Desalination of Brackish water using Solar still with Phase Change Material

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ABSTRACT

The only nearly inexhaustible sources of water are the oceans, which is of high salinity. However, the separation of salts from seawater requires large amounts of energy which, when produced from fossil fuels, can cause harm to the environment. Therefore, there is a need to employ environmentally friendly energy sources in order to desalinate seawater. In this project we designed a solar still (single basin), which can be used for water desalination (removing salt content from water using solar energy). Probably, they are considered the best solution for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable. The purpose of this project is to study the effect of using phase change materials in a solar still, and thus enhance the productivity of water. In present work phase change material(Myristic Acid) is used to store the solar thermal energy in the form of latent heat, which can offer high storage capacity per unit volume and per unit mass and we can get heat in the night time for desalination.

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1. INTRODUCTION:

Contaminated drinking water is one of the reasons of major health hazards responsible for almost 90 % of the health problems in rural areas. Women and children are mostly affected because they are quite vulnerable to water borne diseases. Out of 40–50 litres per capita per day (lpcd) of water requirement for domestic consumption, only 2 lpcd is the drinking water. A total amount of 5–10 lpcd water is needed for drinking and cooking purposes and thus, it is only this quantity of water that needs to meet the stringent quality standards of portability prescribed by W.H.O. or other similar agencies, whereas the remaining amount of water needed for washing and cleaning can be of intermediate quality. Intensive use of chemical fertilizers in agriculture and enhanced Industrial activities cause the natural and inorganic pollutants to leach down to underground sub surface water and hence, the drawing of water through Hand-Pumps may not remain safe for drinking purpose. Keeping in view the poor paying capacity of people, water supply to remote areas through pipeline could be uneconomical and moreover, it also encourages wasteful use of high quality water in washing, cleaning and toiletries. Water and energy are two inseparable items that govern our lives and promote civilization. Looking into the history of mankind one finds that water and civilization were also two inseparable entities. It is not a coincidence that all great civilizations were developed and flourished near large bodies of water. Rivers, seas, oases and oceans have attracted mankind to their coasts because water is the source of life. The transportation of drinking water from far-off regions is usually not economically feasible/desirable, desalination of available brackish water has been considered as an alternative approach.

1.1 Solar still operation

A solar still used for converting brackish/saline water into potable water using solar energy is called solar still. It consists of a shallow blackened basin of saline water covered with a sloping transparent roof. Solar radiation that passes through the transparent roof heats the water in the blackened basin, thus evaporating the water which gets condensed at underside of the glass and gets collected in the tray as distillate attached to the glass. In present project a phase changing material is placed at the bottom of the water tray which is in contact with the water tray at the bottom and helps in evaporation by liberating heat after sunset.

2. EXPERIMENTAL SETUP:

The present project consist as an equipment called solar still, which consist of a basin made up of stainless base, having a length of 90cm and 60cm width with 30 cm height. Inside this basin another basin is placed with a distance of 8cm leaving a gap from bottom and sides and in between this gap an insulation material (thermocol)is placed to prevent loss of heat. The inner box is filled with phase changing material (PCM) with a thickness of 7cm, here the PCM used is Myristic Acid which will change their phase from solid to liquid during day time and liquid to solid in the night, above the PCM a 2, 4 and 6cm height of saline water is filled which will evaporate when gets heated by solar radiation. At the top of the basin a transparent glass is placed at an inclination of 30deg which is having a thickness of 0.5mm which will allow the solar radiation to enter into basin consisting of water. When water gets heated it starts evaporating and collects at the underside of the glass cover as vapours. This collected vapours move on to the condensate channel which is provided inside the basin. The basin also consists of one inlet at the rear end for water input and two outlets at front end to collect the water from two condensate channels. In addition to this certain important parameters are to measured simultaneously which are temperature, global solar radiation, water temperature and ppm rating of water, these are measured using infra- red laser sensor,digital thermometer and tds meter respectively.

Fig.-2.1: Solar still with PCM material

2.1 Selection of Phase Change Material

The measurement of PCM was done in Netzsch Technologies India Pvt Ltd, Chennai, India by using the deferential scanning calorimetry (DSC) technique. The measurements were carried out under the following conditions for the evaluation of melting and heat of fusion.

- Temperature range: 0-80 C.
- Heating rate: 10 K/min.
- Atmosphere: Static Air.

The measurements conditions of heat capacity of Myristic acid are as follows:

- Temperature range: 0-80 C.
- Heating rate: 10 K/min.
- Atmosphere: Nitrogen.

The measurements were repeated to check the reproducibility of the results. Therefore, myristic acid, a bye product of milk, has been used as a latent heat storage material due its low cost and easy availability. Table 2.1 summarizes the thermo physical properties of myristic acid used in the experiment

Table- 2.1: Thermo-physical properties of Myristic acid

PROPERTIES	VALUE
Melting point	50-54 [℃]
Latent heat of fusion	177 [$KJkg^{-1}$]
Thermal Conductivity	0.25 [$Wm^{-1}C^{-1}$]
Specific heat	
Solid at 35℃	1700 [$Jkg^{-1}C^{-1}$]
Liquid at 55℃	2040 [$Jkg^{-1}C^{-1}$]

Differential scanning calorimetry (DSC)

In DSC test, the sample and the reference (with known thermal properties) are maintained at the almost same temperature throughout measurement process, and by measuring the difference of heat added between the sample and the reference, many thermal properties of the sample can be obtained, such as heat of fusion, heat capacity and melting/solidification temperature.
The DSC method can also be used for analysing the thermal properties of

PCM-wallboards. Through DSC test, not only can the melting temperature and heat of fusion of PCM be obtained, but also the distribution of PCM in wallboard, the heat storage capacity of PCM wallboard and the effect of multiple thermal cycling on thermal properties of PCMs can be tested.

Differential thermal analysis (DTA)

In DTA test, the heat applied to the sample and the reference remains the same (rather than the temperature in DSC test). The phase change and other thermal properties can then be tested through the temperature difference between the sample and thereference.

2.2 Efficiency of the still

If Q_t(in Joules/m^2 day) is the amount of solar energy incident on the glass cover of a still and Q_E(in Joules/m^2 day) is the energy utilised in vaporizing water in the still, then the daily output of distilled water M_e (in kg/m^2 day) is given by

$$M_e = \frac{Q_e}{l}$$

Where l (in Joules/kg) is the latent heat of vaporization of water. The efficiency of the still is given. An ideal still is considered to be a still with zero conductive heat losses and with zero heat capacities of water, glass and insulation. Cooper has shown that efficiency of such a still as high as 60 % for high values of solar insulation.

3. METHODOLOGY:

All the experiments were conducted between the time periods of 09:00 to 17:00hrs when the solar still is without PCM and this time period is extended to two more hours' i.e. Up to 19:00hrs.when the PCM is used in the solar still, because to see the effect of PCM in solar still. Thermometers were fixed to take the temperature of water, PCM, glass, insulation and ambient temperature. The experiment is conducted during the time period of 09:00 hrs to 17:00hrs in the absence of PCM. The 6 cm height water tray is filled with 2 cm of brackish or saline water. The above procedure is repeated for 4 and 6 cm height of water in tray.

4. CALCULATIONS:

1. PCM Used:

Volume of copper tube = $(\pi/4) \times (1)^2 \times 60$

= 47.12 cm^3

2. for 6 copper tubes:

Volume required = 235.7 cm^3

Mass of PCM material = 235.7 ×0.0024

= 0.56 kg

3 .Stainless steel:

Volume of the stainless steel= 87 × 57 × 0.5

= 2479.5cm^3

Capacity of salt water = 87 × 57 × 10

=35460 cm^3

Volume in litres = 35.46 litres

Total surface area of stainless steel = 2 (57 × 20) + 2 (87 × 20) + (87 × 57)

= 10719 cm^2

4. Heat required for water desalination:

Q = q_1+q_2

q_1= m × C_p × ΔT

= 10×4.184×80

= 3347.2 KJ

q_2 = m × Δh

=10×2260

=22600 KJ

Q = 25947.2 KJ

5. Heat transfer in the three layers of box

K_w = 0.1 W/mK

K_{th} = 0.033 W/mK

K_{ss} = 15 W/mK

Q = $\frac{\Delta T}{R}$

$$R = \left(\frac{1}{h_a} + \frac{l_1}{k_1 A} + \frac{l_2}{k_2 A} + \frac{l_3}{k_3 A} + \frac{1}{h_b}\right)$$

Q

$$= \left(\frac{1\times10^{-2}}{0.1} + \frac{1\times10^{-2}}{0.033} + \frac{1\times10^{-2}}{15}\right) = 0.403$$

Q = $\frac{10}{0.403}$= 24.81 KW/m²

6. Heat transfer in copper tubes

$$Q = \frac{\Delta T}{R}$$

$$R = \left(\frac{1}{(2\pi \times l \times k)}\right) \ln\left({}^{r_1}/_{r_2}\right)$$

7. Heat incident

Solar incident in Chennai = 5.08 KW/m^3/day

Amount of solar incident throughout the year:

$Q_{inc} = \frac{5.08 \times 1000}{24}$ = 211.66 W/m^2

Glass transmits a minimum of 80% of light ray incident on it.
Q_{inc} = 211.66 x 0.8 = 169.33 W/m^2

Assume a period of 8 hours incident of solar

Q_{inc} = 169.33 × 8 × 3600 = 4876.8 KJ/m^2

5. RESULT AND DISCUSSIONS

Table- 5.1: Temperature vs Time

TIME	OBSERVATION
10 A.M	20
10:45 A.M	26
11:15 A.M	33
1:30 A.M	53
3:00 A.M	49
4:00 A.M	46

Observations

Time taken for drop to come to the channel = 1 hour
Time taken to drop to come out of channel = 0.5 hour
Amount of brackish water poured initially = 10 litre
Amount of pure water obtained at the end of the experiment = 1.5 litre
Temperature of the condensate = 32℃
TDS of purified water = 81 ppm

Efficiency of the solar still

The theoretically obtained amount of pure
water = 2.33 litre The practically obtained
amount of pure water = 1.05 litre.

Efficiency = (Actual amount of pure water/ Theoretical amount of pure water) x100
= (1.5/2.33) x 100 = 64.37%

6. CONCLUSION:

We can conclude that increase in temperature shows that evaporation is maximum in the period of 11:15 am to 1:30 pm. The maximum temperature achieved is 53℃ which is at 1:30 pm and then the temperature decreases. The aim of the project was to get pure water from brackish water is achieved. The brackish water supplied was 14 litres and at the end of experiment we got about 1.5 litres. The tds level of purified water obtained is 81 ppm. So the water is potable. Theoretically the experiment should fetch out 2.33 litres. So the efficiency of the system is 64.37%.

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