Design of Solar Distillation 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.*

1. Introduction

Water is the basic necessity for human along with food and air. There is almost no water left on Earth that is safe to drink without purification. 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.

Moreover, typical purification systems are easily damaged or compromised by disasters, natural or otherwise. This results in a very challenging situation for individuals trying to prepare for such situations, and keep themselves and their families safe from the myriad diseases and toxic chemicals present in untreated water.

Everyone wants to find out the solution of above problem with the available sources of energy in order to achieve pure water. Fortunately there is a solution to these problems. It is a technology that is not only capable of removing a very wide variety of contaminants in just one step, but is simple, cost-effective, and environmentally friendly. That is use of solar energy.

1.1. About Solar Energy

The sun radiates the energy uniformly in all direction in the form of electromagnetic waves. When absorbed by body, it increases its temperature. It is a clean, inexhaustible, abundantly and universally available renewable energy[1].

Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used, it will be one of the most important supplies of energy, especially when other sources in the country have depleted.

This solution is solar water distillation. It is not a new process, but it has not received the attention that it deserves. Perhaps this is because it is such a low-tech and flexible solution to water problems. Nearly anyone is capable of building a still and providing themselves with completely pure water from very questionable sources. 3.8x1024 joules of solar radiation is absorbed by earth and atmosphere per year. Solar power where sun hits atmosphere is 1017 watts and the total demand is 1013 watts. Therefore, the sun gives us 1000 times more power than we need. If we can use 5% of this energy, it will be 50 times what the world will require. The energy radiated by the sun on a bright sunny day is 4 to 7 KWh per m2 [2].

2. Introduction to Solar Still

Solar distillation is a tried and true technology. The first known use of stills dates back to 1551 when it was used by Arab alchemists. Other scientists and naturalists used stills over the coming centuries including Della Porta (1589), Lavoisier(1862), and Mauchot (1869)[3].

The first "conventional" solar still plant was built in 1872 by the Swedish engineer Charles Wilson in the mining community of Las Salinas in what is now northern Chile (Region II). This still was a large basin-type still used for supplying fresh water using brackish feed water to a nitrate mining community. The plant used wooden bays which had blackened bottoms using logwood dye and alum. The total area of the distillation plant was 4,700 square meters. On a typical summer day this plant produced 4.9 kg of distilled water per square meter of still surface, or more than 23,000 litres per day. Solar water Distillation system also called "Solar Still". Solar Still can effectively purify seawater & even raw sewage. Solar Stills can effectively removing Salts/minerals {Na, Ca, As, Fe, Mn} ,Bacteria { E.coli, Cholera, Botulinus}, Parasites ,Heavy Metals & TDS[2].

Basic principal of working of solar still is "Solar energy heats water, evaporates it (salts and microbes left behind), and condenses as clouds to return to earth as rainwater".

2.1 Solar Still Operation

Water to be cleaned is poured into the still to partially fill the basin. The glass cover allows the solar radiation to pass into the still, which is mostly absorbed by the blackened base. This interior surface uses a blackened material to improve absorption of the sunrays. The water begins to heat up and the moisture content of the air trapped between the water surface and the glass cover increases. The heated water vapor evaporates from the basin and condenses on the inside of the glass cover. In this process, the salts and microbes that were in the original water are left behind. Condensed water trickles down the inclined glass cover to an interior collection trough and out to a storage bottle.

Feed water should be added each day that roughly exceeds the distillate production to provide proper flushing of the basin water and to clean out excess salts left behind during the evaporation process. If the still produced 3 litres of water, 9 litres of make-up water should be added, of which 6 litres leaves the still as excess to flush the basin.

2.2 Types of Solar Still

Basin Type: It consist of shallow, bracken basin of saline/impure water covered with a sloping transparent roof solar radiation that passes through the transparent roof heats the water in blackened basin. Thus evaporating water which gets condensed on the cooler under side of the glass and gets collected as distillate attached to the glass[4].

Wick Type Solar Still: It consists of a wick instead of a basin. The saline/impure water is passed through the wick or absorbed by the wick at a slow rate by capillary action. A waterproof liner is placed between the insulation and the wick. Solar energy is absorbed by the water in the wick which gets evaporated and later condensed on the underside of the glass and finally collected in the condensate channel fixed on the lower side of the bottom surface[4].

3. Design of Solar Distillation Plant

3.1 Construction of Solar Still

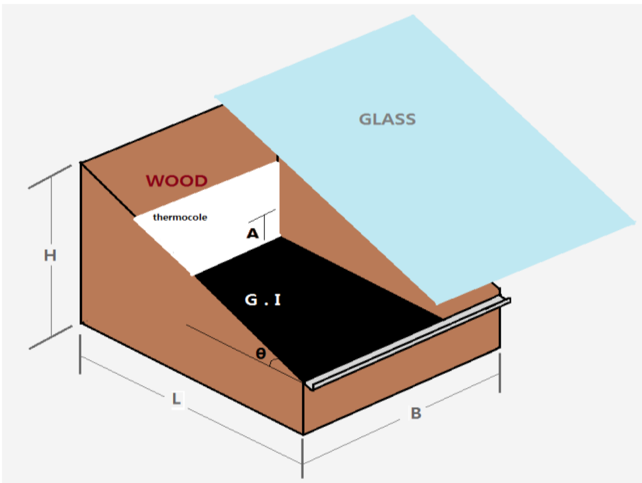


Figure.1 Proposed Model of Solar Distillation System

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 Θ = 150 .

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.

3.2 Details of Different Parts of the System

3.2.1 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 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 platic) 5. G.I. (galvanised iron).

We have used blackened galvanised iron sheet(K= thermal conductivity= 300W/m0C) (3mm thick).(SIZE:: 4' X 2' X 10 cm BOX OF G.I.).

3.2.2 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 (refer fig.no.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). (Size:: wood(k= thermal conductivity=0.6W/m0C):-- 8 mm thick, thermocol(k= thermal conductivity=0.02W/m0C):--- 15 mm thick).

Figure.2 Side Walls for Solar Still

3.2.3 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. 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.

We have used glass (3mm) (figure 3)thick as top cover having rubber tube as frame border. (size: ---- 4' x 2'cm).

Figure.3 Solar Still Glass with Cover

3.2.4 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 (figure.4)(size:: 4.5’ X 1” cm).

Figure.4 Solar Still Channel Design

3.2.5 Supports for Top Cover: The frame provided for supporting the top cover is an optional thing. I.e. it can be used if required. We have used fibre stick as a support to hold glass (size :: 5 mm X 5mm).

The only change in our model is that we have to make the model as vacuumed as possible. So we have tried to make it airtight by sticking tape on the corners of the glass and at the edges of the box from where the possibility of the leakage of inside hot air is maximum.

Figure.5 Working model of solar distillation system

4. Results and Discussion

Experiment is performed from 10:00am to 04:00pm in winter season.

4.1 Readings taken for still:

Table 1 represents the reading taken for solar still.

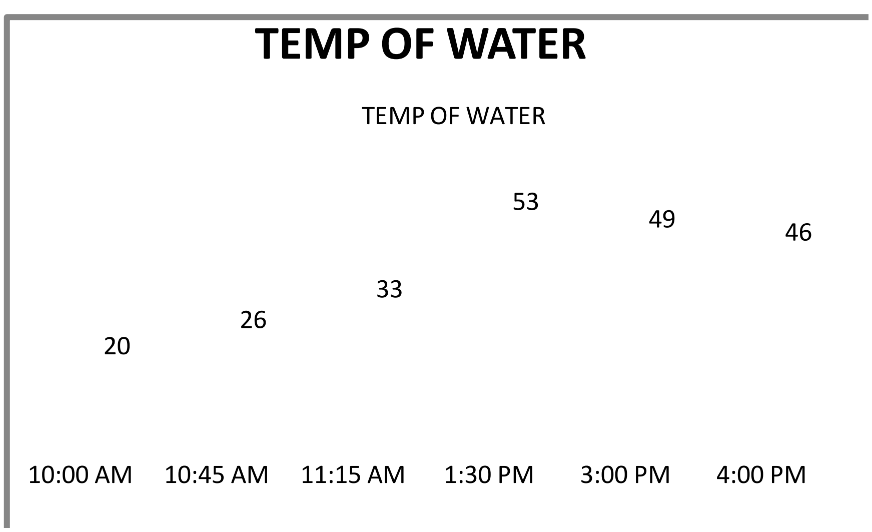
Table. 1 Reading for Solar Still

Time	Temp of Water ^{0}C
10:00 AM	20
10:45 AM	26
11:15 AM	33
1:30 PM	53
3:00 PM	49
4:00 PM	46

4.2 Observations:

- Time taken for drop to come to channel = 1 hour
- Time taken for drop to come out of channel = 0.5 hour
- 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 ^{0}C
- TDS of purified water = 81 ppm

4.3 Graph: Graph.1 represents the temperature variation in the solar still during six hours. The maximum temperature in the system is of 53^{0}C obtained at 01:30pm.



Graph 1: Temperature Variation in Solar Still

4.4 Efficiency of Still: The theoretically obtained amount of pure water = 2.33 litre
The practically obtained amount of pure water = 1.5 litre.
Efficiency=(actual amount of pure water)/(theoretical amount of pure water)*100
= (1.5 / 2.33) *100
= 64.37 %

4.5 Cost Chart: Table 2 represents the cost of manufacturing solar distillation plant.

Table 2. Material Cost in Indian Rupees

Sr. No.	Materials	Qty	Cost
1	Wood	1*450	450
2	Thermocol	6*15	90
3	G.I.	1* 200	200
4	Glass	1*290	290
5	P.V.C. Channel	1*20	20
6	Fibre Stick	2*10	20
7	Tap & Coupling	2*30	60
8	Tank	1*80	80
9	Fabrication	260	260
10	Stationary	200	200
Total		1670	

5. Conclusion

From the graph 1, we can conclude that the increase in temperature and hence the evaporation is maximum in the period of 11:15 am to 1:30 pm. The maximum temperature achieved is 530c which is at 1:30 pm. 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 1.5 litres. The experiment was carried out in winter season.

The TDS level of purified water obtained is 81 PPM. So the water obtained is potable.

Theoretically, the experiment should fetch out 2.33 litres. So the efficiency of the system is 6%.

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