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Continuous desalination process of sea water using solar energy in Bangladesh

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ABSTRACT
Safe drinking water sources are limited and only 3% of total earth's water are drinkable. Approximately 97% of earth's water are salty and not allowed to use without desalination. For purifying the water a huge amount of conventional energy are depleted. In this paper presents the continuous desalination process of sea water using solar energy without any electricity or external power. The desalination process is designed through using flat plate and parabolic solar collector. The flat plate solar collector preheats the water and increase the temperature about 55℃ to 60℃. Then parabolic solar collector heating the water and allowed to vaporization above 85℃ temperature. In this process water supply in the heating pot continuously through the float valve system and at the time of heating the flat plat preheat the water. Finally collected the fresh water using condenser pipe. For large water output multi system of the panel can be applied.

Keywords: Solar, Water, Desalination, Bangladesh, Renewable energy.

1. Introduction

Water is the essential resource to sustain our existence. Mankind scarcely pass a single day without water. Though our earth is abundant of water resource we face scarcity of fresh water. The total volume of water on Earth is estimated at 1.4 billion km³, with 97.5% being salt water and 2.5% being fresh water. However, only about 0.014% of the total is directly available for human beings and other organisms as fresh water [1]. People living in coastal areas and any other region of different countries are facing salinity in water and excessive salinity cause stomach problem and discomfort of taste. According to WHO normal salinity limit in water up to 500 ppm but seawater's salinity is normally range from 35,000 to 45,000 ppm [2]. Producing fresh water from saline water by Electro dialysis, Mechanical vapor compression and Reverse Osmosis process need much electrical energy and abundant installation costs. Some processes need much conventional fuel energy. However for rural people and who are living in remote place can use solar powered water desalination unit to collect fresh water. Besides producing fresh water from saline water using solar energy is environment friendly and save conventional energy and cost.

Desalination using solar energy practiced from the former historic period of history. In 1774, a French chemist named Lavoisier used large glass lenses, which was mounted on structures to concentrate solar energy on distillation flasks [3]. Also in 1872, a Swedish engineer named Carlos Wilson build a large scale solar distillation plant to supply a mining community with drinking water in Chile [4]. From 1965 to 1970 to provide fresh water to small communities on Greek Islands solar distillation plants were built [5]. In 2009 Galveza developed a desalination process of sea water using solar powered membrane distillation unit [6]. Modern developments have discovered that solar powered desalination methods are superior to the alternatives including Reverse Osmosis, ED for fresh water delivery in remote areas [7].

Bangladesh located between 20° 34´-26° 38´ north latitude and 88° 01´-92° 41´ east longitude [8]. The solar radiation effect in Bangladesh is comparatively high for its position in the world map. The solar radiation effect in this region is satisfactory to utilize solar energy for both photovoltaic solar panel and solar collector. So solar energy in Bangladesh is strong alternative sources rather than hydro, wind and tidal energy [9]. The annual solar intensity in Bangladesh is about 1400 to 1700 w/m^2 which can easily use to concentrate in parabolic solar collector to evaporate saline water and finally condensing the steam fresh water is collected [10].

In this paper present the continuous desalination process where eliminate the electric power or external energy and apply only the solar energy as suitable renewable sources. Two types of solar collector are used for effective output of the system. By using only parabolic dish collector is not so efficient and time consuming for the continuous desalination process. Because feeding water needs much time to raise its vaporized temperature from ambient temperature in desalination pot. So flat plate solar collector is used as a preheater to heat up the saline water initially and then final heating is done by the parabolic solar collector. In this continuous desalination process at the time of heating other amount of water preheat in the system. This combined system accelerates the desalination process and decrease the time to raise the vaporized temperature and also increase the overall efficiency of the system. Finally distilled water is collected by condensing the vapor water and can use for a particular operation. Though distilled water is tasteless calcium and mineral can be added for drinking purpose. The experimental setup of the project is described in the second section of this paper and the third section is decorated with the working procedure of the system. The fourth section is compiled with the data collection and analysis and fifth section posses with calculations. Finally in the last section of the paper discuss the conclusion and outcomes of the experimental project.

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2. Experimental setup

In this experiment eliminate all kinds of electric and external power. The experimental setup of continuous desalination system is made out only using solar energy. The total system constructs with three detached units. For continuous desalination the following three units work together.

1. Preheating Unit
2. Heating Unit
3. Condensing Unit

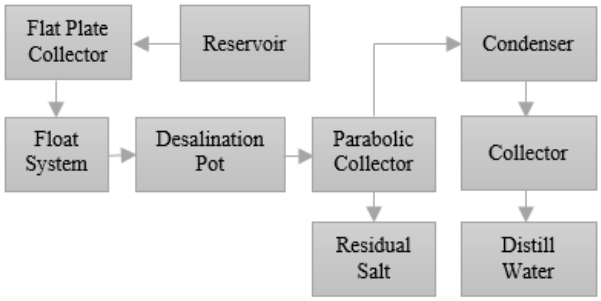

Fig.1 Flow diagram of desalination process

2.1 Preheating unit

In the experiment the main concern is that to supply salty or sea water in heating unit and finally heating the water until its vapor. It is more effective to preheat the water before final heating. When the heating unit works and started to vapor it's taken large time for vaporization. The heating operation was done in a closed system and that time no water is allowed to supply the heating unit. In this idle time the preheating unit is used to preheat the water. The preheating unit consist of a flat plate solar collector, inlet reservoir tank and pipeline with get valve. The inlet reservoir tank is used for input water through the system and flat plate solar collector is used for preheating water.

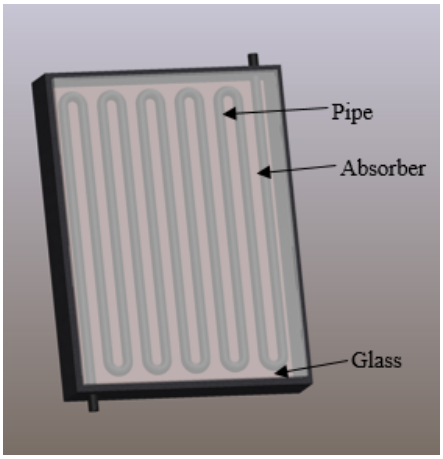

Fig.2 Flat plate solar collector

A flat plate solar collector consists of pipe line covered with dark colored absorber plate and transparent glass which placed in metallic box. The flat plate solar collector is shown in the Fig.2. The main function is that to capture solar radiation from sunlight and absorbed the heat in the absorber. The transparent glass is used as a trap to prevent the heat loss. [11]

2.2 Heating unit

Heating unit is the final operational unit. In this unit pre heated water is allowed for heating until its vaporization. The unit consists of parabolic solar collector, desalination pot and a floating system valve. The parabolic solar collector is made of iron rim decorated with a number of glass pieces focusing on a single point. The parabolic solar collector is shown in the Fig.3. It is used to concentrate the heat in the desalination pot and finally vaporized the preheated water in this desalination pot. The floating system worked as a lock system to prevent supply water from preheating unit at the time of heating. But when steam is produced in the desalination pot the volume of water is decreasing and for minimizing the water the float system allowed water in the pot. This float system supplies water continuously in the desalination pot and produce steam continuously.

Fig.3 Parabolic solar collector

2.3 Condensing unit

Condensing unit consists of a condenser and reservoir tank. The vaporized water turned to a liquid state by the condenser pipe. The condensing pipe is set aside to air cooling rather than power cooling to save electric power. Manual cooling like chiller and water used for rapid cooling of the condenser pipe. Thus the vaporized water from heating unit is directly converted into liquid. It is the final step to collect condensing water and reserved the condensed liquid water in the reservoir tank. Though distilled water is tasteless to drink some mineral rock is kept in the reservoir of mineralized water.

3. Working procedure

For continuous desalination process seawater passes through the inlet port of flat plat plate solar collector from the reservoir. Sea water then fills the pipeline of preheating unit. Preheating unit absorbs ample solar energy to heat up the sea water quickly. When the vaporization starts in distillation unit this time preheating unit increase temperature of sea water about 40-50 ℃. Sea water when

filled up the desalination pot at certain level floating system valve automatically closed. At this time no preheated sea water will enter into desalination pot until abundant sea water vaporized. In a parabolic dish solar collector sun rays incident upon the segments of the mirror. All incidents rays focused to the focal area that mean the lower surface of desalination pot. Incident solar intensity varies with 1100-1500 W/m^2 in experimented areas. This solar intensity is enough to vaporize the sea water. Sea water normally starts vaporization prominently after 15 minutes of the process starts. Approximately 30 minutes later its mass flow rate is about 0.1-0.2 Kg/hr. Mass flow rate varies with different times of the day. When ample water vaporized and passes through the outlet port to the condenser water level falls float system valve opened to fill up the level. The vaporization process maintains about 70-100℃ so salt cannot vaporized because boiling point of salt much higher than water. Some vapor condensed in the desalination pots upper inclined surface and droplet creates. Droplet goes to the outlet port along with the inclined surface due to gravity. Outlet port situated at the end of inclined surface. Due to the vapor pressure in the desalination pot generated vapor enter into the condenser pipe which is ice chilled. Upper portion of the condenser is ice chilled so that steam can quickly condensed. Another portion can condense in the condenser by natural air. Condenser pipe constructed such way that condensed pure water can flow down to the collector by gravity action. In collector distilled water is mineralized by calcium and magnesium rocks. The experimental setup of desalination process is shown in Fig.4.

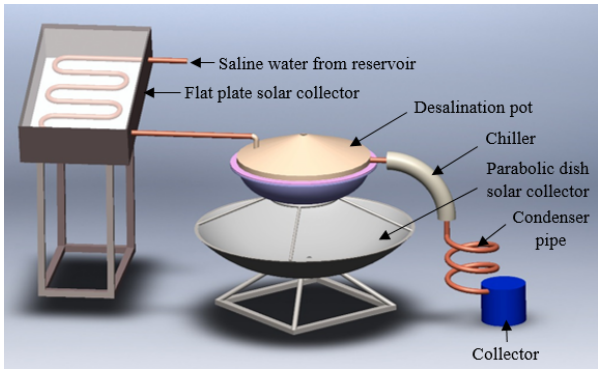

Fig.4 Experimental setup of desalination process

4. Data collection and analysis

This desalination process is done by the solar energy and ultimately solar energy depended on sunshine. So the data of the experiment are vary according to different day and time. It assumes that the vaporization is started partially above 85℃ temperature and by the experiment, it found that only 30 minutes need to raise the final temperature above the desired temperature in parabolic solar collector while preheating at 64℃ temperature. The flat plate solar collector preheats the water before supply in the desalination pot. For flat plate solar collector the different temperature at the same time interval is shown in Fig.5. It takes an average 30 minutes to increase the temperature from 32℃ to 64℃.

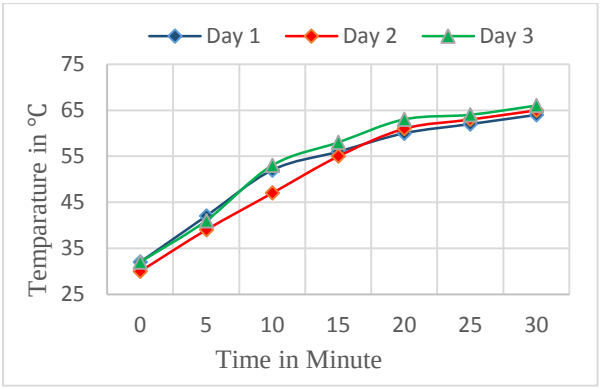

Fig.5 Temperature Vs. Time for flat plat collector

In the parabolic solar collector the preheated water, which temperature is above 60℃ allowed for final heating and it took 25 to 30 minutes to raise temperature above 85℃. The different temperature at different time of parabolic solar collector are shown in Fig.6.

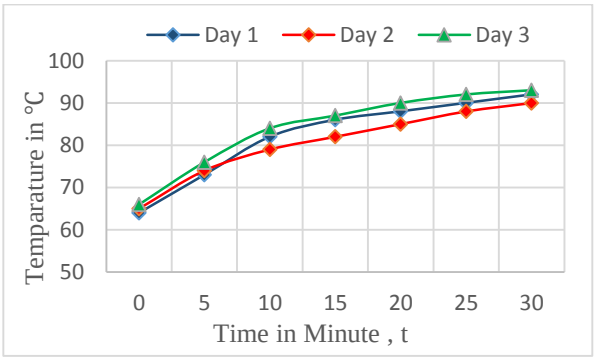

Fig.6 Temperature Vs. Time for parabolic collector

For the data analysis the fate plate solar collector initial temperature is assumed T_1 and the final temperature is assumed T_2. The final temperature of the flat plate is considered as the initial temperature of the parabolic solar collector and finally the ultimate temperature is assumed T_3. For the desalination process more rapid at the time of vaporization at parabolic collector the flat plate collector preheat the water for next vaporization process. The combined work of the two collectors at the same time interval are shown in the Fig.7.

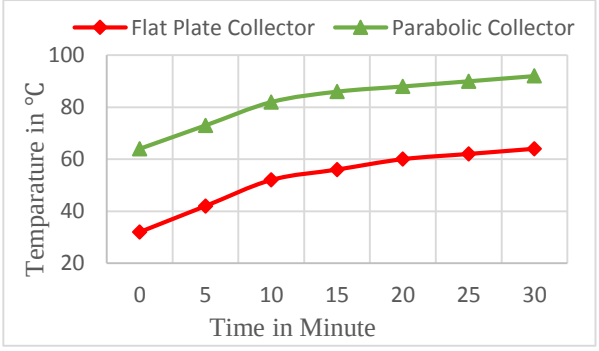

Fig.7 Temperature Vs. Time for combined system

5. Calculations

The efficiency of both flat plate solar collector and parabolic solar collector is calculated separately and finally find out the overall efficiency and mass flow rate. The surface area of the flat plate is 0.8387 m^2. There are 11 pieces of pipes which diameter is 0.5 inches and length 36 inch. The volume of pipe is equal to the water volume and it converts into the mass of water. It found 1.294 kg water allowed to preheat from 32℃ temperature to 64℃ temperature in the flat plate solar collector. The average solar intensity for both the collector is assumed 1400 W/m^2.

$$\eta_1 = \frac{m \times S \times (T_2 - T_1)}{A_1 \times I \times t} \quad (1)$$

By the equation 1 the efficiency of the flat plate solar collector is calculated and it was found 8.39%.

The surface area of the parabolic dish solar collector is calculated by equation 2 using the diameter 44 inch and height 7 inch.

$$A_2 = \left(\frac{\pi}{6}\right)\left(\frac{r}{h^2}\right)\left[(r^2 + 4h^2)^{\frac{3}{2}} - r^3\right] \quad (2)$$

The surface area of the parabolic solar collector is found 1.097 m^2. By this collector the temperature is increased from 64℃ to 92℃ and 35 g steam is produced within 30 minutes. In this distillation pot always 1 kg water allowed to heat. The efficiency of the parabolic solar collector is calculated by using equation 3 and it found 7.09%.

$$\eta_2 = \frac{mS(T_3 - T_2) + \Delta m \times Lv}{A_2 \times I \times t} \quad (3)$$

The continuous desalination process is done with combined system. In this system finally increase the temperature above 92 ℃ from 32 ℃ . The overall efficiency is equal to the summation of the both efficiency. Finally it found that the overall efficiency is 15.48% and mass flow rate of condense water 1.67 g/min.

6. Conclusion

The continuous desalination process of sea water was done by flat plate and the parabolic dish solar collector. The variation of the sunshine affects the producing rate of steam and slow down the output production. The following conclusions were drawn from the experiment:

a. Conventional desalination process as Electro dialysis, Mechanical vapor compression, and Reverse Osmosis can be replaced by this continuous desalination method for eliminating the electric energy.
b. Low installation cost and environment friendly.
c. Using solar energy as renewable sources it has zero running cost.
d. In flat plate collector water temperature raises up to 60℃ and in parabolic dish solar collector its temperature raises up to its vaporization temperature.
e. The individual efficiency of parabolic solar collector and flat plate solar collector are 7.09% & 8.39% respectively. But unification of these two system give overall efficiency is 15.48%.
f. The mass flow rate of condense water is found 1.67 g/min.
g. Higher efficiency and mass flow rate can be expected with larger unit and more series connection of the collectors.

NOMENCLATURE

A_1 : Flat plate surface area, m^2
A_2 : Parabolic dish surface area, m^2
r : Parabolic dish radius, m
h : Parabolic dish depth, m
η : Efficience, %
T_1 : Inlet temperature of water in flat plate, ℃
T_2 : Outlet temperature of water in flat plate, ℃
T_3 : Final temperature of water in parabolic dish, ℃
S : Specific heat of water, $J \cdot kg^{-1} \cdot °K^{-1}$
L_v : Latent heat of vaporization, $J \cdot kg^{-1}$
m : Mass of water in the desalination pot, kg
Δm : Mass of vapor produced, kg
I : Solar intensity, W/m^2
t : Total time required, sec

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