Passive Solar Still For Solar Desalination

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Abstract : Water is basic necessity for human being and animals along with food. Water fit for human consumption is called portable water. Supply of portable water is a major problem in underdeveloped as well as in some developing countries. Solution for this can be to obtain distilled water from saline water which is in abundant by process of distillation. It requires huge energy to perform distillation. Conventional fuel used are expensive and create huge environmental pollution. Solar energy which is free and nonpolluting can be used to obtain distilled water. Simple device using direct energy of the Sun for distillation is called solar still. This paper through light on passive solar still.

IndexTerms - solar still, solar distillation.

I. INTRODUCTION

Water is need for human and animal life along with food. Currently, freshwater is becoming a scare commodity and as is used unsustainably in the majority of the world's regions. Although 70% of the Earth's surface is covered by water but most of it is unsuitable for human consumption. Oceans contains 97.5% of total water and fresh water being 2.5%. Fresh water is present in atmosphere, ice mountains, freshwater lakes, rivers and groundwater. Of this total water about 0.014% is directly available for human beings and other organisms. It is estimated that one fifth of the world's population live in areas where water is scarce. Few billion people have no access to a potable source of water and about 1.76 billion people live in areas already facing a high degree of water shortage. Supply and demand of portable are not matching, demand keeps on increasing because of population growth, urbanization, and industrialization and living standard. As drinking water can be obtained from sea water by various processes called desalination. Seawater desalination technology are used areas with less fresh water called arid areas of the world, such as the Middle East, the Mediterranean, and the Caribbean. 65% of global water desalination capacity is installed in middle east. Saudi Arabia, UAE, U.S., Spain and China have the highest desalination capacity. Mostly fossil fuel is used to source energy for desalination. Use of fossil fuel is costly and creates pollution. Solar energy can be used as source of energy for desalination. Solar energy is free and non polluting. But intensity on solar energy is less and requires large area to collect.[1].

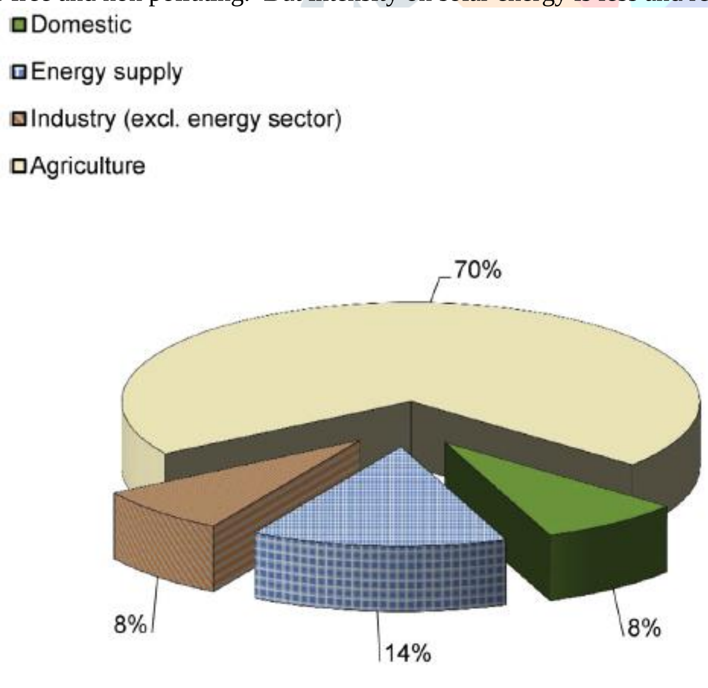

Fig. 1 Global use of fresh water. Based on data from UN-Water [3]

Use of freshwater in the world is shown in Figure 1. On an average consumption of drinking water is 2.4 L/day for adults and 0.75 L/ day for infants. Domestic water consumption for washing and cooking varies significantly in different countries, typically between 50 and 500 L/day. For agricultural very huge fresh water about 70% is used. It is mostly used for irrigation. Agricultural water demands are particularly high for arable farming in hot climates and for high value products. Water extraction, treatment and distribution accounts for 8% of global energy consumption. This energy is mainly required for pumping water from bores and through pipelines, for sewerage treatment and desalination. The term water scarcity relates to per capita availability of fresh water resources. Scarcity can be a genuine lack of water called physical scarcity or by a lack of water infrastructure called economic scarcity or a combination of both.

Water scarcity is caused by high density of population, intensive agriculture, water demanding industries, waste of water during use etc. Table 1 shows criteria of scarcity as per UN-water [3]

Table 1 Scarcity of water available for human consumption [3]

Degree of water scarcity experienced	Fresh water availability, N (m^3/capita/year)
Sufficient supplies	N >2500
Vulnerable	1700 ≤ N < 2500
Stress	1000 ≤ N < 1700
Scarcity	500 ≤ N < 1000
Absolute scarcity	N < 500

Distillation process takes saline water as input and converts to distill water. Distillation byproduct being water with very high salt concentration. Distillation requires a large amount of energy to remove a portion of pure water from a salt water source. 1 kg water to evaporate requires about In conventional process the production of 1000 m3 per day of freshwater requires about 10,000 tons of oil per year. People in major parts of the world have neither the money nor oil resources to use for distillation. The World Health Organization estimates that over a billion people lack access to purified drinking water and the vast majority of these people are living in rural areas where the low population density and remote locations make it very difficult to install the traditional clean water solutions. High cost of fuel and associated pollution is motivating us to go for non-polluting and free solar energy. Owing to low energy intensity of solar energy and large area needed to collect solar energy it is suitable for small scale production. It is useful for region where conventional energy is costly. Solar energy can directly or indirectly be used for distillation.[4]

A solar still is a simple device which can be used to convert sea water and brackish water into drinkable water. Figure 2 shows working of basin type solar still. Solar still consists of a blackened basin filled with brackish or saline water upto a certain depth and covered by an inclined glass to facilitate transmission of solar radiation. Inclined glass also facilitates to condense vapour by releasing heat to surrounding and allows condensate droplet to slide down on side to collector. The solar radiation entering the basin heats up the blackened liner which in turn heats up the water causing evaporation. The condensate obtained will be of high quality and low quantity in the range of 2– 3 l/m2/day. Because of high temperature in basin majority of micro-organism get killed. [5]

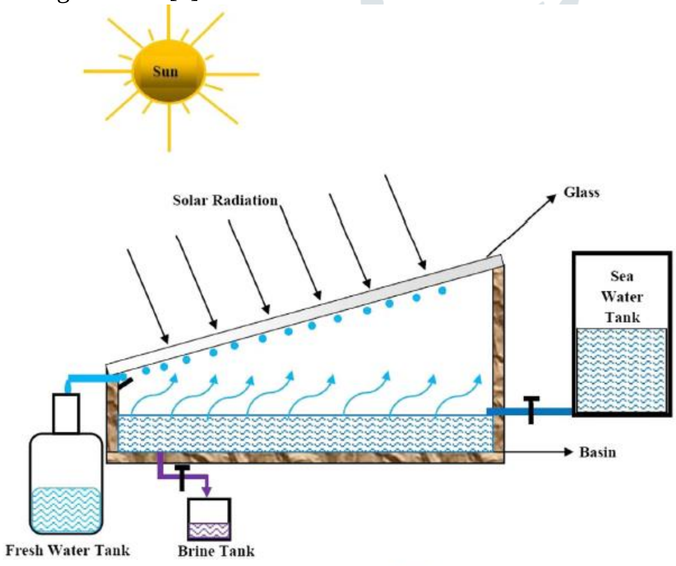

Fig. 2. Simple solar still [31].

Fig. 2 Basin type solar still [5]

In the fourth century Aristotle described a method to evaporate impure water and then condense it for potable use. Oldest documented work on solar distillation by Arab alchemists in the 16th century. [2]

II. TYPES OF SOLAR STILL

Wherever Solar stills are broadly classified into two categories namely

a)Passive stills:- Here directly sunrays are used to evaporate brackish water. Here as less heat input output of distillate is less. But cost wise cheaper. and

b)Active stills:- Main drawback with passive stills is solar radiation directly received by basin water is only source of energy to raise the temperature of the water. In order to overcome this drawback, active stills have been developed. An extra thermal energy is supplied to the basin through some external mode to raise the temperature of water. This increases heat, resulting in increase of evaporation rate and in turn improves the efficiency of the still. Here external sources like solar heaters, concentrators, PV/T systems which are coupled to the still. It is costly. [6]

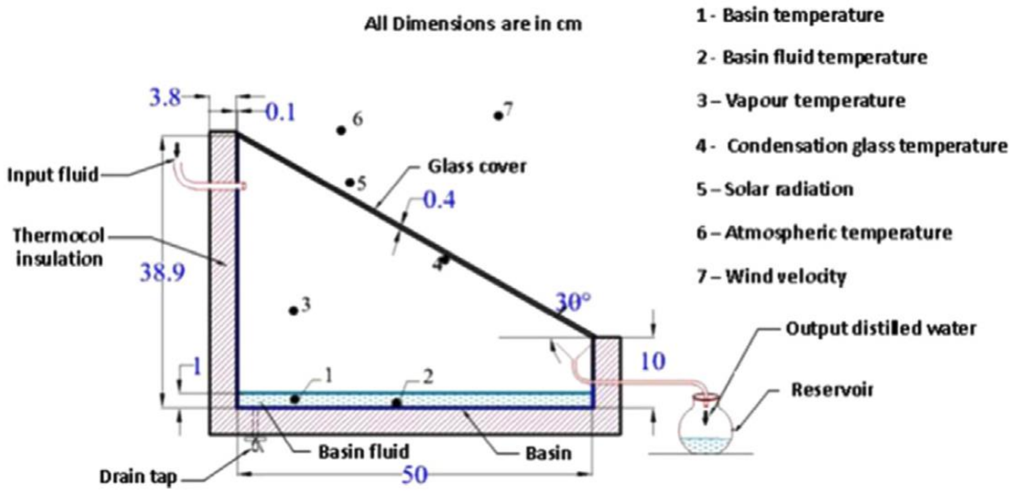

Fig. 3 Passive solar still using only direct sun energy [6]

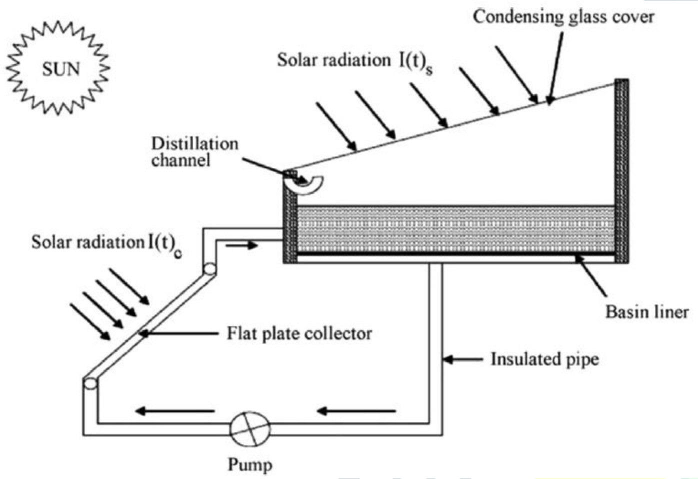

Fig. 4 Active solar still using direct solar radiation plus heating of water in solar water heater [6]

Various shapes of solar still are single slope basin, double slope, triangular pyramid, square pyramid, conical and spherical.

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III. Parameters Affecting Performance of Solar Still

The various factors affecting the productivity of solar still are,

a) solar intensity:-
b)wind speed
c)surrounding temperature
d)water–glass temperature difference
e)free surface area of water
f) absorber plate area,
g)temperature of inlet water,
h)glass angle
and
i)depth of water.

Environmental factors like solar intensity, wind speed and surrounding temperature cannot be controlled. Productivity of solar still is directly proportional to solar intensity as shown in figure 5.[7]

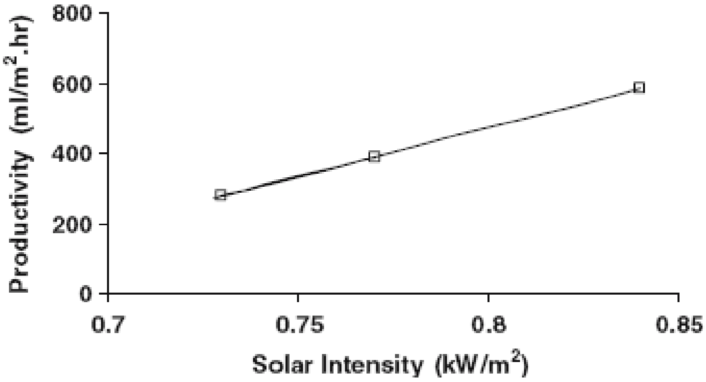

Fig. 5 Effect of solar intensity on productivity of solar still [7]

Output of solar depends on the difference between water and glass cover temperatures. The temperature difference between water and glass acts as a driving force of the distillation process.

Evaporation rate depends directly on free surface area of water. More the free surface area more is evaporation.

Output of the solar still increases with increase in absorber area. Fins can be used to increase the absorber plate area. By providing fins performance of solar still improves.[8]

Fig. 6 Absorber plate with copper fins.[slb1]

The evaporation rate of saline water increases with increase in the temperature of the inlet saline water.

The annual yield of the solar still was maximum when the condensing glass cover inclination is equal to the latitude of the location as per Singh and Tiwari. [9]

Productivity is high if water depth is least see figure 7. But with low water depth dry spot may occur. To maintain minimum depth, wick can be used to increase productivity of solar still. [2]

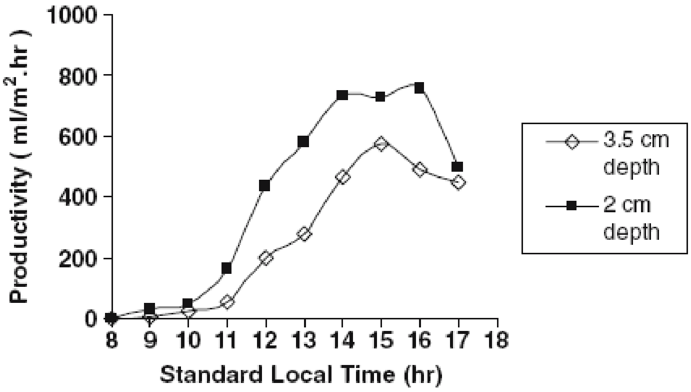

Fig 7 Effect of water depth in basin on productivity [7]

IV. MATHEMATICAL MODELING OF SOLAR STILL [7]

The theoretical analyses can be performed by energy balance on various components of the still. Following assumption made in energy balance,

a)inclination of glass is very small

b) The heat capacity of the glass cover, the absorbing material and the Insulation are negligible.

c) Solar still is leak proof.

Figure 7 shows energy flow through single slope basin.

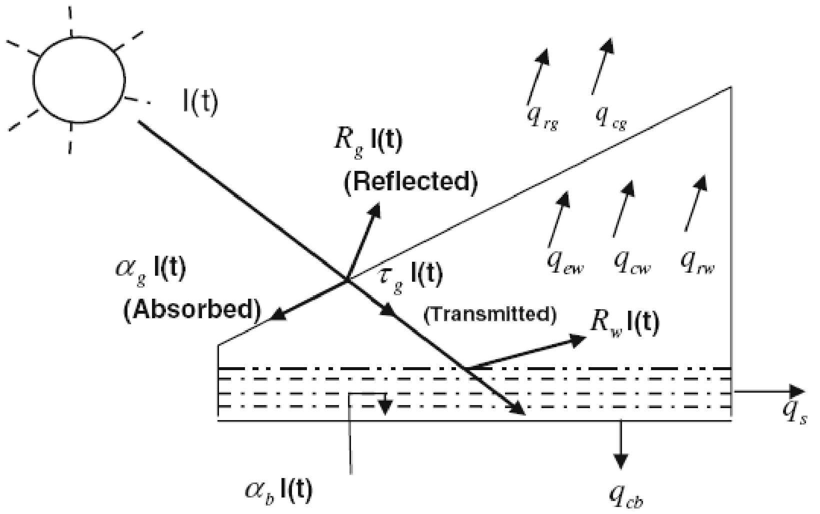

Fig 7 Energy flow through single slope basin solar still [7]

a) Energy balance at glass cover:
As shown in figure 7 heat received from the Sun is utilized in three parts at glass, a)transmitted through glass, $\tau_g I$, b)absorbed by glass, $\alpha_g I$ c)reflected by glass $R_g I$. Glass radiates heat q_{rg}, and loose heat by convection q_{cg}. Glass receives heat from radiation, convection and condensation. Glass releases heat to surroundings by convection and radiation.

$$Radiation\ absorbed\ by\ glass + heat\ received\ from\ water = heat\ loss\ from\ glass\ to\ surrounding$$

$$\alpha_g I(t) + (q_{rw} + q_{cw} + q_{ew}) = q_{rg} + q_{cg}$$

b) Energy Balance at bottom plate (basin liner):
At basin energy balance is as follows,

$$Radiation\ absorbed\ by\ basin = heat\ transfer\ from\ basin\ to\ water + heat\ loss\ from\ basin\ to\ ground + heat\ loss\ from\ sides\ of\ solar\ still\ to\ surrounding$$

$$\alpha_b I(t) = q_b + \left[q_{bg} + q_s \frac{A_{ss}}{A_s}\right]$$

c)Energy balance at water mass:
In water, energy balance is as follows,

$$Radiation\ absorbed\ by\ water + heat\ received\ from\ basin\ to\ water = change\ in\ internal\ energy\ of\ water + heat\ loss\ from\ water\ to\ glass$$

$$\alpha_w I(t) + q_b = (MC)_w \frac{dT_w}{dt} + (q_{rw} + q_{cw} + q_{ew})$$

Where,

A_s	basin liner still area, (m^2)
A_{ss}	side still area (m^2)
I	solar intensity (W/m^2)
(MC)w	water heat capacity rate of water per unit area (J/m^2K)
q_g	rate of total energy from the glass cover (W/m^2)
q_b	rate of total energy from basin liner (W/m^2)
q_{bg}	rate of energy lost from basin liner to the ground (W/m^2)
q_{cg}	rate of energy lost from the glass cover by convective (W/m^2)
q_{ew}	rate of energy lost from water surface by evaporation (W/m^2)
q_{cw}	rate of energy lost from water surface by convection (W/m^2)
q_{rg}	rate of energy lost from the glass cover by radiation (W/m^2)
q_{rw}	rate of energy lost from water surface by radiation (W/m^2)
q_s	rate of energy lost from the basin liner through the side of the still (W/m^2)
T_a	ambient temperature (K)
T_b	basin liner temperature (K)
T_g	still glass cover (K)
T_v	still vapor temperature (K)
T_w	still water temperature (K)

V. FUTURE SCOPE

Huge research work is done in area of passive solar still, needs effort to commercialize cheap and long life solar stills so drinkable water is made available in rural part of India having shortage of portable water. We need to also create aware among people for availability such simple solution.

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