Experimental Study of Solar Still Performance using Natural Energy Storage Materials

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ABSTRACT

Saline and polluted water can be purified using solar still method. Due to uneven solar irradiation the yield decreases, hence in the present study materials which can absorb solar irradiation and can retain it are used in solar still and their performance is studied. In the present study natural energy storage materials like pebbles, gravels and charcoal were used to store energy in the solar still. It was seen that there was an improvement in the performance of the solar still when compared to without energy storage materials. Further among pebbles, gravels and charcoal it was seen that charcoal had higher yield of 2250ml/m^2/day whereas for pebble and gravel yield were 1210 ml/m^2/day, 1620 ml/m^2/day.

KEYWORDS: *Energy storage materials, Sea water, Charcoal, Solar energy, Desalination, Solar still*

1.0 INTRODUCTION

Water plays a crucial role for all living organisms. Water is present in abundance in nature, nearly 71% of the earth surface is covered by water. Even though there is vast reservoir of water in the earth surface, the availability of fresh water for human consumption is scarce. Further water pollution of the existing fresh water is also a topic of concern, and lead to life threatening circumstances. Hence purification of water is necessary for drinking purpose. Giwa et al. (2017) suggested the various water purification method by solar still, it is a process which involves evaporation of contaminated water using sunlight to produce water vapor which is than condensed on a glass surface which drips down and collected to get pure water. Here the solar energy of sun is used to produce distilled water from the contaminated water. Solar energy is a renewable source of energy which is available free of cost. Manju et al. (2017) discussed about the contaminated or polluted water which is unfit for human consumption can be sea water which has high content of chloride ions, waste water are waters which is used and discarded after use and it can have both biological and chemical contaminants, waste water without fecal matter disposed from private and commercial sector are called grey water and waste water which contain fecal matter and deadly pathogens are called as black which are usually discharged from toilet.

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The solar energy of sun can be used from sun rise to sun set, solar irradiation gradually increase after sunrise and after that before sun set it gradually decreases. The solar energy can be absorbed and stored in the solar still by using certain natural energy storage materials such as pebbles, gravels and charcoal and the energy can be used while there is a fluctuation in the solar irradiation which helps the smooth functioning of solar still in cloudy days and extending the time of working hours of solar still after sunset. Garg (2019) discussed about the energy-powered membrane technology and analysis for low cost energy consumption with new development of bio-membrane. They conducted many experiments about the solar energy-powered membrane technologies with new design of bio-membrane to increase the production rate of pure water. Zarzo et al. (2018) discussed about the desalination and energy consumption in present method and the expectations for future. They also indicated the need of 92.5 million m^3 water per day for over 300 million people globally. Pouyfaucon et al. (2018) conducted many experiments on solar thermal powered desalination technologies for increasing the capacity of water production. They designed a new solar collector multi-effect distillation plant and improved the capacity by 72 m^3/day. They successfully installed 14 effective multi-effect distillation plants. Amy et al. (2017) analyzed desalination process using membrane for seawater and improved the productivity water. They conducted experiments on the design of membrane for development of economical desalination unit. Giwa et al. (2017) studied the various brine management methods involved in desalination processes. They suggested that the desalination technology processes are thermal processes where when solar energy is coupled with heat produced by electricity results in high production of water in low cost.

Shahzad et al. (2017) suggested that the world population and the varying water consumption pattern leads to increase demand of pure and unpolluted water. He suggested a strong interconnection between water, energy and desalination. Manju et al. (2017) suggested that in the year of 2025 there will be a water scarcity leading to no access to pure water and will effect nearly two-third of the population. There will be discrepaency in fresh water requirement and availability due to urbanization, population growth, climate change, increase in demand for domestic and industrial need etc. He suggested that the desalination process has the essentials to answer water scarcity issue in the future. Koleva et al. (2016) experimentally investigated various water treatment processes to increase the yield rate of pure and clean drinking water. They designed a desalination unit with optimized production rate. They suggested that the global pure water consumption will increase by two fold in every two decades. Bandi et al. (2016) suggested that the solar powered multi-stage flash uses solar energy to evaporate salt water at high pressure by passing it series of chambers with successive chambers at lower pressure compared to previous. When salt waters are passed in series of chambers with gradual decrease in pressure leads to increase in the vaporization of salt water. The middle east multistage flash thermal technology is more preferred and fossil fuels are also used as heating source. Similarly, Wang et al. (2016) also suggested the importance of pressure difference and increase vaporization due to it.

An attempt has been made in the present study to increase the production of pure water from salt water by using natural energy storage materials in solar still. Further the change in efficiency of solar still is compared for pebbles, gravels and charcoal.

2.0 MATERIALS AND METHODOLOGY

The single basin single glass cover passive type solar still is fabricated with black lime stone and the performance of the solar still is to be compared with different energy storage materials such as gravels, pebbles and charcoal. This methodology is carried out through the experimentation of the parameters such as solar radiation, energy storage value and solar still basin top glass cover inclination. These parameters enhanced the production rate of solar still. Ansys software is used to simulation of solar still optimization parameters.

2.1 Experimental set-up

The solar still basin is made up of black lime stone. The main reason for usage of black lime stone material for basin is to increase the absorption and storage of solar irradiation. The top of the basin is covered with 0.003 m thick white glass cover with 30˚ slope angle. The height of the lower side is 0.200 m and higher side is 0.400 m. Effective area of the black lime stone basin is 0.600 m × 0.450 m. The natural energy storage materials are placed inside the solar still basin. The quantity of each energy storage material is 500 grams and the volume of solar still basin water is 13.6 liters. The polluted sea water is filled at the inlet of the solar still and the pure water produced from the solar still is collected at the outlet end of basin. Figure 1 shows constructional view of the solar still which is made up of black lime stone for absorbing and storage more solar irradiation. Figure 2 shows the pebbles used in the experiment. The specific heat capacity of pebble is 0.775 KJ/kgK. Figure 3 shows the gravels used in the experiments and the specific heat capacity of gravel is 0.920 KJ/kgK. Figure 4 shows the charcoals used in the experiment and the specific heat capacity of charcoal is 1.015 kJ/kgK. In Table 1 the specific heat capacity of natural energy storage materials pebbles, gravels, charcoal and black limestone is mentioned.

Table 1. Specific heat capacity of natural energy storage materials

Sl.No	Energy Materials	Specific heat capacity (KJ/kg.K)
1	Pebbles	0.775
2	Gravels	0.920
3	Charcoal	1.015
4	Black lime stone	0.910

Figure 1. Constructional view of solar still

Figure 2. Pebbles

Figure 3. Gravels

Figure 4. Charcoals

2.2 Principle of Solar Still

Figure 5 shows the working principle of solar still. In this process, the solar irradiation is used to evaporate the salt water present in solar still, the water vapour condenses on the glass top cover and drip downwards and is collected at the outlet. The amount of salt water vapourized, condensed and collected at the outlet depends on specific heat capacity of the natural energy storage materials, intensity of solar radiation, angle at which the glass top is placed and the basin materials.

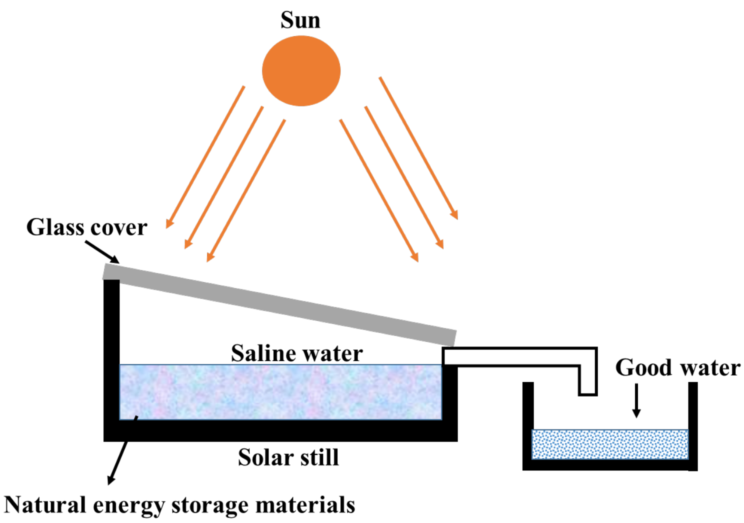

Figure 5. Principle of solar still

3.0 RESULTS AND DISCUSSION

Different natural energy storage materials i.e. gravels, charcoal and pebbles are used in the basin along with basin water to improve the heating capacity, radiation absorption capacity and enhance the evaporation rate. Table 2 contains day yield rate per hour of solar still for gravels, charcoal and pebbles.It shows that the hourly average values calculated from 9.00 am to 6.00 pm. The yield rate is less in morning time and gradually increased in the mid day and gradually decreased in evening time. The optimization result of the yield is in the mid day time (1.00 to 2.00 pm) is 380 ml for charcoal.

Table 3 contains the cumulative yield rate variation of solar still for gravels, charcoal and pebbles. It shows that the hourly average values calculated from 9.00 am to 6.00 pm. The cumulative yield rate is less in morning time and gradually increased in the mid day and gradually decreased in evening time. The cumulative result of the yield for pebbles, gravals and charcoal were 1210 ml, 1620 ml and 2250 ml.

Figure 6 shows that the graph between time and yield per every hour of solar still for gravels, charcoal and pebbles, for pebbles and gravels yield was 1210 ml and 1620 ml. Amoung the various energy materials, the charcoal material gives maximum cumulstive day yield rate of solar whereas pebbles give less day yield result of solar still. The charcoal matreial gives maximum day yield result than the rest of material. Figure 7 shows that the cumulative day yield rate of solar still for gravels, charcoal and pebbles. It can be clearly seen that the yield was more in all the cases when compared to no energy storage material that the yield was maximum in charcoal which was 2250 ml. Figure 8 shows the graph of comparative day yield rate per hour for various natural energy storage materials. The maximum solar still discharge rate of yield is 380 ml and the yield rate was more at 2.00 pm. Pressure variance of critical temperature controls chances and changing directions, normal pressure variance is listed in the Figure 9. This method results are shown the better pressure variance of Z- directions and constant velocity. Table 4 shows that the total day variation of solar radiation for various natural energy storage materials such as pebbles gravels, and charcoal. More radiation is required for pebbles and gravels are 6420 W/m^2 and 6390 W/m^2. But charcoal required the radiation value is 6350 W/m^2. Figure 10 shows that the graph between total solar radiation per day and absorbtiopn of energy materials in solar still, such as pebbles gravels and charcoal. More radiation is required for pebbles and gravels, but in low radiation, the charcoal gave maximum yield rate. Figure 11 shows that the day variation of wind speed from 9.00 am to 6.00 pm. The variation of wind speed for energy absorbing materials with respect to local time during the experimental days the wind speed is low at 2.00 to 3.00 pm and more in evening time. Ansys workbench 16.2 version is used to simulation of solar still optimization parameters such as pressure varience of Z co-ordinate in solar still.

Table 2. Contains day yield rate per hour of solar still for various natural energy storage materials

Time	No Energy Material (ml)	Pebbles (ml)	Gravels (ml)	Charcoal (ml)
9am	0	0	0	0
10am	10	50	90	130
11am	30	90	140	200
12am	50	140	190	260
1pm	90	180	240	320
2pm	130	240	290	380
3pm	90	210	250	340
4pm	60	150	190	270
5pm	30	100	140	210
6pm	10	60	90	140

Table 3. Cumulative yield rate of natural energy storage materials

Time	No Energy Material (ml)	Pebbles (ml)	Gravels (ml)	Charcoal (ml)
9am	0	0	0	0
10am	10	50	90	130
11am	40	140	230	330
12am	90	280	420	590
1pm	180	460	660	910
2pm	310	700	950	1290
3pm	400	910	1200	1630
4pm	460	1050	1390	1900
5pm	490	1150	1530	2110
6pm	500	1210	1620	2250

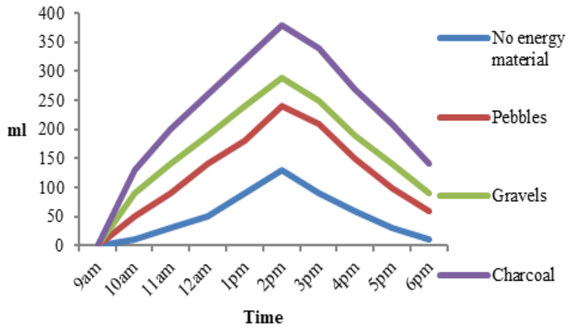

Figure 6. Day yield rate per hour

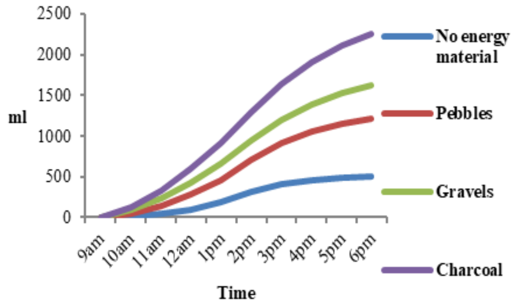

Figure 7. Cumulative day yield rate

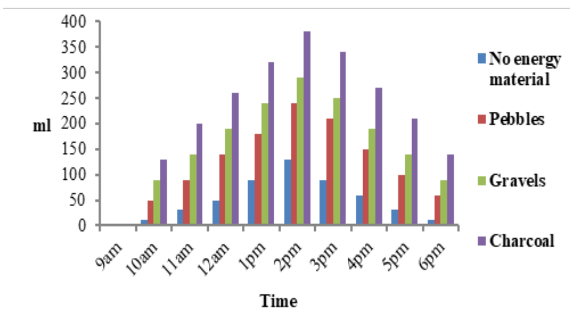

Figure 8 Comparative yield rate per hour

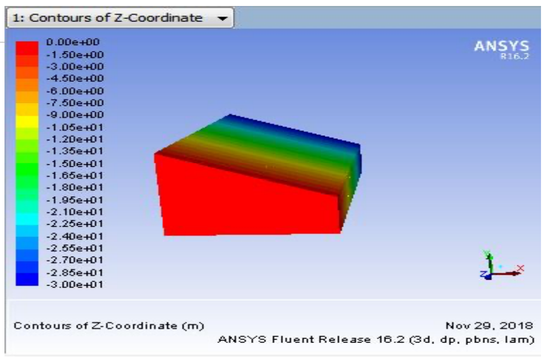

Figure 9 Pressure variance of Z co-ordinate of solar still.

Table 4. Total day solar radiation

Sl.No	Content	Radiation (W/m^2/ day)
1	No Energy Material	6480
2	Pebbles	6420
3	Gravels	6390
4	Charcoal	6350

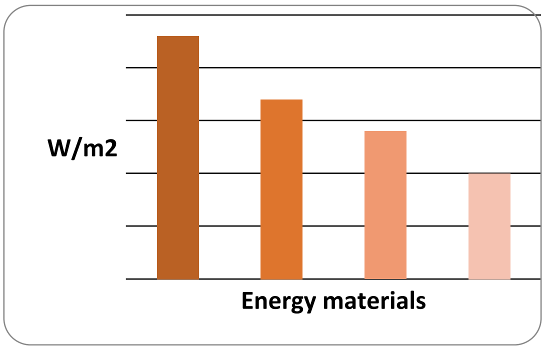

Figure 10. Solar radiation absorbtion of materials

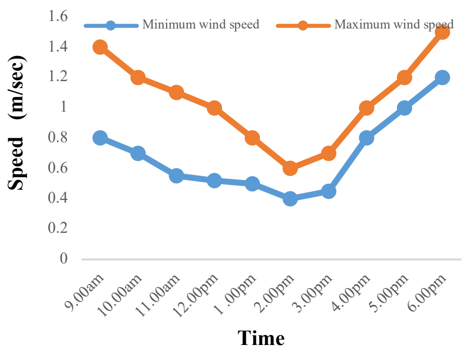

Figure 11. Day variation of wind speed

Figure 12 Lux meter

Figure 13. Anemometer

Figure 12 shows that the the lux meter and is used as a measure of the solar intensity. Lux is the SI unit of illumines and it is equal to one lumen per square metre (lm/m^2) and the corresponding radiometric unit, which measures irradiance, is the watt per square metre (W/m^2). Figure 13 shows that the anemometer is used to measure the atmospheric air circulation and its range is 0–15 m/s. So the ambient air velocity is measured by using anemometer. The anemometer readings are measured in every one hour. The measuring air velocity readings are in m/s.

5.0 CONCLUSION

In this paper, the solar still performance was studied with various natural energy storage materials for converting sea water into pure water. From the experimental results, solar still with the charcoal as energy storage material gave maximum amount of yield comparing to the rest of energy storage materials and the results showed that the charcoal is proved with the highest productivity due to its natural black colour and porosity. The bed of charcoal has higher solar absorption co efficient than saline or salt water bed.So more solar radiation is converted into thermal heat. The basin water raises in temperature quickly. The best energy storage material was found as charcoal material. Because it is having more solar absorption than the other energy storage materials Even after the sun set timing, the charcoal material release the stored heat to keep the continuous of evaporation. In that way also the system produces more distilled water. Among the materials pebbles, gravels and charcoal, it was seen that charcoal had higher yield of 2250ml/m^2/day where as for pebble and gravel yield were 1210 ml/m^2/day, 1620 ml/m^2/day. Thus charcoal bed enhances the production of distilled water and compared to still plain solar.

6.0 ACKNOWLEDGEMENT

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