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Review Article

A review on design parameters and climatic conditions affecting the distillate output of a solar still

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Abstract

About 71% of earth is covered with water and yet it is ironical that one most the most dangerous problem the world is facing now is water scarcity. About 97% of available water is in the form of ocean so it is not potable. Conventional desalination processes involve use of either coal or electricity, but as climate change is becoming a serious problem with each passing day more research needs to be done in using non-conventional sources for heating water like solar or wind energy. This paper is a review of various design parameters and climatic conditions that affect the output of a solar still. It also deals with the effects of use of carbon nano particles and PCM (Phase Change Materials) on the output of a solar still.

Keywords:*Desalination, Solar still, Solar energy, PCM*

1. Introduction

Water is one of the most important constituent for the sustenance of mankind. It is useful for many purposes like agriculture, irrigation and domestic purposes like cooking and so on. The same basic principle that is involved in the production of rainfall through the hydrological cycle which occurs in nature is implemented in all the man-made desalination systems in order to produce fresh water from the salty resources. The removal or separation of salts from the water cannot be achieved automatically but it is done in desalination systems by the aid of some energy source. (Imad Al-Hayek, 2004)

Major desalination techniques like vapour compression distillation, reverse osmosis and electrolysis used electricity as input energy.

Nevertheless, in recent years, most of the countries in the world have been significantly affected by the energy crisis because of heavy dependency on conventional energy sources (coal power plants, fossil fuels, etc.). Hence, the environment and economic growth of these countries is affected significantly. However, these technologies are not appropriate for remote villages and small islands. To provide freshwater for these places, solar stills may be potentially applicable (P.Vishwanath Kumar, 2015).

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Various design modifications can be broadly classified in two groups: Passive solar stills and Active solar stills. Passive solar stills utilize the internal heat from the still for the evaporation process, while active stills make use of external sources, such as solar collectors or waste heat from industries (P.Vishwanath Kumar, 2015).

In this paper, we are going to discuss the effect of various design parameters (brine depth, inclination of cover, material of cover, thickness of insulation etc.) and climatic parameters (wind speed) on the output of passive basin type solar still.

Effect of Design Parameters

The major problem of a solar still is the reduced output. Therefore, effect of change in any design parameter should be viewed as per the change in output it is causing. In design of a solar various parameters like depth of brine, inclination of cover, shape of cover, material of cover, thickness of insulation etc. are considered. The effect of change in these parameters on the distillate output is discussed subsequently.

1.1 Depth of Brine

Depth of brine is an important parameter to be considered while designing solar still. Fig.1 shows variation of still output at various hours of day. It can be concluded that the distillate output increases with decrease in depth of brine during the initial hours of a day(Abdul Jabbar N. Khalifa, 2009)(H. Al-Hinai, 2002)(Kianifar, 2011). But as time increases distillate output decreases as depth of brine decreases. To increase the nocturnal output some amount of brine depth must be given.(Khalifa, 2011) concluded that with increase in depth of brine from 1cm to 10 cm output of a still increases from 0.35 to 0.93 l/m^2 day. Fig. 2 shows the variation of nocturnal output and daily output with variation of depth of brine. It is found that that for depth of 6cm maximum efficiency of 35% was found.

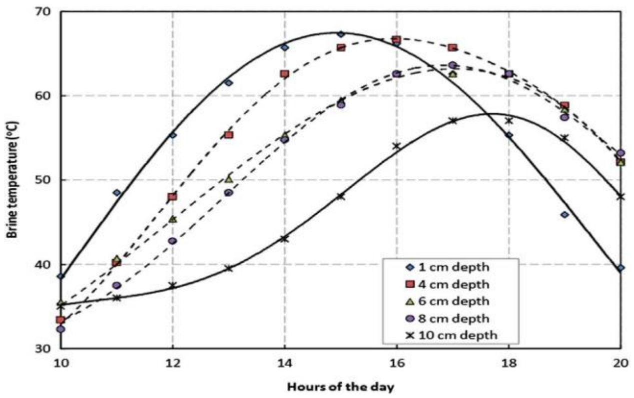

Fig.1 Variation of still output with depth of brine at various hours of a day(Abdul Jabbar N. Khalifa, 2009)

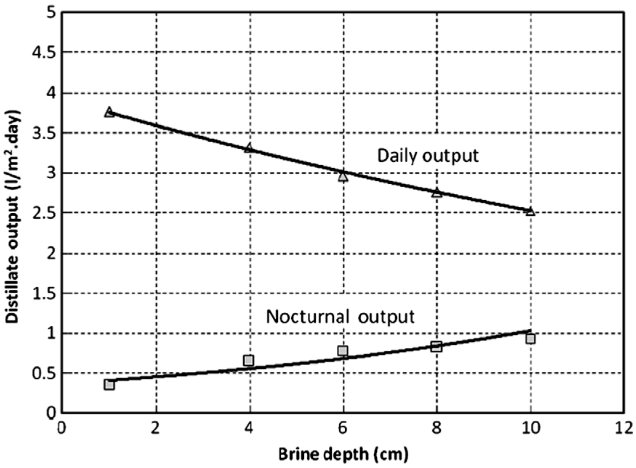

Fig.2 Variation of still output with depth of brine (Abdul Jabbar N. Khalifa, 2009)

1.2 Thickness of Insulation

Insulation is provided on the walls of still to reduce the loss of radiation. As the thickness of insulation increases so does its tendency to reduce the heat loss. But increasing the thickness of insulation beyond a certain limit may not affect the output of the still by a great degree but it will increase the cost of still. Thickness of insulation of up to 9mm is most suitable for operation of a still(Kianifar, 2011).

1.3 Cover Inclination

Cover inclination has a major role to play in increasing the productivity of still. As the cover inclination increases the speed at which water droplets fall to the collection tray also increases. But if the cover angle is too large thermal losses may increase. As the inclination increases the productivity of still also increases(Khalifa, 2011). But selection of a suitable cover angle depends on various parameters like season, geographical location of still. Cover inclination should be equivalent to latitude of the geographical location of the still(Kianifar, 2011). Fig. 3 shows the variation of cover tilt with latitude. Besides this cover inclination during winters should be larger as compared to summer.

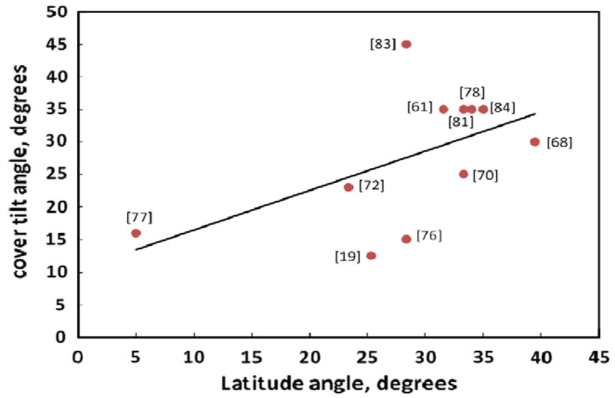

Fig.3 Variation of cover angle with latitude (Khalifa, 2011)

1.4 Material of Base

A large amount of incident solar radiation to solar still is lost. Fig. 4 shows the heat transfer process taking place in solar still.

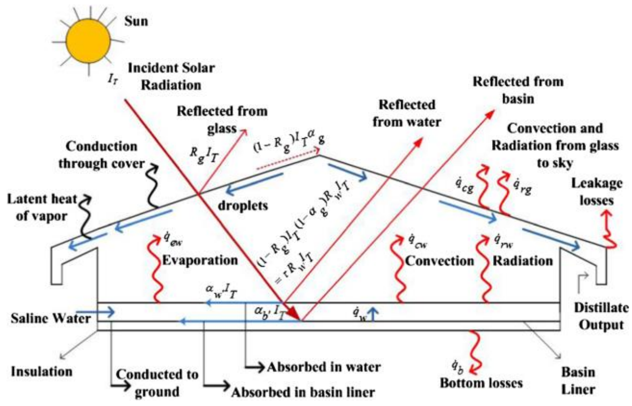

Fig.4 Heat Transfer Process in Double Slope Solar Still(Lovedeep Sahota, 2016)

To reduce the lost heat the material of base should have high absorptivity, low reflectivity, and low transmissivity. Due to higher thermal conductivity of Nano particles dissolved in base solution (water), temperature of water increases very rapidly (as the incident radiation is directly absorbed by Nano particles and due to their higher thermal conductivity transferred to water)(Lovedeep Sahota, 2016). Therefore, the use of Nano fluids is gaining momentum. Use of FGN (Flake Graphite Nano Particles)(S. W. Sharshir, 2017), lining of PCM (Phase Changing Material) like wax increases(Mohamed Asbik, 2016)the productivity of still. Enhancement in productivity of still observed with FGN, FGN and PCM, are 50.28%, 65% respectively (S. W. Sharshir, 2017)

1.5 Temperature of Cover

Lower the temperature of cover, higher the rate of condensation(K. Vinoth Kumar, 2008). With use of FGN; and film cooling FGN, PCM, and film cooling the increase in productivity observed is 56.15%, 73.8%, respectively(D. Dsilva Winfred Rufuss, 2016). Fig. 6 shows the variation of distillate output with external cooling and without external cooling.

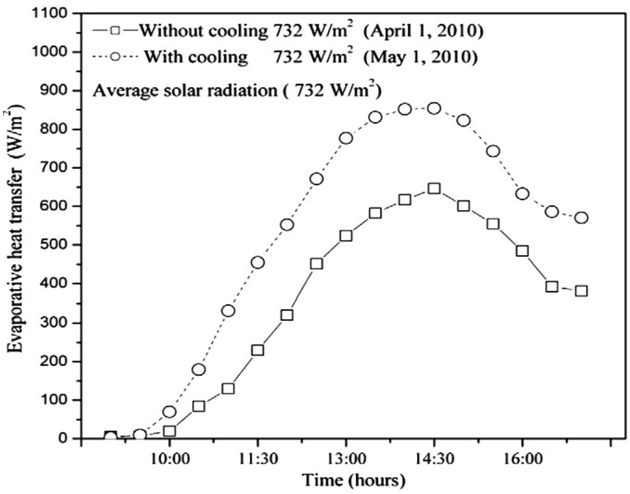

Fig.5 Variation of distillate output with and without external cooling(T. Arunkumar, 2012)

1.6 Shape of Cover

The amount of radiation entering the still, Output of still, Rate of condensation etc. depend on the shape of cover. Cover may be pyramidal (double slope) (Imad Al-Hayek, 2004)(P.Vishwanath Kumar, 2015)(Kianifar, 2011), spherical(T. Arunkumar, 2012). Fig. 6 shows spherical solar still. As hemispherical shaped cover provides more surface area compared to normal inclined cover the rate of condensation of water increases and hence distillate output increases(D. Dsilva Winfred Rufuss, 2016)(Imad Al-Hayek, 2004)(P.Vishwanath Kumar, 2015)(T. Arunkumar, 2012). Fig. 7 shows double slope solar still.

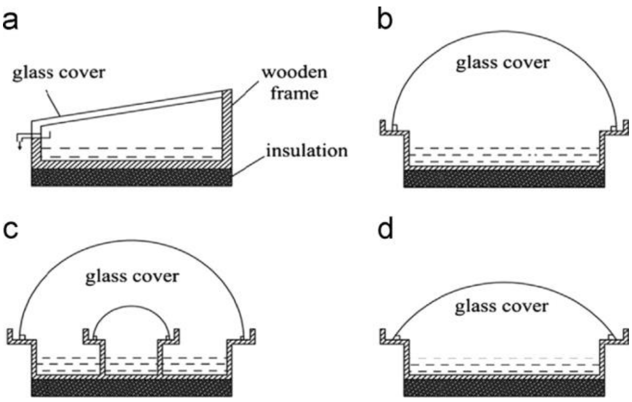

Fig.6 Various shapes of glass covers(P.Vishwanath Kumar, 2015)

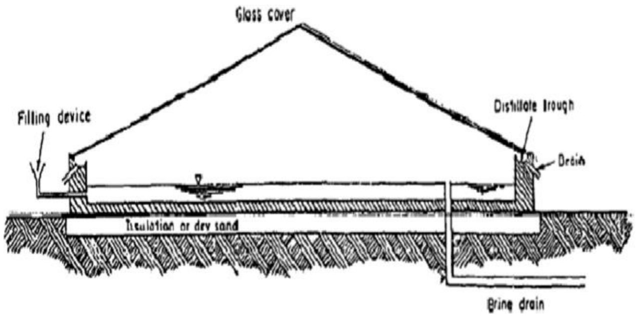

Fig.7 Double Slope Solar Still(P.Vishwanath Kumar, 2015)

2. Climate Parameters

The productivity of a solar still is influenced and affected by environmental conditions such as solar intensity, ambient temperature, relative humidity, wind velocity and cloud and dust cover, which are not controllable by humans.

2.1 Wind Speed

Variation of Wind velocity affects the distillate output of solar still. As the wind velocity increase the convective heat transfer co-efficient from glass cover to the surrounding increase and temperature difference between water and inner side glass cover increase and eventually performance of solar still increase(H. Al-Hinai, 2002)(Kianifar, 2011)(Mohammed Shadi S. Abujazar, 2016). Fig. 8 shows variation of distillate output with wind velocity.

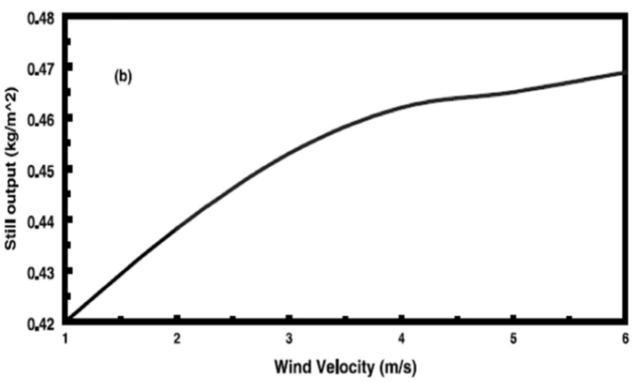

Fig.8 Variation of distillate output with wind velocity(Mohammed Shadi S. Abujazar, 2016)

2.2 Ambient Temperature

As Ambient Temperature increases the Output of still increases. Fig. 9 shows variation of distillate output with ambient temperature.

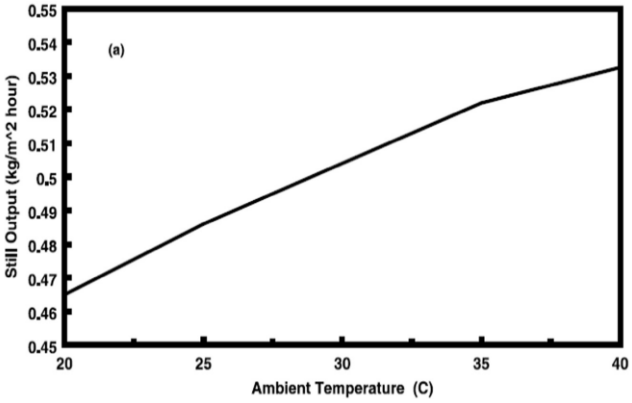

Fig.9 Variation of distillate output with Ambient Temperature(Mohammed Shadi S. Abujazar, 2016).

2.3 Relative Humidity

As Relative Humidity is a natural phenomenon, humans cannot control it. Experiments have shown that with increase in Relative Humidity the distillate output of solar still also increases. Fig. 10 shows the variation of distillate output with relative humidity.

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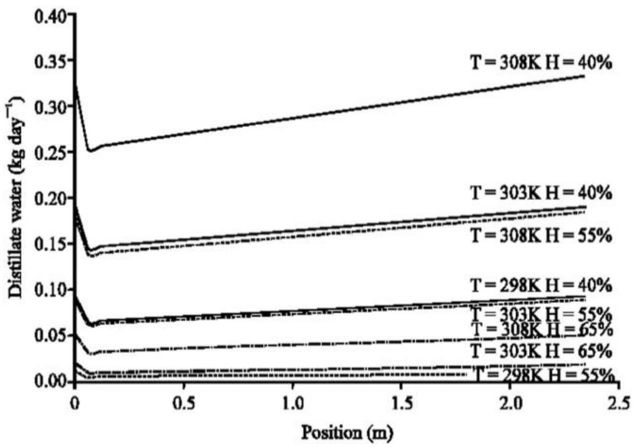

Fig.10 Variation of distillate output with Relative Humidity(Mohammed Shadi S. Abujazar, 2016).

Conclusions

- In this paper, we discussed various design and climatic parameters which affect the output of a solar still.
- Design Parameters include Depth of Brine, Cover Inclination, Thickness of Insulation, Shape of Cover etc.
- The optimum value of depth of brine, cover inclination, thickness of insulation should be 6cm, latitude of the place, 9mm respectively.
- Natural climatic parameters like Ambient Temperature cannot be controlled by human but are deciding factors in the output of solar still.

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