Solar desalination of seawater using a single-basin single sloped solar still with a parabolic concentrator

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Abstract – *Many countries around the world have inadequate supply of drinking and usable water although around 71% of the earth's surface is covered by water. This is because of the rapid growth of population and industries worldwide. Desalination of water is one of the economical solution for water scarcity problem especially in coastal areas where there is insufficient supply of fresh water and electricity. Conversion of the available brackish water into potable water can be accomplished in many ways such as distillation, ion exchange, desalination using membranes and solar desalination etc. Solar desalination using solar still is the compact, easy to fabricate and cost effective method of desalination of seawater. The fabrication of solar still involves the components wooden box, aluminium plate, water collector and glass cover. The working of the solar still is that when the solar radiations enter the solar still through the glass cover and reaches the aluminium plate mounted at the bottom of the still. The aluminium plate which is coated with black paint, has high thermal conductivity. Solar radiations are absorbed by the aluminium plate and it conducts heat to the salt water above the plate. After few hours, this heat becomes sufficient enough to form water vapour. Water vapour condenses on the glass cover and then gets collected in the water collector and passed into the measuring beaker through the outlet tube. It is found that the solar still with parabolic reflector is more efficient than the conventional solar stills.*

***Key Words*: Desalination, Solar still, brackish water, aluminium plate, parabolic reflector.**

1. INTRODUCTION

Water is necessary for all plants, animals and humans. Water covers around 70% of the earth's surface. About 97% of the water on earth exists as the salt water in the oceans and the remaining is the water in the form of ice contained in the frigid zones, groundwater, lakes and rivers. These sources furnish most human and animal needs. Only about 1% of fresh water is available for human use. Even this small fraction is believed to be adequate to support life and vegetation on earth.

Most of the fresh water comes from the hydrological cycle, which itself is a very large-scale process of solar distillation to produce fresh water. However, rapid growth of population and industries worldwide has resulted in an exponential growth in the demand for freshwater, both for domestic and agricultural purposes. Solar stills have the potential to provide desalinated water with minimal cost in coastal areas since it uses renewable solar energy and efficient components.

1.1 Literature review

A vast amount of research work has been carried out in the area of solar still. Author would like to list a few important works.

In the fabrication of solar still, Tiwari et al.[1] studied the effect of cooling the glass cover on the performance of a single basin solar still. By passing the cold water at a constant velocity, the water collected is almost increased by two times when compared to a solar still with uncooled glass cover. Dependence of various operating parameters on the performance of the system has also been studied.

Lawrence et.al. [2] have analysed a solar still by considering the effect of flow of water across the glass cover and by varying the volume of water present in the basin. It was found that, increase of water output and efficiency was 9% and 5%, respectively, when the water was flowing at 1.5 m/s.

Bilal et.al [3] has conducted experimental analysis by using different absorber materials to enhance the efficiency of the single-basin solar still. A single-basin solar still with double slopes was used having an effective area of insulation of 3 m^2. It was observed that by the use of absorbing materials such as black rubber mat, black ink and black dye, water production were increased by 38%,45% and 60% respectively.

Dr.S.Shanmugam[4] has conducted experimental study on a solar still with different energy absorbing materials like pebbles, black granite stones, and concrete stones immersed in salt water. These stones act like fins and helped in effective heat transfer. It is found that the concrete stones having low density and higher thermal conductivity when compared to other stones produced at least 0.9 liters water more than other stones.

Pankaj K. Srivastava.[5] has investigated the performance of the single sloped single-basin solar still with the easily available floating porous absorber materials such as jute fabric and cotton cloth. It was observed that there was a 12% increase in production of water with the use of jute fabric when compared to cotton cloth. This is due to the fact that jute fabric has higher absorptivity, easily available and less costly.

A Kuhe and A O Edeoja[6] have used phase change material(PCM) to improve the productivity of water in the single slope single basin solar still. 14kg of beeswax was sandwitched between the bottom of the still and the absorber plate. A parabolic concentrator was used to reflect the sun rays on to the still. Experiments conducted showed that there was an improvement in the productivity of water by 62% when compared to the solar still without PCM. Further during 4pm to 5pm, the discharge of water was almost 2-3 times that of the solar still without PCM.

A.E. Kabeel et.al [7] studied the improvement in the performance of a solar still of base area $0.81m^2$by using a parabolic solar concentrator. The experimental results revealed that the production of water for solar still with a parabolic concentrator is higher than that of conventional solar still. The water production rate is approximately 4.25 L/m^2 day for the solar still with a parabolic concentrator while it is 2.78 L/m^2 per day for the solar still without concentrator. The parabolic concentrator improves the production rate of water by 52-54%.

Kwaghger Aondona et.al [8] have done an experimental investigation on the performance of a single basin single slope solar still with a parabolic solar concentrator. The solar still having a base area 0.3 m2 and height 0.1m. The parabolic concentrator is having a diameter of 0.67m and a height of 0.075m and focal point of 0.374m. Solar still with parabolic concentrator yielded water 2.5-3 times to that of solar still without concentrator. The quality of water collected in a solar still with concentrator. was also found better when compared to a solar still without concentrator.

From the literature it is clear that the use of absorber with high thermal conductivity and parabolic concentrators lead to increase in productivity of water and solar still efficiency.

2. COMPONENTS OF SINGLE SLOPE SOLAR STILL

3.1Wooden box

The Wooden box is the outer casing of the solar still made up of plywood which acts as a thermal insulator helps in retaining the heat absorbed by the water. Hence, leads to the increase in the rate of evaporation of the water poured into the solar still in the form of salt water. It is also easily available and fabrication is easy.

Fig -1: Wooden box of 10mm thick plywood

3. 2 Aluminium plate

Aluminium plate is used as a heat storage material as it has thermal conductivity (205 W/m-K) and also has a good corrosion resistance. It is coated with black paint to absorb more radiations.

Fig -2: Absorber with aluminium bottom coated with black paint.

The top cover of the wooden box is taken as glass as it allows more amount of solar radiations to pass inside the solar still and increases the absorption of solar radiations by the aluminium plate.

3.3 Glass cover

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3.4 Parabolic reflector

Parabolic reflector is a reflective surface used to collect and reflect the solar energy. It is in the shape of parabola. Parabolic concentrator of diameter 1200mm and depth 110mm is fabricated. The concentrator collects the sun rays and concentrates it at a point called as focus point. The focus point is calculated mathematically and the solar still is kept at the focal point. With the use of parabolic reflector, the extra amount of heat in the form of concentrated solar radiation will reach the bottom of the solar still. The surface of parabolic reflector is laminated using aluminium foil to ensure better reflectivity of the surface.

Fig-3 shows the parabolic reflector with stand. A stand is made of M.S angles and has a provision to mount the parabolic reflector.

Fig -3: Parabolic reflector with stand.

4. FABRICATION AND WORKING OF SOLAR STILL

4.1 FABRICATION OF SOLAR STILL

Aluminium sheet metal of size 610 X 460 mm^2 is cut. Aluminium sheet metal of length 60 mm is welded along the sides of aluminium sheet. Aluminium plate is painted with black color to ensure more absorption of heat energy. Plywood is brought and cut into different sizes. Holes are drilled at points required and screws are fixed. The base of casing is left open without any plywood cover. A glass cover of size 640 X 480 mm^2 and thickness is mounted on the wooden casing at an angle of 20^0. A U-shaped PVC pipe is placed at an inclination to collect the desalinated water. Cold rolled sheet is used as material for parabolic reflector. Aluminium foil is used to cover the parabolic dish. This parabolic reflector is then mounted at a height of 520mm on to the stand. The solar still is mounted above parabolic reflector with the help of a rod and rope.

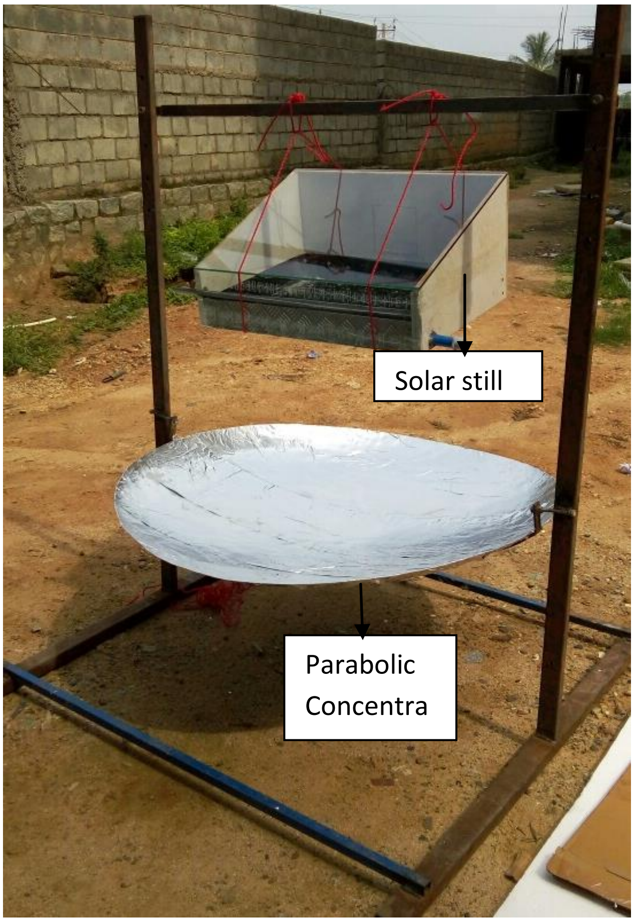

Fig -4: Assembled setup of solar still with parabolic solar concentrator

Fig -5: Water collection

4.2 WORKING OF SOLAR STILL

Solar still is made of a single-basin with a black painted aluminium absorber of thickness 4mm at the bottom which contains sea water. This is enclosed in an insulated chamber formed by a transparent glass cover which is sealed to prevent heat loss. Incident solar radiation passes through the transparent cover and is absorbed by the black aluminium plate. Heat transfer takes place from absorber plate to the water. Consequently, water contained in the basin gets heated up and evaporates slowly. Water vapor rises up and condenses on the inner surface of the glass cover. The condensed water flows downwards along the glass cover bottom surface because of gravitational force and is collected using water collector which is placed above the surface water level. Thermometer is used to measure glass cover and water temperature. Water volume is measured using a measurement glass jar.

The performance of the solar still is influenced by several factors such as intensity of sun rays, wind velocity, ambient temperature, and glass cover temperature, surface area of water, area of the absorber plate and inlet water temperature, inclination of the glass cover and height of water in the still.

5. RESULTS AND DISCUSSIONS

The ambient temperature, water temperature and collected water volume were measured on hourly basis on a sunny day from morning 8:00am to evening 4:00pm. Chart-1 indicates the ambient temperature during the day.

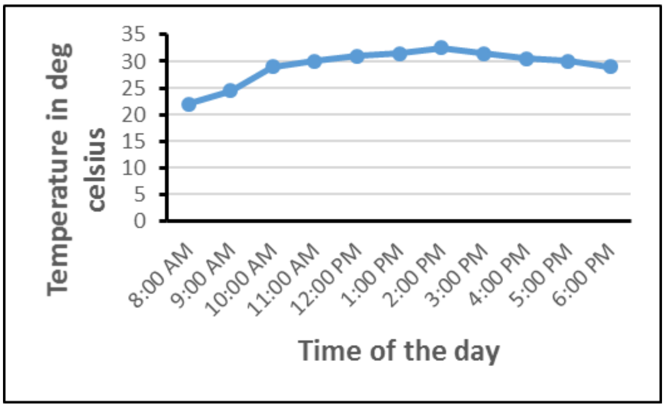

Chart -1: Graph of Time of the day vs ambient temperature in ^{0}C.

Totally about 805ml of desalinated water is obtained in one day for five litres of salt water poured into the solar still of which has a cross sectional area of 0.3m^2. A major amount of desalinated water is obtained during the time period of 11AM to 2PM.

The Chart-2 shows the temperature of glass cover with respect to time. It can be observed from the graph that there is a significant change in temperature when a parabolic reflector/concentrator is used.

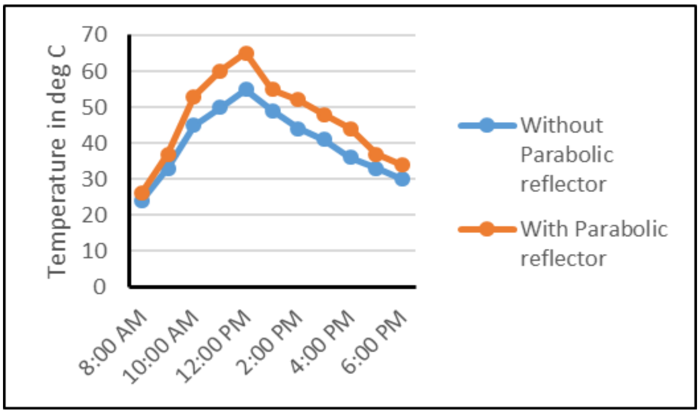

Chart -2: Graph of Time versus glass cover temperature

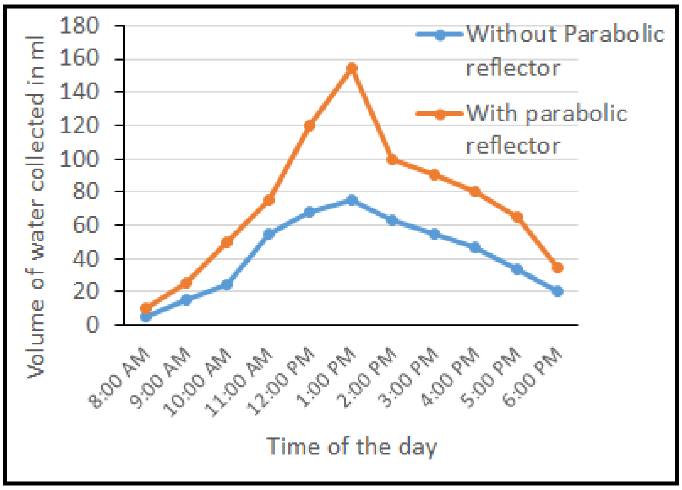

Chart -3: Volume of water collected in ml versus time of the day.

Chart-3 indicates the Volume of water collected in ml versus time of the day. Maximum amount of 460ml desalinated water is collected during the day without the use of parabolic concentrator. Solar still with concentrator has produced 805ml during the same period. It shows that parabolic concentrator has resulted in 75% increase in the productivity of water.

It is clear that the amount of desalinated water obtained depends mainly on solar intensity and material used for heat absorption purpose.

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