Mitesh I. Patel, P. M. Meena, Sunil Inkia / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 www.ijera.com
Vol. 1, Issue 3, pp.456-460

Effect of dye on distillation of a single slope active solar still coupled with evacuated glass tube solar collector

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ABSTRACT

On the basis of different literature survey, a single slope active solar still is selected for further development and performance analysis which is subjected to be coupled with evacuated glass tube solar collector for high temperature water feeding in to the basin of solar still. The developed solar still basin area of 1 m^2 is proposed to be tested with different surface coatings/materials and performance variation with different sensible heat storage materials like black, blue and red dye used inside the brackish water. The test results are to be compared with literature and with & without absorber media inside the still with different heat and mass transfer coefficients like evaporative, radiative and convective heat transfer. When it is exposed to sunrays temperature inside the evacuated glass tube is more than 80^o C. The experimental set up was analyzed by with and without dyes. It has been seen that output with black dye is higher compare to other dyes, while output was lower without dye.

Keywords - **Evacuated glass tube, Solar still, Thermocouples**

1. Introduction

People can survive for day, weeks or months without food, but cannot live for more than a week without water. The body use water for digestion, absorption, circulation, transporting nutrients, building tissues, carrying away waste and maintaining body temperature. The average adult consumes about 2.5 to 3 litters of water per day to drink.

Today fresh water demand is increasing continuously as discussed by El-Sebaii et al., [1] because of the industrial development, intensified agriculture, improvement in standard of life and increase in the world population. Only 3% of total water is potable but this amount is also evenly not distributed over the earth. Lack of fresh water is a prime factor in inhibiting regional/economical development. Often, water sources are brackish/containing harmful bacteria, therefore cannot be used directly for drinking purpose. The oceans constitute an inexhaustible source of water but are unfit for human consumption due to their salt content in the range of 3% to 5%. In addition, there are many coastal locations where seawater is abundant but potable water is not available. Therefore it is an urgent need for clean and pure drinking water in many countries. In order to solve this problem, some new drinking water sources should be discovered and new water desalination techniques be developed.

In recent years desalination of water has been one of the most important technological work undertaken in many countries. The fossil fuel burning water desalination techniques are in use since long back. These systems range up to 10 ton/day capacity. The main water desalination or purification methods are distillation, reverse osmosis and electro dialysis. Cleaner energies such as natural gas, solar thermal power and photovoltaic technology must be integrated with desalination technology. For bigger systems, reverse osmosis and electro dialysis are more economical, but for smaller ones, simple solar stills could be preferred because of their low costs and less floor area. A number of solar still units are installed in West-Indian Islands, Saudi Arabia, Mexico and Australia etc for solar distillation. On deserts and islands where underground water is not readily available and cost of water shipping is high, it is worthwhile to produce potable water from saline water using solar energy. Utilization of solar energy for water desalination is becoming more attractive as the cost of conventional fuels/energy is continuously increasing. Solar desalination is particularly important for locations where solar intensity is high and there is a scarcity of fresh water. Solar desalination is a process where solar energy is utilized to distill the fresh water from saline/brackish water for drinking purposes, in charging of the batteries, research laboratories and medical appliances etc.

Prasad and Tiwari, [2] coupled a compound parabolic concentrator (CPC) to the basin of solar still in which additional thermal energy at higher temperature was fed for production of maximum distilled water. This type of system is referred to as an active solar system. From experimental results it was concluded that the rate of thermal energy release increases with increase in glass cover inclination. Hence, optimization of glass cover inclination wais needed for higher yield. This system can produce 7 lpd from 1m^2 of solar still basin area and of CPC.

Boukar and Hannim, [3] compared the effect of desert climatic conditions on performance of a simple solar still with a similar one coupled to a flat plate collector. They tested whole day under clear sky conditions with different depth levels (2.5 to 3.5 cm.) of brackish water. The still productivity in summer varied from 4.01 to 4.34 l/m^2/d for simple basin and 8.02 to 8.07 l/m^2/d for the coupled one. Abdallah *et al.,* [4] used heat absorbing materials in four identical solar stills. The first three stills contained uncoated metallic wiry sponge, coated metallic: wiry sponge and black volcanic rocks. The fourth one used as reference still does not contain any absorbing materials (black painted). The results showed that uncoated sponge has the highest water collection during day time, followed by black rocks and then coated metallic wiry sponges. On the other hand, the overall gain in overnight water collection was 28%, 43% and 60% for coated and uncoated metallic wiry sponges and black rocks respectively.

The thermal performance of a single slope solar still coupled with solar collector using different insulation thickness (1, 2.5, and 5 cm), solar intensity, overall heat loss coefficient, absorptivity, transmissivity, wind speed, temperature difference between cover and water were studied by Badra (2011) and concluded that overall system efficiency in terms of daily distillate output would increase by increasing the basin water temperature using circulated hot water from the solar collector. Singh, [5] experimented on single slope solar still integrated with solar water heater during low sunshine or cloudy conditions due to distillation process and concluded that water productivity increased up to 120% when solar still basin combined with solar water heater and nocturnal (during night) production contributes up to 14%.

Mamlook and Badran, [6] conducted a study on solar distillation system by fuzzy sets. The study reveals that wind speed, ambient temperature, solar intensity, sprinkler, coupled collector, solar concentration, water depth etc affect on yield of solar still. Badran.et.a1., [7] developed single slope solar still with reflecting mirrors fixed on interior sides was coupled with a flat plate collector. He found that the daily productivity increased (5310 ml), 36% more than normal still operation (2240 ml) due to coupling with solar collector. He also observed that increased in basin water depth decreases the productivity and still productivity was proportional to the solar radiation intensity. Shanmugan *et al.,* [8] attached booster mirror (acrylic) just above the glass cover of still basin of area 1m^2. The results showed with mirror booster the unit output was 4.2 l/m^2/d at 890 W/m^2 and enhancement was 20 to 26%. Kabeel, [9] studied about the evaporation and condensation surfaces used play important roles in the performance of basin type solar still. In present study, a concave wick surface was used for evaporation and four sides of a pyramid shaped still were used for condensation. The use of jute wick increased the amount of absorbed solar radiation and enhanced the evaporation surface area. A concave shaped wick surface increases the evaporation area due to the capillary effect. Results showed that average distillate productivity was 4.111m2/d and a maximum instantaneous system efficiency of 45% and average daily efficiency of 30% were recorded. An estimated cost of 1 litter of distillate was $ 0.065 for the presented solar still.

2. Experimental Set Up

Fig.1, Solar still coupled with Evacuated glass Tubes.

In this experimental set up, a single slope passive solar distillation unit is coupled with rows of parallel transparent evacuated glass tubes(EGT), each of which contains an individual absorber tube covered with a selective coating to warm the water additionally prior to sending it to the solar still. An evacuated glass tubes are integrated with the basin-type single slope solar still (Fig.1). Water in the basin is passed in to the evacuated glass tubes. The water in the basin is heated by the solar energy directly received through the glass cover of the still and the solar radiation passes through the outer glass tube and fluid flowing through the absorber. Evacuated tubes are modular tubes that can be added or removed as the temperature of the hot-water required. Solar still has Fiber reinforced plastic (FRP) painted basin of area of 1m^2 filled with brackish water supplied to it from a EGT which preheats the water by use of solar energy, such kind of solar still also called Active Solar still. The evaporating basin is covered by a sheet of toughened glass having 5 mm thickness which allows the sunrays directed to basin. Angle of tilting the glass cover is 38 degree. A trough running along the bottom side of the glass cover ensures the collection of the potable water toward the collection vessel. The glass also holds the heat inside the still for continuing the evaporation of water inside the basin. An inlet pipe is fixed at the rear of the still for feeding the brackish water. Holes were drilled in the body of still to fix the k-type thermocouples (to measure the various temperatures of solar still). An Evacuated glass tube Collector (1500 mm long, 47 mm width and 10 mm thick) has been used to evaporate the water which is inside the basin. Silicon rubber is used as sealant to prevent the heat losses between the solar still and evacuated glass tubes as well as leakage losses. The side walls and base of the solar still are insulated with polyurethane form having thermal conductivity of 0.034 W/m^2 K of 10 mm thick. Upper glass of the solar still is fitted with the dammar roll. A constant Head tank was used to control the brackish water inside the solar still. Depth of water level was maintained 10 cm during the period of investigation work.

2.1. Technical Specification

Table 1: Technical specifications of the solar still

Specifications	Dimensions
Inclination of Glass	38°
Basin area, m²	1
Glass area, m²	1.043
Glass depth, mm	5
Number of glass	1
Material	M.S
Material of the paint	FRP

Table 2: Technical specifications of the Evacuated glass tube(EGT)

Specifications	Dimensions
Inclination of EGT	31°
Number of EGT	14
Length of EGT, mm	1500
Inner diameter of EGT, mm	37
Outer diameter of EGT, mm	47

2.2. Experimental condition

The experimental set up has been installed & operated at Mehsana-gujarat (Latitude:23° 35' 58.128". Longitude:72° 23' 29.5188"). from 22-5-2011 to 25-5-2011under clear sky conditions.

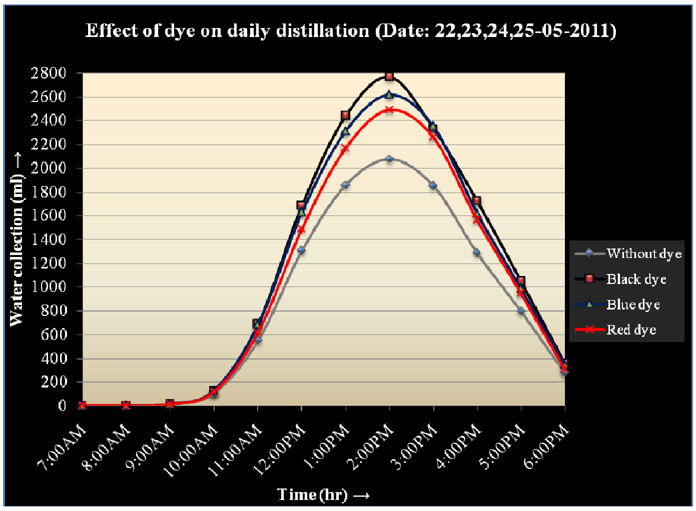
3. Result and Discussion

From above mention experiment Table 3 has been developed.

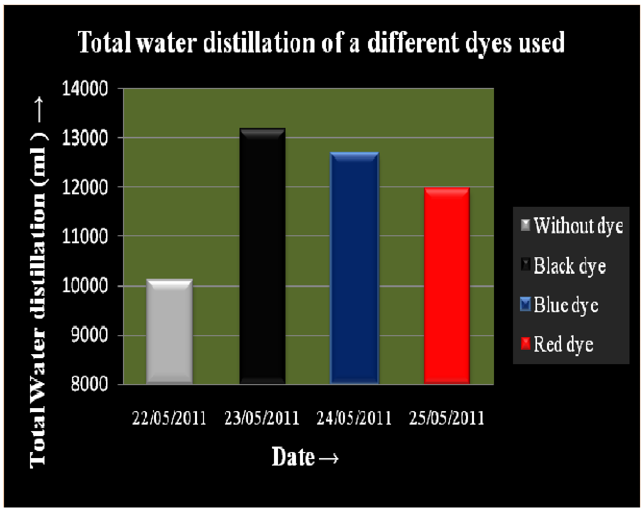
Table 3: Distill water collection for Clear sky condition.

Time,	Ambient Temperature, (°C)				Output of a water collection, (ml)			
(Hr.)	Day-1	Day-2	Day-3	Day-4	Without dye	Black dye	Blue dye	Red dye
7:00 AM	28.3	28.0	27.8	29.5	0	0	0	0
8:00 AM	29.6	29.2	30.0	29.8	0	0	0	0
9:00 AM	31.4	31.4	30.8	31.0	12	14	15	13
10:00AM	33.6	34.4	34.0	33.2	102	122	126	114
11:00AM	36.0	36.8	38.1	37.5	550	688	682	616
12:00PM	38.3	39.0	39.3	37.0	1305	1683	1627	1488
1:00 PM	40.0	40.7	41.2	39.6	1854	2440	2310	2169
2:00 PM	41.6	41.0	42.5	42.0	2073	2765	2616	2488
3:00 PM	41.4	41.7	42.0	41.8	1850	2331	2351	2257
4:00 PM	41.2	41.5	40.8	40.0	1285	1722	1618	1564
5:00 PM	40.2	41.1	40.5	39.7	795	1049	988	946
6:00 PM	38.6	36.8	39.2	39.0	278	359	345	309

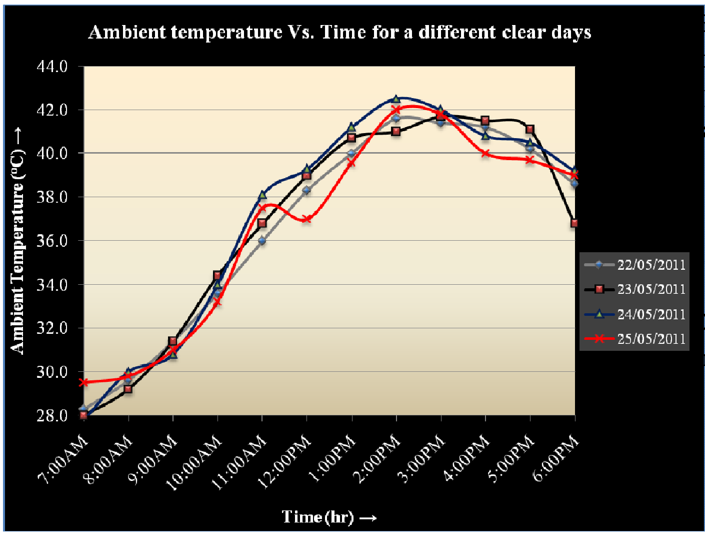
Now using data mention in table 3, graph 1 and 2 has been plotted.



Graph 1: Effect of dye on daily distillation.



Graph 3: Total water distillation using different dyes.



Graph 2: Ambient temperature Vs. Time.

The above plotted graph 1 shows that by using black dye maximum output can be obtained, further blue, red and shows output in descending order.

Table 4: Effect of dye on daily distillation.

Dye used	Daily productivity for 10 cm		Productivity increase in
	With dye	Without dye	
Black	13173	10104	30.38
Blue	12679	10104	25.48
Read	11963	10104	18.40

raph3 is plotted by using data of table4 and it shows that otal water distillation capacity increased in case of black ye with respect to pure water without any dye is 30.38%.In ase of blue and red 25.48% and 18.40% respectively.

. Conclusion

n the basis of above experiment, the following conclusions re drawn:

- Increase of 30.38% of the productivity was observed with the presence of black dye in water for solar still containing saline water up to a depth of 10 cm.
- Black and blue dyes are most appropriate for increase in the productivity of the still.
- For water depths larger than 10 cm, the productivity with and without dye appears to be independent of the depth.
- Marginally better performance was noticed for the small depths of water with the use of dye.

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