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Design and experimental analysis of solar water desalination system

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ABSTRACT

There is almost no water left on earth that is safe to drink without purification after 20-25 years from today. This is a seemingly bold statement, but it is unfortunately true. Only 1% of Earth's water is in a fresh, liquid state, and nearly all of this is polluted by both diseases and toxic chemicals. For this reason, purification of water supplies is extremely important. Keeping these things in mind, we have devised a model which will convert the dirty/saline water into pure/potable water using the renewable source of energy (i.e. solar energy). The basic modes of the heat transfer involved are radiation, convection and conduction. The results are obtained by evaporation of the dirty/saline water and fetching it out as pure/drinkable water. The designed model produces 1.5 litres of pure water from 14 litres of dirty water during six hours. The efficiency of plant is 64.37%. The TDS (Total Dissolved Solids) in the pure water is 81ppm.

Keywords: Renewable energy, pure water, TDS.

Abbreviations: TDS - Total Dissolved Solids; RPF - Reinforced plastic; G.I - Galvanised iron

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1. INTRODUCTION

Water is essential to sustain human life. It is abundant, but not infinite in quantity. Man is dependent on rivers, lakes, and underground water to get fresh water, but these sources are not always clean. Salts and organisms will be present and the maximum salt level in fresh water for human consumption is only 550 ppm (Malik et al. 1982). With the present rise of world population, intensified agriculture, possible climate change and industrial growth in certain parts of the world, the available annual water supply will probably be insufficient on a world basis. Unfortunately a major portion of the fresh water supply is not available where it is needed. The problem can be partially solved by transporting potable water to some of these communities, but the costs involved are of such magnitude that this proposition is not feasible. Some other way of obtaining potable water will have to be found. One of the promising options to solve this problem of water shortage appears to be desalination. Desalination methods are already mitigating water shortages in parts of the world adjacent to the sea or saline bodies of water by desalination plants.

Solar desalination can be used to purify either seawater or brackish water in areas which lack potable water and have abundant solar radiation such as some of those located in the Middle East (Kumar et al. 1989). Solar distillation has been long known and the earliest documented work is that of the Arab alchemists in 1551. A very comprehensive review of the history, theory, applications and economics of solar stills has been prepared by (Aakash et al. 1998). It describes the work done in various countries from 1872 to 1970. Large installations and small laboratory scale models are described (Sahoo et al. 2007) have reviewed, thoroughly, the work on solar distillation. They have described the design and performance of a wide range of solar stills. Coupling a solar still with hot water storage tank was investigated by (Garg et al. 2008). Experimentally, (Sahoo et. al 2007) tested several single sloped concrete basin-type solar stills in Ryadh, Saudi Arabia. The stills had various thicknesses and slopes of glass cover and their water trays were covered with different solar absorbent materials e.g. black and red sand, black stones, straw and charcoal. They found the optimum thickness and slope of the glass cover to be 3 mm and 200 respectively. Rai, (2000) studied, experimentally, the effect of salinity of the input water on the performance of a single basin-type solar still connected with a solar collector. Tiwari et al. (2002) used charcoal particles as absorber medium inside a basin-type solar still. In (David, 2008) presented another thorough review of progress on the work done on single basin passive type still to improve its productivity. The objective of the author is to design a solar water desalination system and to check its feasibility.

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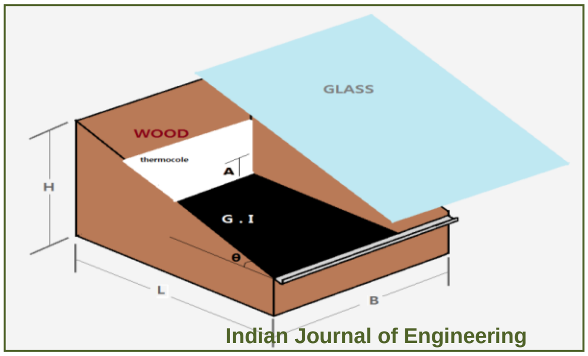

Figure 1
Schematic diagram of solar distillation system

Figure 2
Side walls for solar still

Figure 3
Image for top cover

Figure 4
Image for the channel

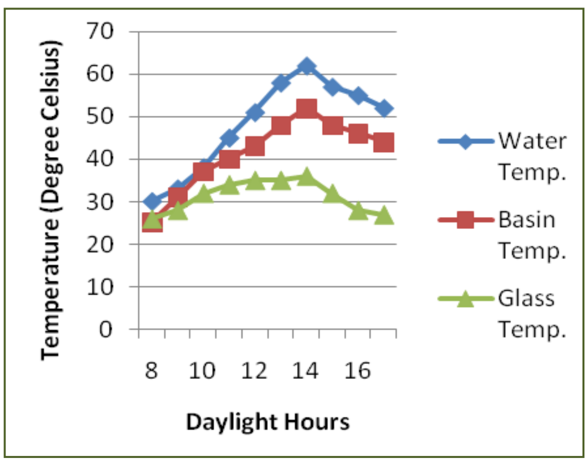

Figure 5
Variation of daylight hrs with temperature

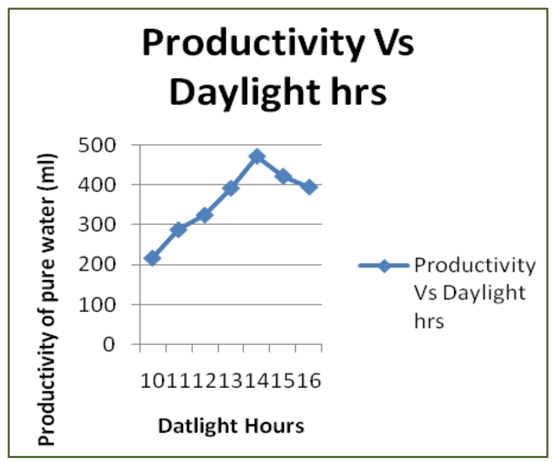

Figure 6
Variation of Daylight hrs with productivity

Reinforced plastic:
Reinforced plastics are a recent class of materials in which the low modulus and temperature limitations of plastic is overcome by reinforcing it with fibres of high modulus.

Galvanised Iron:
It is a building material composed of sheets of hot-dip galvanised mild steel, cold-rolled to produce a linear corrugated pattern in them.

2. DESIGN OF SYSTEM

2.1. Construction of Solar still

The base of the solar still is made of G.I. box of dimension (4' x 2' x 10 cm). This box is embedded into another box of wood shown in Figure 1. Here length L= 65 cm, Breath B= 125cm, Height H= 30 cm. and at opposite side = 13 cm, Angle α = 45°. This also contains same box of thermocol inside it between the G.I box and wooden box. The thermocol is having 15 cm thickness. The channel is fixed such that the water slipping on the surface of the glass will fall in this channel under the effect of gravity. A frame of fibre stick is fixed with the wooden box so that glass can rest on it. This completes the construction of the model. The holes for the inlet of water, outlet of brackish water and outlet of pure water is made as per the convenience. We have made the outlet of brackish water at right bottom of the model (seeing from front of the model), outlet of the pure water at the end of the channel and inlet at the right wall above the outlet.

2.2. Details of different types of system

2.2.1. Still basin

It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material have high absorbtivity or very less reflectivity and very less transmitivity. These are the

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Table1
Details of still basin

Material	Thermal Conductivity	Thickness
G.I. Sheet	300 W/m^{o}C	3 mm

Table 2
Details of side walls

Material	Thermal Conductivity	Thickness
Wood	0.6 W/m^{o}C	8 mm
Thermocol	0.02 W/m^{o}C	15 mm

Table 3
Details of glass used

Material	Thickness	Size
Glass	3 mm	4'x2'

Table 4
Cost of manufacturing solar distillation plant

Materials	Quantity	Cost
Wood	1x450	450
Thermocol	6 x 15	90
G.I.	1 x 200	200
Glass	1 x 290	290
P.V.C.	1 x 20	20
Fibre stick	2 x 10	20
Tap and Coupling	2x30	60
Tank	1 x 80	80
Fabrication	260	260
Stationary	200	200
Total		Rs. 1690

Table 5
Experimental Details of the solar still

Observations	Details
Time taken for drop to come to channel	1 hr
Time taken for drop to come out of channel	0.5 hr
Amount of brackish water poured initially	14 litre
Amount of pure water obtained at the end of the exp.	1.5 litre
Temperature of the condensate	29^{o}C
TDS of purified water	81 ppm

criteria's for selecting the basin materials. Kinds of the basin materials that can be used are as follows: 1. Leather sheet, 2. Ge silicon, 3. Mild steel plate, 4. RPF (reinforced plastic) 5. G.I. (galvanised iron). Details are shown in Table 1.

2.2.2. Side walls

It generally provides rigidness to the still. But technically it provides thermal resistance to the heat transfer that takes place from the system to the surrounding. So it must be made from the material that is having low value of thermal conductivity and should be rigid enough to sustain its own weight and the weight of the top cover as shown in Figure 2. Different kinds of materials that can be used are: 1) wood, 2) concrete, 3) thermocol, 4) RPF (reinforced plastic). For better insulation we have used composite wall of thermocol (inside) and wood (outside), (Table 2).

2.2.3. Top Cover

The passage from where irradiation occurs on the surface of the basin is top cover. Also it is the surface where condensate collects as shown in Figure 3. So the features of the top cover are: 1) Transparent to solar radiation, 2) Non absorbent and Non-adsorbent of water, 3) Clean and smooth surface. The Materials Can Be Used Are: 1) Glass, 2) Polythene. Details of glass are shown in Table 3.

2.2.4. Channel

The condensate that is formed slides over the inclined top cover and falls in the passage, this passage which fetches out the pure water is called channel. The materials that can be used are: P.V.C., 2) G.I., 3) RPF . We have used P.V.C channel as shown in Figure 4 having size equal to 4.5' X 1" cm.

2.3. Cost of the system

The cost of manufacturing the system has been shown in Table 4. The total cost of the system is Rs. 1670.

2.4. Efficiency of the system

Efficiency of the system can be calculated according to the following equation;

$$\text{Efficiency of the system} = \frac{\text{Actual amount of pure water}}{\text{Theoretical amount of pure water}} \times 100 \ldots\ldots \quad (1)$$

3. RESULTS AND DISCUSSIONS

The system is kept outside for the analysis. The experiment is performed from 10:00 AM in the morning to the 4:00 PM in the evening. The details of the solar still are shown in Table 5. Figure 5 shows the variation of temperature of water with the sunlight. It has been found that the water temperature get increases with time and maximum temperature is attained during 2 P.M. It is seen from the figure 5 among the water temperature, basin temperature and the glass temperature, the temperature of water is more as the sunlight directly falls on the water. Figure 6 shows the variation of productivity of pure water with sunlight. The maximum pure water obtained during six hours is 1.8litres.The efficiency of the system comes out 62.17%.

4. CONCLUSION

From the Figure 5, we can conclude that the increase in temperature and hence the evaporation is maximum in the period of 11:15 am to 2 pm. The maximum temperature achieved is 62^{o}C which is at 2p.m. then the temperature decreases. The aim of our experiment was to get pure water from the brackish water available. The brackish water we have supplied was 14 litres and at the end of the experiment we got 1.8litres. The TDS level of purified water obtained is 81 PPM. So the water obtained is potable.

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Single-basin solar stills can be used for water desalination. Probably, they are considered the best solution for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable. However, the amount of distilled water produced per unit area is somewhat low which makes the single-basin solar still unacceptable in some instances. The purpose of this paper is to study the effect of using different absorbing materials in a solar still, and thus enhance the productivity of water.

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