Data Article

Double slope solar still distillate output data set for conventional still and still with or without reflectors and PCM using high TDS water samples

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ABSTRACT

The rate of distillate and temperatures are important factors for analyzing the solar stills. The higher rate of distillate and hence the higher efficiency can be achieved by engrossing different measures to develop the still, for example; double slope instead of single slope, incorporating reflectors for maximum insolation, use of PCM for increasing the time period of operation of solar still after sun hours. The data associated with developed double slope solar still is presented to correlate variation of distillate output with the still basin and glass cover temperatures as well as stills with and without reflectors and PCM for different types of high TDS level water samples. The data set of temperature and distillate output can be used to analyze the working of stills for its efficiency and effectiveness in terms of distillate yield.

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Specifications table

| Subject area                  | Solar Energy & Desalination |
|-------------------------------|-----------------------------|
| More specific subject area    | Solar Distillation          |
| Type of data                  | Table, graph, figure        |
| How data was acquired         | Temperature measurements, flow measurements, pH and TDS tests |
| Data format                   | Raw, analyzed               |
| Experimental factors          | High TDS Water Samples      |
|                               | Sample 1 – brackish water (high contents of Sodium Carbonates – 40% soap solution) |
|                               | Sample 2 – waste water of RO plant (45% TDS) |
| Experimental features         | The temperatures measured by using 12 Channel DTI-101 M with J-type thermocouples. |
|                               | Output flow measurements done using 1000ml measuring cylinder of model23702. pH measured using PHH222 pH meter. |
|                               | TDS measurement done by PHH-126 m. |
| Data source location          | Solapur, Maharashtra, INDIA |
| Data accessibility            | The data is with this article |
| Related research article      | Kumbhar, S. V., Status of Groundwater Contamination and Health Hazards Due to Arsenic and Fluorides: A Review. International Journal of Water Resources, 2017, Vol. 3, Issue 1, pp. 1–4 [1]. |

Value of the data

- The data can be used to correlate distillate output with respect to still basin temperature and time
- The data demonstrates greater insights on how distillate output varies with glass cover temperatures
- The extensive comparison of conventional solar still and developed solar still (comprising of double slope, reflectors, PCM) shall help for obtaining higher distillate output
- Use of high TDS water in basin facilitates in determination of effectiveness in working of still as to similar purification techniques

1. Data

The experimental investigations performed on the developed solar still acquires the temperatures of basin, water and glass cover and the corresponding distillate output [Tables 1–6]. The values are plotted with respect to time and temperature [Figs. 1, 3, 5, 7, 9 and 11]. The distillate output is plotted with respect to time [Figs. 2, 4, 6, 8, 10 and 12].

The samples of water used are:
Sample 1 – Brackish Water (High contents of Sodium Carbonates – 40% soap solution).
Sample 2 – Waste water of RO plant (45% TDS).

The experiments are conducted on solar still with/without reflectors and/or PCM.

The case by case basis experimental investigations are then done with different combinations as follows.

Case-1: Still – Without reflector and without PCM tank; Sample 1.

Table 1: Observations case-1.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) |
|--------------|---------------------------------|---------------------------|----------------------------|------------------------|
|              | Inside                          | Outside                   | Inside                     | Outside                |                        |
| 10           | 25                              | 31                        | 36                         | 34                     | 0                      |
| 11           | 55                              | 55                        | 48                         | 42                     | 110                    |
| 12           | 68                              | 60                        | 55                         | 45                     | 260                    |
| 13           | 71                              | 68                        | 60                         | 47                     | 530                    |
| 14           | 65                              | 64                        | 59                         | 48                     | 750                    |
| 15           | 68                              | 72                        | 55                         | 44                     | 940                    |
| 16           | 60                              | 67                        | 50                         | 42                     | 1070                   |
Case-2: Still – Without reflector and without PCM tank; Sample 2.

Table 2
Observations case-2.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) |
|--------------|---------------------------------|---------------------------|-------------------------------|------------------------|
|              |                                 |                           |                              |                        |
|              | Inside 36                       | Outside 32                |                               | 0                      |
|              | 11 53                           | 56                        | 50                            | 110                    |
|              | 12 58                           | 60                        | 57                            | 270                    |
|              | 13 55                           | 58                        | 56                            | 520                    |
|              | 14 56                           | 57                        | 55                            | 770                    |
|              | 15 56                           | 57                        | 48                            | 985                    |
|              | 16 52                           | 53                        | 47                            | 1135                   |

Case-3: Still – With reflector and without PCM; Sample 1.

Table 3
Observations case-3.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) |
|--------------|---------------------------------|---------------------------|-------------------------------|------------------------|
|              |                                 |                           |                              |                        |
|              | Inside 30                       | Outside 32                | 30                            | 0                      |
|              | 11 61                           | 64                        | 57                            | 56                     |
|              | 12 68                           | 70                        | 69                            | 371                    |
|              | 13 68                           | 72                        | 61                            | 610                    |
|              | 14 69                           | 74                        | 64                            | 859                    |
|              | 15 61                           | 63                        | 60                            | 1108                   |
|              | 16 59                           | 60                        | 59                            | 1260                   |

Case-4: Still – With reflector and without PCM; Sample 2.

Table 4
Observations case-4.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) |
|--------------|---------------------------------|---------------------------|-------------------------------|------------------------|
|              |                                 |                           |                              |                        |
|              | Inside 30                       | Outside 31                | 30                            | 0                      |
|              | 11 58                           | 62                        | 55                            | 100                    |
|              | 12 65                           | 69                        | 67                            | 330                    |
|              | 13 74                           | 74                        | 68                            | 615                    |
|              | 14 69                           | 70                        | 61                            | 880                    |
|              | 15 62                           | 64                        | 59                            | 1105                   |
|              | 16 60                           | 61                        | 58                            | 1255                   |

Case-5: Still – With reflector and with PCM; Sample 1.

Table 5
Observations case-5.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) | Wax Temperature (°C) |
|--------------|---------------------------------|---------------------------|-------------------------------|------------------------|----------------------|
|              |                                 |                           |                              |                        |                      |
|              | Inside 30                       | Outside 32                | 31                            | 0                      | 32                   |
|              | 11 30                           | 62                        | 57                            | 160                    | 57                   |
|              | 12 30                           | 72                        | 68                            | 460                    | 71                   |
|              | 13 30                           | 74                        | 62                            | 780                    | 74                   |
|              | 14 30                           | 65                        | 54                            | 920                    | 77                   |
|              | 15 30                           | 59                        | 54                            | 1130                   | 60                   |
|              | 16 30                           | 65                        | 53                            | 1350                   | 60                   |
|              | 17 30                           | 63                        | 48                            | 1480                   | 59                   |
|              | 18 30                           | 52                        | 40                            | 1540                   | 54                   |
|              | 19 30                           | 50                        | 35                            | 1580                   | 52                   |
Case-6: Still — With reflector and with PCM; Sample 2.

Table 6
Observations case-6.

| Time (hours) | Temperature of Basin water (°C) | Temperature of Basin (°C) | Glass Cover Temperature (°C) | Distillate output (ml) | Wax Temperature (°C) |
|--------------|---------------------------------|---------------------------|-----------------------------|------------------------|----------------------|
|              | 10.30                            | 32                        | 33                          | 30                     | 32                   |
|              | 11.30                            | 63                        | 64                          | 58                     | 35                   |
|              | 12.30                            | 71                        | 73                          | 68                     | 45                   |
|              | 13.30                            | 73                        | 71                          | 63                     | 44                   |
|              | 14.30                            | 65                        | 68                          | 58                     | 42                   |
|              | 15.30                            | 62                        | 64                          | 54                     | 39                   |
|              | 16.30                            | 65                        | 70                          | 56                     | 42                   |
|              | 17.30                            | 55                        | 64                          | 50                     | 41                   |
|              | 18.30                            | 54                        | 52                          | 40                     | 35                   |
|              | 19.30                            | 51                        | 50                          | 38                     | 34                   |

Fig. 1. Graph of Time v/s Temperature (Case-1).

Fig. 2. Graph of Time v/s Distillate Output (Case-1).
Figs. 1, 3, 5, 7, 9 and 11 show the typical variation of temperature with time throughout the sun hours. It is seen that temperature reaches peak value of 70–75°C around 1200–1400 Hrs of day time, on clear sunny day. While the distillate output rate is high around 1300–1600 Hrs, as shown in Figs. 2, 4, 6, 8, 10 and 12, which resembles heat gain by water and time taken for evaporation and condensation.

Different water mixtures with variable TDS levels may have different distillate output depending on water level in basin and ratio of TDS to water. Water mixtures of high specific heat and thermal conductivity TDS, add to requirement of more heat to evaporate water thus affecting efficiency.

1.1. Test reports of distilled water

Analysis of Sample 1 — Brackish Water (High contents of Sodium Carbonates — 40% soap solution) [Table 7]
2. Experimental design, materials, and methods

The design methodology of the project involves designing symmetrical double slope solar still as per the output desired. The solar still is designed for an estimated output of around 2 liters. In addition, external reflectors and PCM energy storage unit has been used to increase the output efficiency [1,2]. Fig. 13 shows the actual setup of Double Slope Solar Still.

Base Area:

Estimation of base area is required for determining the quantum of incident solar radiation necessary for producing the desired output. With a desired output of 2 liters of water, the amount of solar energy required can be calculated as
\[ M_w = \frac{Q_{req}}{\text{Latent Heat of vaporization}} \]  

Therefore, \( Q_{req} = 4520 \text{ kJ} \)

Now, in order to calculate the amount of incident solar energy \( Q_{\text{incident}} \) it is needed to analyze the data of the average amount of solar energy incident in Solapur every month. The average solar energy received in Solapur throughout the year is 533 W/m\(^2\)

\[ I = \text{Average solar incident radiation for Solapur region.} \]

\[ I = 533 \text{ W/m}^2 \]

Generally glass transmits 80% of light through it. Let us consider 70% of solar rays incident are utilized.

![Graph of Time v/s Temperature](Fig. 7. Graph of Time v/s Temperature (Case-4).)

![Graph of Time v/s Distillate output](Fig. 8. Graph of Time v/s Distillate Output (Case-4).)
Available = \tau_{glass} \times I \quad (5)

\[ Q_{available} = 331.8 \text{ W/m}^2 \]

Thus, \[ Q_{incident} = Q_{req} \]

Therefore area required to get 4520 kJ is

\[
\frac{Q_{req}}{Q_{available}} \quad (6)
\]
Assuming that the system works 6 hrs/day

\[ Q_{\text{available}} = 7166.88 \text{ kJ/m}^2 \]
Area required = 0.63 m²

Reflector:
In order to increase the incident solar radiation into the still, the external reflectors are incorporated [1,2]. Due to this evaporation rate is increased. The additional amount of solar energy incident on the solar still, due to the external reflector can be calculated as follows.

Considering 4000 KJ of excess energy is available, area of reflector required to obtain this energy. Average solar incident radiation for Solapur region is 533 W/m²

\[
Q_{\text{req}} = \tau_{\text{glass}} \times A_{\text{reflector}} \times I
\]

\[
Q_{\text{req}} = 331.8 \text{ W}
\]
Phase Change Material (PCM):
For 1 kg pure water, additional 2600kJ energy is needed. To store 2600 kJ energy in storage material i. e paraffin wax,

\[
Q = \left( m \times C_p \left(T_{melting} - T_{ambient}\right) \right)_{solid} + (m \times L_h) + \left( m \times C_p \left(T_{max} - T_{melting}\right) \right)
\] 

(8)

Therefore, mass of PCM, \( m = 6.5 \) kg

Dimensions of Solar Still [Table 10]:

| Sr. No. | Parameters               | Values  |
|---------|--------------------------|---------|
| 1       | Area of basin            | 0.65 m² |
| 2       | Height of basin          | 0.15 m  |
| 3       | Area of glass            | 0.648 m²|
| 4       | Thickness of glass       | 0.004 m |
| 5       | Inclination of glass     | 23°     |

2.1. Materials and methods

2.1.1. Basin (Fig. 14)
Shape = Rectangular
Area = 0.9 m × 0.7 m
Height = 0.15 m
Material = G.I
Specific heat of G.I. = 0.45 KJ/kg.K
Black spray painted base, so as to increase the absorptivity.

2.1.2. Transparent glass cover (Fig. 15)
Thickness = 5 mm
Area = 720 mm × 900 mm

2.1.3. PCM (Phase Change Material) tank (Figs. 16 and 17 & Table 11)
Area of Tank = 0.9 m × 0.7 m
Thickness of Tank = 15 mm
PCM = Paraffin Wax
Quantity = 6 kg

Fig. 14. CAD model of basin.
2.1.4. Reflectors

Highly polished silver coated mirrors are used for high reflectivity of ~0.99; so as to transmit maximum amount of radiation to the basin. Total reflector area is 1.5 m².

2.1.5. Insulation material for basin

Material = Ceramic wool; Thickness = 50 mm

Density = 64kg/m³; Thermal Conductivity = 0.25 W/m.K

Fig. 15. Transparent glass cover.

Fig. 16. Phase change material (PCM) tank
2.2. Efficiency

The efficiency of solar still (Case 1–4) [Table 9] is given by

$$\eta = \frac{\sum M_{ew} \times L}{A_{glass} \times I \times t} \times 100$$ (1)

The actual maximum efficiency of solar still (Case 5 & 6, using PCM), needs total energy stored in PCM to be taken into account, which is

$$Q = \left\{ m \times C_p \left( T_{melting} - T_{ambient} \right) \right\}_{solid} + \left( m \times L_h \right) + \left\{ m \times C_p \left( T_{max} - T_{melting} \right) \right\}_{liquid}$$ (2)

Therefore, efficiency [Table 9] of solar still using energy storage material is given by

$$\eta = \frac{\sum M_{ew} \times L}{A_{glass} \times I \times t} + Q \times 100$$ (3)

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**Table 11**

Properties of paraffin wax – PCM.

| Sr. No. | Property               | Value                                   |
|---------|------------------------|-----------------------------------------|
| 1       | Form and appearance    | White solid at room temperature         |
| 2       | Melting temperature    | 55 °C                                   |
| 3       | Latent heat            | 215 kJ/kg                               |
| 4       | Specific heat          | 2.14–2.9 kJ/kg                          |

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*Fig. 17. Paraffin wax PCM.*
Nomenclature

TDS : Total Dissolved Salts
Meq : Mass of evaporated water
PCM : Phase Change Material
L : Latent Heat
RO : Reverse Osmosis
Aglass : Area of glass cover
I : Incident Radiation Intensity
t : Time
Q : Total heat stored
m : Mass of PCM
Cp : Specific heat
T : Temperature
η : Efficiency
τglass : Transmissivity of glass cover
Areflector : Area of Reflector
G.I. : Galvanized Iron

Transparency document

Transparency document associated with this article can be found in the online version at https://doi.org/10.1016/j.dib.2019.103852.

References

[1] S.V. Kumbhar, Status of groundwater contamination and health hazards due to arsenic and fluorides: a review, Int. J. Wine Res. 3 (1) (2017) 1–4.
[2] S.V. Kumbhar, B.K. Sonage, Adaptation and implementation of solar distillation plants for pure water: a review, J. of Water Pollut. & Purif. Res. 4 (1) (2017) 1–3.