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Performance Analysis of Flat-Plate Solar Distillation and Domestic Hot Water System

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Abstract: *Many parts of the India have not clean drinking water because of rising population and unsustainable usage of water leads to insatiate increase demand of pure water. Most of the water available in hydrosphere carries parasites or saline which is simply not fit for drinking and therefore it causes significant health issues. There are various Desalination Technologies to curb the water shortages on the planet. In order to run such plants, again depends on fossil fuels, provided some part of this kind of system is integrated to solar energy but it leads to high cost. Poverty stricken region do not have the infrastructure necessary to develop and support large scale water distillation plants. Thus, Solar energy is easily available and natural option for everybody. Solar Water Distillation System (SWDS) works on humidification and dehumidification process, backed by the energy solely given by Sun. SWDS is fed with Brackish water and gives maximum output with zero total dissolved salts(TDS) of fresh water and Hot brackish water (less TDS) which can be used for domestic purposes. In this phenomenon, water is converted into vapours by utilizing the energy of the sun the water vapors condenses into pure drinkable water. This process removes salts and other hazardous impurities not fit for health associated with the water. ASWDS was designed and tested under actual environmental conditions. The system generates fresh water and hot water simultaneously; which are collected. It was observed that the fresh water generation rate was more in month of April and a bit lower than that during May.*

Keywords: *Desalination, TDS, Solar water, Renewable energy, ppm.*

1. INTRODUCTON

1.1 NEED FOR SOLAR WATER DISTILLATION SYSTEM

In the developing countries, unsafe drinking water, poor sanitation, malnutrition, and poverty are the major causes of epidemic and deadly diseases. "Half of the World's hospital beds are occupied by people suffering from water borne diseases". In India, water-borne diseases alone are said to be the causes of 73 million work-days every year. The cost incurred in medical treatment and loss of production is around Rs.24, 000 million per year. More than 70 % of Indian population lives in rural and backward areas. India has nearly 559,553 villages, out of which about 28% are reported to have unsafe drinking water due to chemical adulterant as reported by World Health Organisation (WHO).They do not have the infrastructure which is necessary to develop and support large scale water distillation plants have tested with variants [1].: bare plate, black cloth-wick and black fleece wick and pointed out that by making longer path of incoming water on flat plate, greater the rate of evaporation and hence fresh water production rate was increased two to three times using wick instead of bare plate [2]. It has been carried out a numerical study to investigate the performance of a simple solar desalination system using humidification-dehumidification processes and found that by increasing the solar intensity, ambient temperature and decreased wind velocity increases system productivity. Increasing the air flow rate up to 0.6 kg/s increases the productivity, after which it has no significant effect. The feed water flow rate has an insignificant influence on system productivity [3].

Irrigation in India accounts for 84% of the ground water consumption and India is considered to be one of the fastest and largest consumers of ground water in the world, which is less than 1% (Source : Govt. of India 2009) of fresh water present in our hydrosphere [4]. Now apart from consuming water intelligently and spreading awareness of shortages of fresh water supply, there are various solution proposed like the Desalination Plants to produce fresh water and there are nearly 15000 Desalination Plants worldwide so far but the drawback with this kind of technologies: powered by fossil fuels, high cost if backed by Solar Photovoltaic System and thirdly hot Brine released into the river which disturb the ecosystem .Still the Desalination Plants are widely popular in the developed world but most of the people who are suffering from unsafe drinking water are living in rural areas or underdeveloped countries having a bright sunshine day but could not afford to build an infrastructure to support this kind of large scale Desalination plants [5]. FPSWD system can provide an alternative solution especially for rural areas because of low cost and simple design, solely work on the solar thermal energy which is provided by the Sun, as there is limited scope of electrification and shortages of investment in rural areas.

1.2 RENEWABLE ENERGY TECHNOLOGIES

Now a days the practice of Desalination system solve the purpose of water shortages in the areas having large salinity concentration specially Middle East countries beget issues of sustainability; which is still concern to researchers for improvement. The only option is to reorganize and go as far as possible to renewable energy driven desalination, a stronger vision to bring down the cost and a clean environmental impact [6].The sources of renewable energy are natural, free, lifelong and do not exhaust with the passage of time.

1.3 DISTILLATION USING SOLAR ENERGY

Thermonuclear fusion process occurs in the Sun produce electromagnetic radiation. The part of the radiation spectrum received by the Earth can be converted into heat, electrical and mechanical energy. Thus the solar energy is clean, long lasting, silent and abundant in majority of the places on the Earth. However, it has drawbacks of seasonal variation of low intensity and diffusion and a fraction of its energy reaching the Earth can be harnessed [7]. Thus, the study of various parameters as an angle at which the beam incident on the site are important to improve the efficiency of the Solar Plant.

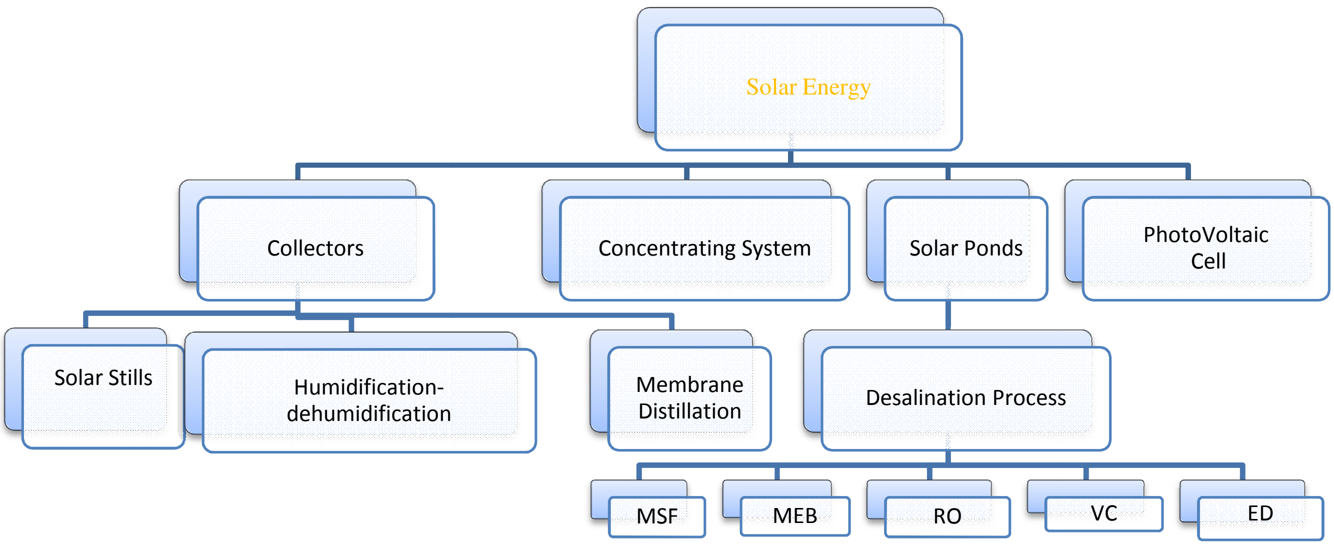

Fig. 1. Utilization of Solar Energy [1]

The Solar Energy can be directly employed to the Distillation system in a solar still or indirectly by converting to heat or electricity to drive a conventional distillation system.

TABLE 1. Specification of instrument:

Manufacturer : the Eppley laboratory Inc. USA
Impedence:650 ohm approx.
Receiver : Circular 1 cm^2, coated with Parson's black optical lacquer.
Temperature Dependence : ±1 % over ambient temperature -20 to 40 degree centigrade
Linearity : ±0.5 % from 0 to 2800 W/m^2
Response time : 1s

1.4 SOLAR IRRADIATION MEASUREMENT: PYRANOMETER

The intensity of solar radiation incident on a horizontal surface is measured by a Pyranometer. The Pyranometer is set to 45^o as the Flat plate panels are set this angle and assumed Global Radiation as its reading is taken on tilted surface.

This logger records,

- Wind speed
- Wind direction
- Global radiation
- Temperatures
- Ambient temperature

Anemometer

- Combined wind speed and direction sensor with 10 meter cable.
- ABS cups with retainer nut.
- Wiring details & test report copy.

Fig. 2. Data Logger with Anemometer [NISE]

2. SYSTEM DESCRIPTION

The inclined Flat Plate Solar Water Distillation (FPSWD) system gives the maximum output with zero ppm of fresh water/drinking water. This system is a most efficient and cost effective from others distilled system. It can produce pure, clean fresh water on any scale from any water sources and also gives hot brine, which gives more advantages and additional efficiency. Each panel of this system is design with area of 3 m^2, weight 17 kg and having a thin black fiber sheet of 0.6 mm for absorbing the input water. The front glazing is of polycarbonate thin sheet (0.2 mm), which is tough, dimensionally stable, high impact resistance, good temperature capability and expected life of 8-10 years.

TABLE 2: System Specifications

No. of Solar Panel	10
Weight of each panel	17 kg
Collector area	30 m^2
Material of Absorber	Black fiber sheet
Thickness of Absorber	0.6 mm
Space between membrane and sheet	25 mm
Material of front Glazing	Polycarbonate thin sheet
Thickness of front Glazing	0.2 mm

The cross section of such incline FPSWD is shown in figure 3The saline water is located at the top side of the panel to the entire width of the black fiber sheet wick with the help of distributor at a flow rate of 6.6 kg/hour such that the entire area of the black sheet remains wet all the time and receives water by gravity into a feeder at the top of the panel. Solar energy absorbed by water in the wick which gets evaporated both of front and back side of the panel at the temperature of 60-65^{0}C and later condensed on the underside of the cover polycarbonate thin sheet and finally vaporized water gets condensed & collected in the condensate channel fixed on the bottom side of the polycarbonate sheet. Remaining hot brine water at the temperature of 45-50 ^{0}C runs down at the bottom of the system.

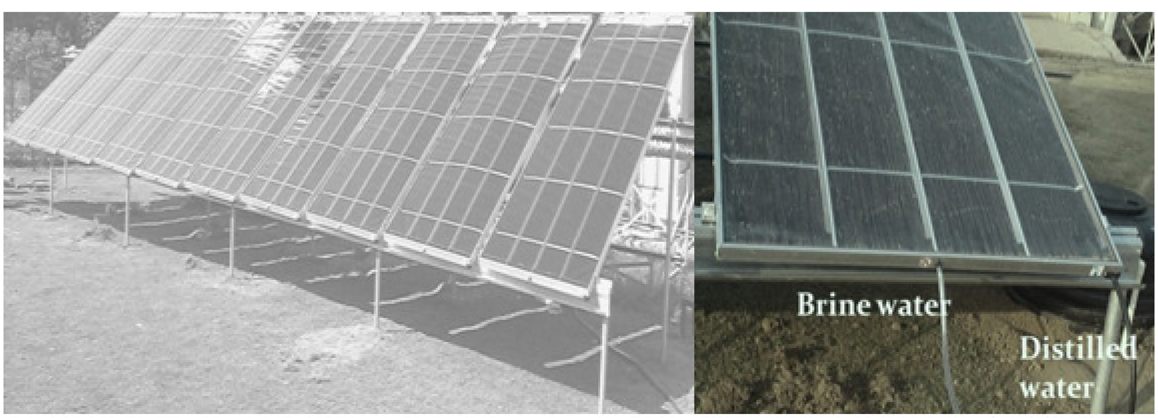

Fig. 3. Experimental setup of Flat Plate type Solar Water Distillation system [NISE]

To simplify the analysis/performance, some assumptions/standard conditions are made;

- Solar irradiance with ±50 W/m².
- Wind speed up to 1.2-5 m/s with ±1.2 m/s.
- Ambient air temperature with accuracy of ±0.1ºC.
- Collector temperature with ±0.1ºC.

3. RESULT AND DISCUSSION

3.1 PERFORMANCE ANALYSIS:

The performance of inclined FPSWD has been carried out by installing the system which consists of 10 panels i.e. area of 30 m^2 at the Out –Door Test Bed of National Institute of Solar Energy, MNRE (latitude: $28^0\ 25'\ 31.2''$N & longitude: $77^0\ 9'\ 18.8''$E) shown in Fig 1. This system has been evaluated and observations were recorded on the basis of field data collected (period of 8-9 hours) in the month of May. The experiment was conducted during daylight between the hours of (9am-5pm) through the 06th of May, 2015 to 18th of May, 2015 to study the performance of the system. In the test, amount of fresh water produced every one hour of the day and measured corresponding to parameters like air temperature, solar radiation and wind speed. Hourly data of Fresh Water and Hot Water production on relatively moderate sunshine in April have been taken for five hours of daylight.

4. EXPERIMENT PERFORMANCE DATA:

TABLE 3: Amount of fresh water and hot water obtained from testing on typical day in April on actual operating condition;

Sl.No.	Fresh Water (liters/hr per m^2)	Hot Water (liters/hr per m^2)	Global Radiation (kwh/m^2)
1	0.67	1.53	6.2
2	0.58	1.62	5.6
3	0.49	1.71	5.01
4	0.37	1.83	3.78
5	0.42	1.78	4.37

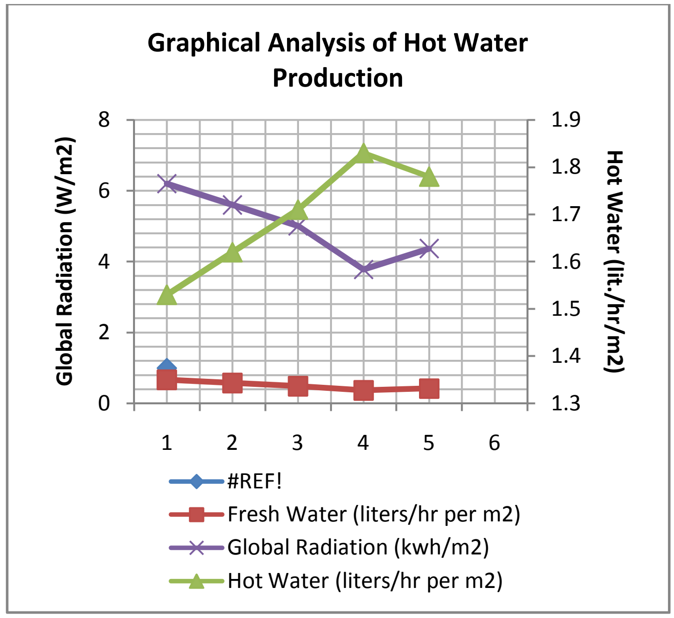

Fig. 4. Graphical Analysis of Hot Water Production

From the Table-3, it has shown that the temperature of hot water is increasing with time, global radiation decreases with time and therefore Fresh Water production decreases. Hence, a continuous supply of hot water is available on a low sunshine hour which acts as a compensation for less production of fresh water [8].

TABLE 4: Average Daily Fresh Water Productions

DATE	Average Fresh water (ml)	Average Inlet Temperature (^{o} C)	Average Global Radiation (W/m^2)	Average Wind Speed (m/s)
06-May-15	383.66	61.15	547.15	2.17
07-May-15	503.87	56.09	613.35	3.13
08-May-15	461.77	46.74	511.16	1.97
09-May-15	482.88	66.13	491.22	1.96
10-May-15	586.66	79	561.04	1.12
11-May-15	556.55	65.86	550.38	1.14
13-May-15	446.22	50.9	587.65	1.78
14-May-15	506.44	65.47	555.86	0.88
15-May-15	463.12	76.54	489.29	1.29
16-May-15	436.88	80.12	496.36	1.057
17-May-15	588	86.3	568.96	1.35
18-May-15	482.88	54	517.1	1.06

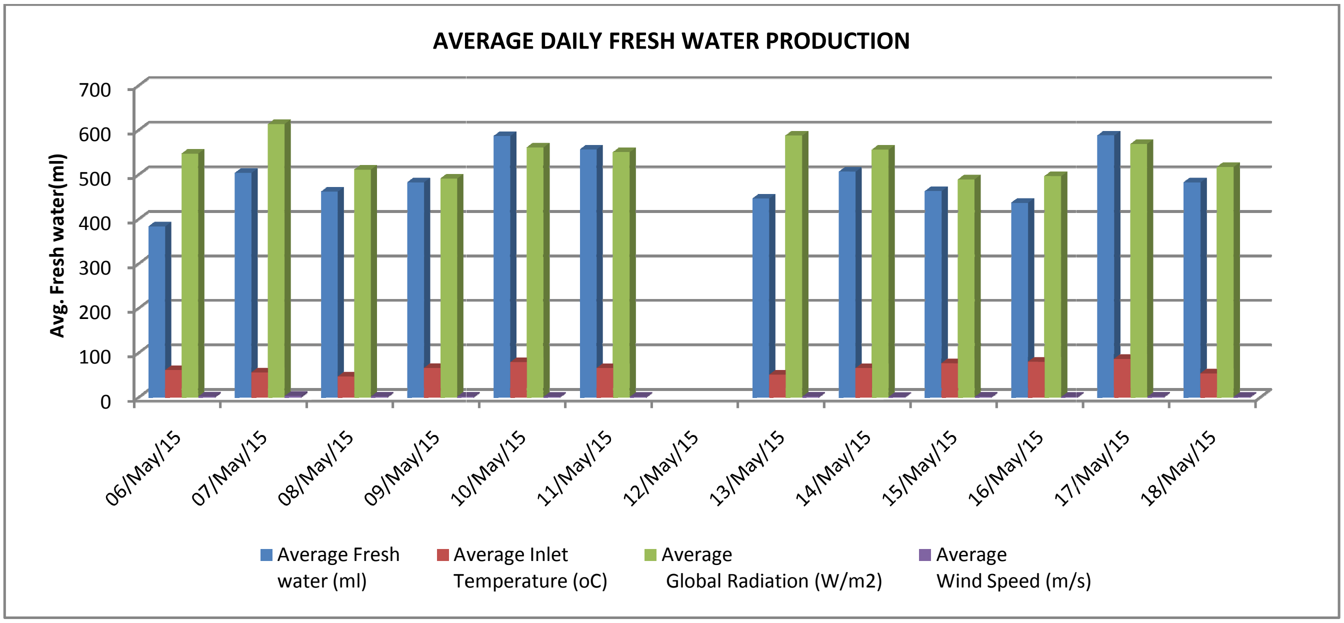

Fig. 5. Graphical Analysis

5. CONCLUSIONS

The performance has been analyzed for the period of 9 hours in day times i.e. 9:00 hours to 17:00 hrs. It is observed that, during the performance testing of inclined FPSWD, average field data on different parameters namely Temperature of cover sheet, hot brackish water (^{0}C), Tilted Global radiation (kWh/m^2),wind speed (m/sec), Ambient Temperature, generation of fresh water, hot brackish water have been recorded.

- The output of fresh water achieved about 5.33 liters/m^2 day at the radiation 5.6 kWh/m^2.
- The hot brine water is achieved about 14.3 litrs/m^{2}day at the temperature of 46^{0}C which is good enough for domestic usage.
- It also observed that, the inlet brackish water was 350 ppm before distillation and distilled water was found at zero ppm.
- In this experiment, the temperature of the hot water, cover sheet temperature were measured with thermocouples. The fresh water and hot water (Brackish water) were measured and accumulated in tanks.
- The inlet feed water from tank is 360 ppm and out let of fresh water & hot brackish water reached at zero ppm & 650 ppm respectively.
- As seen this table-1, the fresh water generation increases as the tilted global radiation increase.
- The fresh water has been achieved 5.2 liters/day m^2 at the titled global radiation of 6.2kWh/m^2.
- The average temperature of hot water (brackish water) is 47 ^{0}C at the ambient temperature of 24^{0}C as shown in table-2.
- The fresh water output is 4.68 liters/day m^2 and collected hot water (brackish water) is reached approximately 480 liters/day at 48^{0}C, which can be used for domestic proposes.
- It is noted that the brackish water temperature is mostly similar to cover sheet/polycarbonate sheet temperature. The temperature of hot brackish water has reached at 53^{0}C.
- It provides clean drinking water without use of an external energy source like fossils fuels and electric power.
- The solar distillation system will earn carbon credits as it is purely clean source of energy and pay-off of bills fast.

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