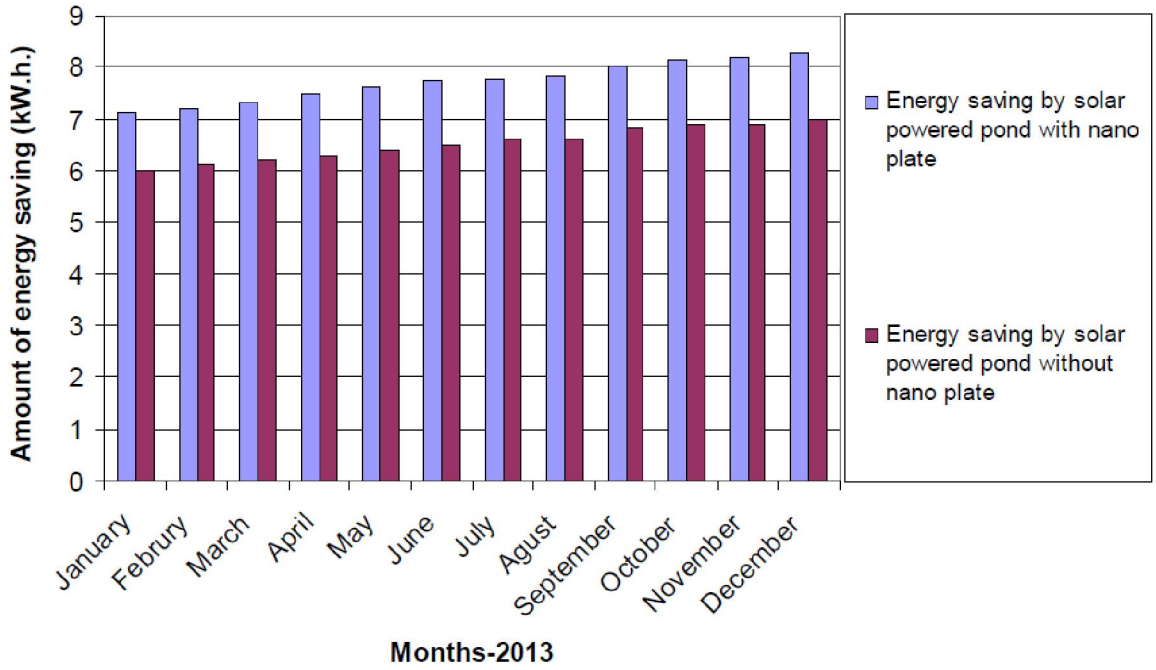

Figure 7 : Comparison between energy saving by solar powered still with nano plate and usual solar powered still

still efficiency is the amount of energy utilized in vaporizing water in the still over the amount of incident solar energy on the still. Maximum and minimum ambient temperature and also moderate insolation rate is obtained in summer and winter respectively. Evaluating the safe capacity of storage tanks for solar still, minimum and maximum amount of produced water is considered. These values are helpful to predict the confident range of produced water to design another solar still in the same place. The maximum and minimum value of produced potable water in July is 22.5 and 13lit/m^2. day, respectively.

The comparison between the amount of water production in the proposed solar powered still equipped by nano plate and usual solar still in different months are given in Figure 6. The specific area of nanoZnO plate is very high. Undoubtedly, the rate of heat and mass transfer is improved by increasing of the area. Therefore, the absorption rate is enhanced and augments evaporation rate; thus, it produces more sweet water and saves more energy. According to the results, using ZnOnano plate improves the performance efficiency of solar still about 16%. Figure 7 shows the amount of saved energy by solar powered still, which is equipped by nano plate and usual solar still. Experimental data proves that efficiency with using this novel solar still is 17% higher than traditional solar powered still.

CONCLUSION

Solar energy is energy supplied by nature; thus, it is free and abundant. Moreover, solar energy can be made available almost anywhere there is sunlight.

The nano plate is synthetized and situated under the proposed solar pond as the floor. Application of nano science and solar energy in fresh water production and also electricity generation from wastewater of desalination unit in one petrochemical industry is considered during a year.

The effect of ZnOnano plate on solar power still efficiency is reported. Experimental data prove that efficiency by using this novel solar still is 17% higher than solar powered still without nano pate.

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