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Productivity of Enhanced Solar Still Under Various Environmental Conditions in Yekaterinburg city / Russia

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Abstract. Water is the most important source for human being and other living creatures. The naturul sources of water started to decline especially in the recent years. Researchers have focused on the productivity of drinking water as one of the main live requirements. Conversion of salt water into drinking water using solar distillation technology can be considered as the most viable methods in the dry climate regions. The productivity of solar stills effected by various parameters such as design, operational and environmental parameters. The current study aims to study the effect of different environmental conditions on improvement rate of productivity for suggested solar still. The tests were conducted at the Ural Federal University / Russia, during four months from June to September 2019 under different environmental conditions. The study results showed that there is a noticeable impact on the improvement rate in the productivity of the enhanced solar still, which depends mainly on solar radiation and ambient temperature. The rate of improvement fluctuated during the four months; the highest rete of enhancement obtained by 200% in September.

1. Introduction

Solar distillation is the best way to provide clean water to rural and remote areas one of the most important issues for human survival. Therefore, the demand for fresh water is increasing day by day due to the population growth and continuous urbanization. At present there are several different techniques for converting polluted and salty water into fresh water such as solar distillation technology [1]. The productivity of solar stills effected by different parameters includes; design, operational and environmental parameters [2]. The control of these environmental parameters is not easy, therefore, the researchers tried to increase the productivity of solar stills by the controlling operational and design parameters [3]. The design parameters are important factors that have strong impact on the productivity of solar stills which can be easily controlled and developed. The design parameters include thermal storage materials, solar tracking, reflectors, water depth, evaporation area, transparent cover angle, thermal insulation and other parameters that have an impact on productivity [4,5]. The thermal storage materials have important role in solar stills, increase the thermal capacity led to increases the productivity of solar still [6]. Solar tracking system was used to follow the sun, in order to improvement the productivity of solar still [7]. By used internal and external refractors to focus intensity of solar radiation on the basin solar still, the solar still efficiency enhanced by 48% [8]. The water depth parameter has also important effect on the productivity of solar still [9]. Increased evaporation area increases solar still productivity, meaning that the productivity of the solar distillers is proportional to the surface area of evaporation [10]. The solar still cover is usually made of glass or plastic and must be has a highly transmittance in order to absorb salt water in basin solar still radiation that passes through the transparent cover. The solar still cover should also have a good thermal insulation to reduce thermal losses to the surrounding. Several attempts have been made to increase the cover transmittance and therefore increase the solar still productivity [11]. The thermal insulation of the solar still is a necessary parameter to be considered, the proper insulation reduces wasted thermal losses from the sides and bottom of the solar still basin [12]. The current study aims to show the effect of environmental parameters on the productivity of an enhanced solar still with a hollow rotating drum.

2. Methodology

Description of the enhanced and conventional solar stills

Single-basin single-slope solar stills are the cheapest and most widespread of all currently available solar distillation systems, its main problem is low productivity. Therefore, in the current research a simple and inexpensive solar distillation system has been designed. Figures 1 shows a photograph view of the experimental station, which includes two types of solar stills. The first type is enhanced single slope solar still with a rotating hollow drum (SSS with RHD) and the second type is a conventional single slope solar still without a rotating hollow drum (SSS without RHD). The two stills have the same dimensions 100*50*60*24.8 cm, with a wooden frame of dimensions 100*50*10 cm with thickness of 0.18cm, with a fixed cover of 0.3cm plexiglass at single slope of 35 degree, from back side. The plexglass was mounted on MDF wooden panel with dimensions 60 * 100 * 0.18 cm and fixed on the wooden frame by using an aluminum channel of 0.1*0.1*0.1 cm to collect condensed water droplets through the plexiglass. The condensed water passed through the aluminum channel to a gradient plastic cylinder installed at the bottom of solar still. The basin was made of galvanized iron with a dimension of 94cm*46cm*10cm, coated with black colour to absorb a large amount of solar enrgy. Silicone glue has been used to instilled all parts of solar still and to prevent air leakage. Within solar still mounted a hollow drum (32 cm diameter, 90 cm length), which was made of Galvanized iron sheet (100 cm × 100 cm × 0.06 cm). Hollow drum mounted on the low carbon steel shaft (diameter 0.8 cm x length 95 cm) by using 0.8 cm ball bearings on the two ends. The hollow cylinder is rotated by using a small 12 v, DC motor, as which used to move glass of car with low power 0.1 A, by a small rubber belt, the rotational motion is transferred from the motor to the hollow cylinder shown in figure 2. The DC motor was fed by a small 30-watt photovoltaic panel during the sunshine days, and connected with a storage battery to power the DC motor in times of shadow and sunsetas.

A cylinder tank 50 cm*100 cm used to feed the solar stills with a brin water, a ball valve has been used to controll on the flow water from a tank and at entrance the solar still, also instilled a ball valve at the bottom of the water basin to clean the basin liner, the water level inside the basin maintained at 5 cm by using a mechanical float. The other technical specifications of SSS with RHD and SSS without RHD are listed in Table 1. 0.3 mm thermocouples K-type used to measure the temperatures at basin water , basin liner, air and vapour temperature within solar still and inside and outside plexiglass cover by using SD data logger 4 channel K thermocouple device (model 88598), all thermocouples have been calibrated between (100-0) ^{o}C. In order to measure out surface hollow drum temperature has been used digital laser infrared thermometer temperature model (TEGMART TE-TEM-LS-PRB). also was used humidity and temperature meter (GM1362) to measure the ambient temperature and relative humidity and It has been placed at a height of 1 m from the surface level in the shade to protect it from the sun radiation. a solar power meter device (TENMARS TM-207) in W/m^2 units used to measure the solar radiation intensity throughout at the sunrise times . Anemometer device (ut363) has been used to measure the wind speed, which was surrounded the stills as shown in table 2.

Test conditions and All tests were carried out during 4 months period from June to Desember at Ural Federal University of Yekaterinburg city/Russia, and at different environmental conditions. Current study consisted of two stages, first stage is the primer testing on the system, in order to

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evaluate performance and the possibility of the amendment in the designs in order to reach the best case. Second stage is an actual test of the system, which included the calculation of the average daily productivity of solar stills every 30 minutes. The results has been compared at different environmental conditions, all tests were started at 8:00 am continued until 20:00 pm (12 hours), the total number of tests was 40.

Figure 1. Photographic view of the experimental station (SSS with RHD and SSS without RHD).

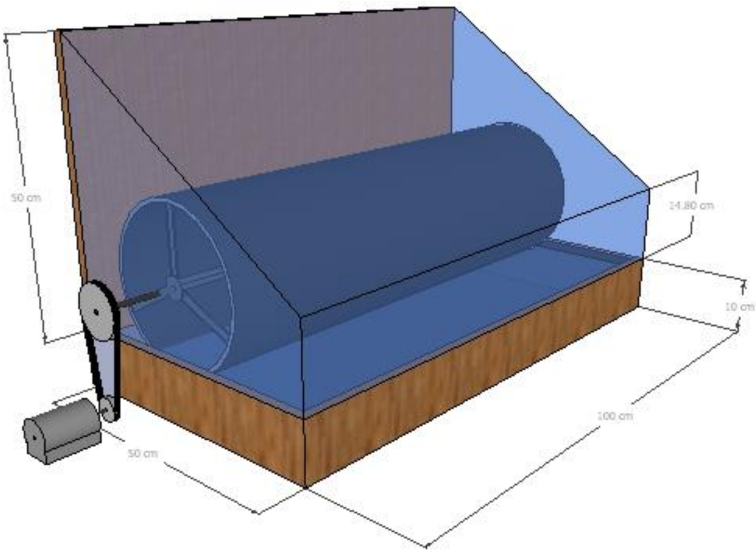

Figure 2. Schematic diagram of SSS with RHD.

Table1. Technical specifications of SSS with RHD and SSS without RHD.

Specifications	Dimensions
Basin area, m^2	0.5
Plexiglass area, m^2	0.825
Hight of basin, m	0.6
Height solar still from ground, m	0.5

Table2. The accuracy of various experimental devices.

No	Device
1	SD data logger 4 channel K thermocouple device (model 88598) ± 0.3% rdg+1℃
2	Digital laser infrared thermometer temperature model (TEGMART TE-TEM-LS-PRB). ± 1.5%
3	Humidity and temperature meter (GM1362). Humidity 3%
4	Solar power meter device (TENMARS TM-207). ±10 $W\ /\ m^2$
5	Anemometer device (ut363). ±5% rdg+0.5℃

3. Results and discussion

The current study used an analytical program (Origin pro 2018) to illustrate effects. Experimental weather data has been studied in detail, which included solar radiation density, relative humidity, ambient temperature and wind speed. Figure 3 shows the experimental results taken for a two days at 12 Jun 2019 and 15 September 2019, which represent the a perfect days of improvement in the rate of productivity between SSS with RHD and SSSwithout RHD at different environmental conditions. It was obvious that the environment parameters varies depended on the weather which is always variable and unstable in the Yekaterinburg city/Russia, rarely the weather was clear and without clouds during the four months of testing.

Figure 3, shows that the amount of water productivity of solar stills greatly influenced by the environmental parameters, the figure illustrated the comparison in the amount of productivity between the SSS with RHD and SSS without RHD during a two perfect days (12.06-15.09.2019). It can be seen that the amount of fresh water productivity during 12 June 2019 is greater than day 15 September 2019. The amount of productivity of fresh water during the 12 hours from 8 am to 20 pm, in 12 June 2019 from enhanced solar still found to be 2350 ml and from conventional solar still 900 ml, while in 15 September 2019 amount of fresh water produced from enhanced solar still is 1500 ml and from conventional solar still was 500 ml. The reason for these differences is that the productivity of solar stills is affected significantly by the intensity of solar radiation, increased the rate solar radiation intensity which reached to the solar still surfaces leads to an increased fresh water production and similar to those found in the literature [13]. Figure 4 shows that the intensity of solar radiation in 12 June 2019 is greater than in 15 September 2019. The other reason was wind speed, which effects on the Plexiglass cover temperature, higher wind speed led to increase the rate of heat transferred from the Plexiglass cover to the atmosphere, due to increase in coefficient heat transfer by convection. This in turn leads to increased evaporation, the amount of condensation and of freshwater production [14]. On the other hand, the improvement ratio in 15 September 2019 is greater than in 12 July 2019, the improvement ratio in 15 September 2019 found to be 200%, while in 12 June 2019 161%, that explanation is due to that the ambient air temperature after 12 noon in 15 September 2019 is greater than in 12 June 2019. The ambient air temperature represents one of the most influential factors on the performance and productivity of solar stills, high ambient air temperature leads to enhanced output [15].

The ambient temperature effects on the parameters within the solar stills, such as glass temperature, vapor temperature within the solar still, basin liner temperature and salt water temperature. Figure 5 illustrates that the temperature of the four parameters in 15 September 2019 almost afternoon was greater than in 12 June 2019. This leads to higher rate of solar radiation intensity which increase the surface temperature of the rotating cylinder and increase the evaporation rate and Plexiglass temperature, and Plexiglass temperature. This leads to reduced the temperature difference between the water surface within solar still and the inside Plexiglass temperature and reduced the condensation rate. However, when the relative humidity is relatively low and intensity of the solar radiation was appropriate and the ambient air temperature relatively high. This leads to increase the rate of fresh water production from SSS with RHD in compression with SSS without RHD.

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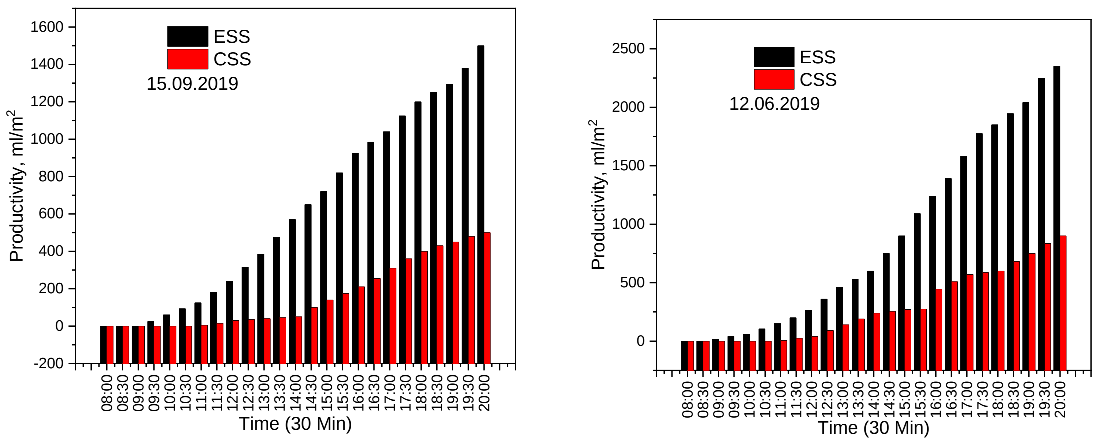

Figure 3. Relation between the time for each 30 minutes and fresh water production for both types of solar stills for two a perfect day 12.06-15.09.2019.

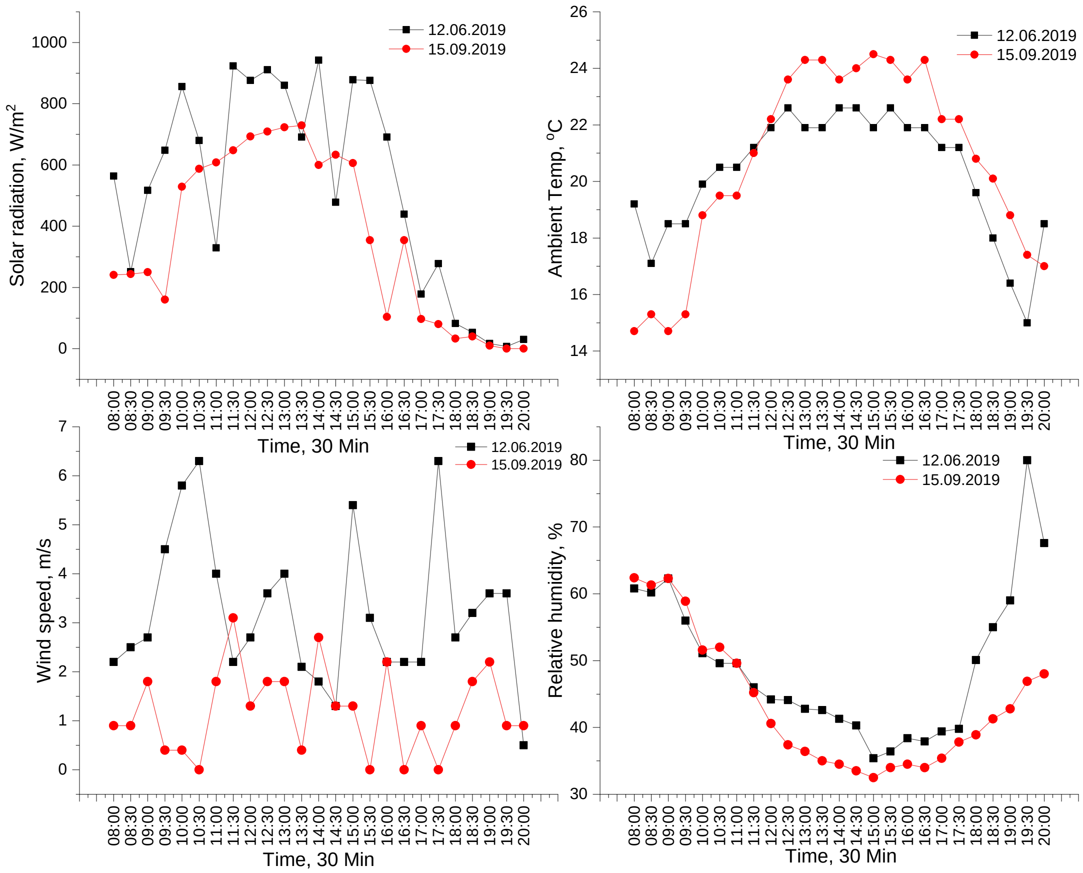

Figure 4. Relation between the time for each 30 minutes and solar radiation intensity, ambient temperature, wind speed and relative humidity for two perfect days 12.06-15.09.2019.

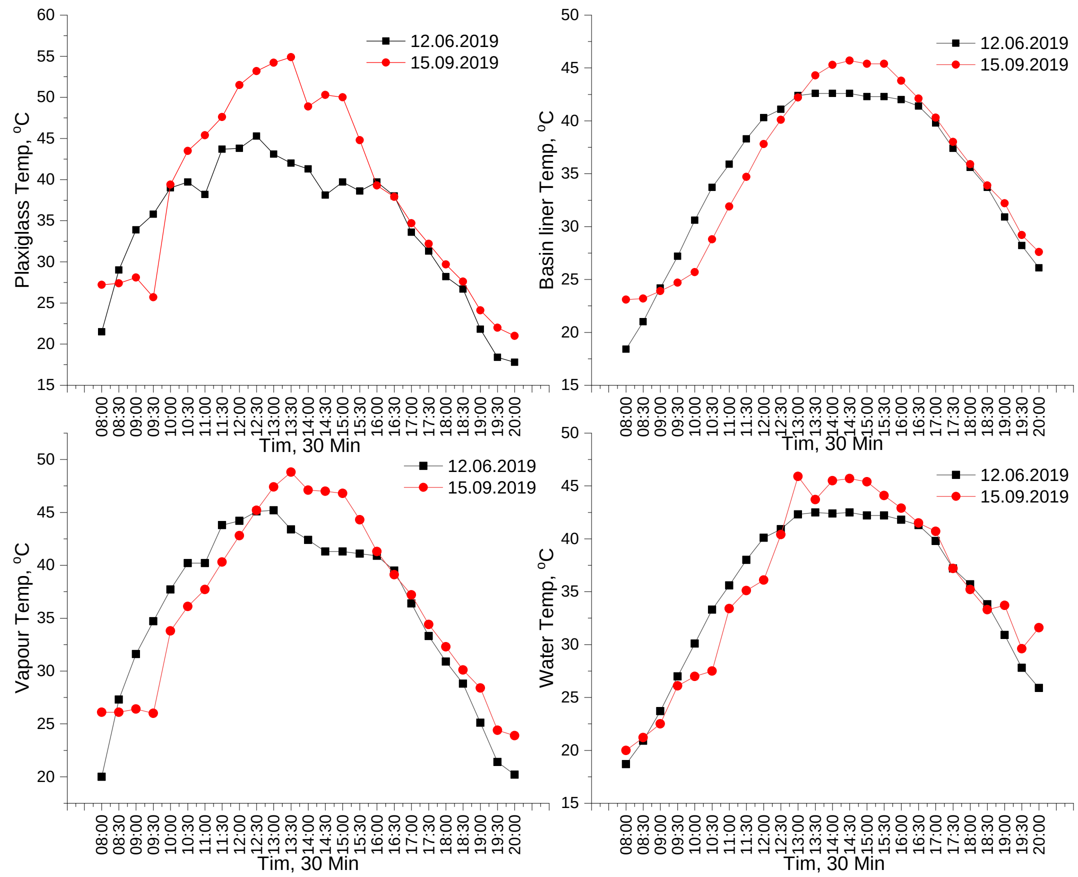

Figure 5. Relation between the time for each 30 minutes and solar radiation intensity, ambient temperature, wind speed and relative humidity for two a perfect day 12.06-15.09.2019.

4. Conclusion

From the results of the present study, the following conclusion has been addressed:

- Environmental conditions have noticeable impact on the daily production rate of the improved solar distillation; the highest rate of improvement ratio was 200% in 15 September 2019.
- Increasing the solar radiation intensity with low relative humidity leads to an increase in the productivity of solar still.
- With high intensity of solar radiation greater than 750 W/m^2, the rate of evaporation increased.
- The wind speed has played an important role to decrease the Plexiglass temperature.
- The process of condensation is occurring due to the temperature's differences between the water and glass cover (an increase of temperatures differences, that's lead to increase of condensate process). This difference is a result of the variation in the thermal heat capacities between both materials (Plexiglass and water).

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