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Performance Evaluation of a Solar Still for Salty Water Desalination

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Abstract
The need to provide clean drinking water for the riverine areas of Nigeria where the water is usually salty is the motivation for this work. A Solar still is a simple solar device used for converting salt /brackish water into potable water and the developing countries can employ this technology for provision of clean drinking water especially in areas where this is in short supply. A performance evaluation was carried out on a double sloped basin type still that was fabricated. The main parts of the still are, the basin, frame, glass cover and support structure. The still was tested using two different materials, aluminum painted black and black leather as the absorber. The Solar Still was tested by feeding it with 40 litres of salt water and the daily temperatures and distillated yield were recorded. It was observed that the yield obtained depended on the daily temperatures attained and the black painted aluminum absorber material produced higher yield compared with the leather material. The salinity test conducted on the distillate shows a value which makes it fit for drinking purposes and thus established the effectiveness of the Solar Still..

Keywords: solar still, distillate, solar energy, purification, desalination

INTRODUCTION

Clean drinking water is a basic human need. Many people, especially in developing countries, do not have access to clean drinking water. Water that is dirty or salty is undrinkable, and untreated water that looks clean is likely to have bacteria and organisms that cause sickness and disease. A solar still is a device that produces clean, drinkable water from dirty water using the energy from the sun (Appropedia, 2010). It usually consists of a shallow, water tight box with a clear glass or plastic top. The bottom of the box is usually painted black to absorb the sun's heat. The Solar Still is filled with non-potable water, for example, brackish water.

The sun's heat evaporates the water and the vapor condenses on the inner surface of the cover. The condensate runs into troughs from which it can be collected in storage containers. The Still cover is tilted to collect the greatest amount of solar energy. Glass-covered Solar Stills are much more rugged and trouble free and are able to withstand climatic and environmental conditions much better than plastic. There are several different types of solar stills (appropedia, 2010). The most basic is the "pit" type, which is most appropriate for emergency survival situations because it has a very low productivity. The "cone" type still looks like an inverted pit-type still. The basin, or box still is the most complex type. There are many different variations, but the two main categories of basin stills are single and double sloped. The basin, or box still is the most complex type. There are many different variations, but the two main categories of basin stills are single and double sloped. The double sloped basin still has two sloped pieces of glass rather than one.

The process of removing salt, other minerals or chemical compounds from impure water is called desalination. It has provided a source of portable water for some communities: (Horace, 1995). Since the water is pure and free of harmful bacteria, there is no fear of water-borne diseases commonly associated with water supplies in many developing countries. In some parts of the world where the major supply of water is the sea or ocean, solar distillation of salt water has proved to be economically feasible when compared to mechanical conversion of water: (Breslin, 2008). The present work presents the performance evaluation carried out on a fabricated solar still for salty water deslination in Warri-Nigeria. Warri town is on latitude 5^{o} 30N and longitude 5^{o} 41'E. The solar still is the double sloped basin type.

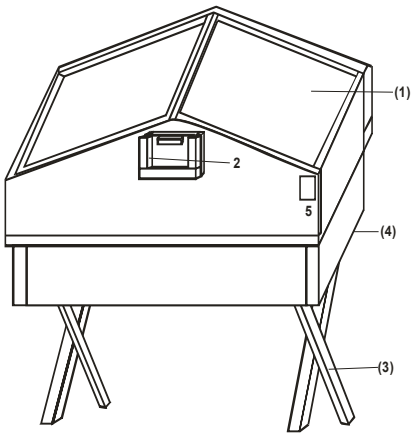
MATERIALS AND METHODS

Description of the solar still:

The Solar Still is a double sloped basin type still. The components are, the basin, frame, glass and the stand. It has an effective basin area of 95cm by 77cm and is made of wood. A glass cover with an inclination of 8.5^{o} to the horizontal is fixed to the top of the vertical walls of the Still with nails. It permits the passage of solar energy into the Still which heats up the water in the basin. The inclination of the glass cover is selected so as to let the water droplets slide down on the inner surface of the glass to the drainage channel made of plastic. Rtv silicon is used to seal any space between the glass and

wood to ensure that vapors are not lost to the atmosphere.

One of the end sections consist of a window where brackish water is fed into the Still. A thermometer is inserted through the window to determine the inner-glass and water temperatures respectively. On the two sides of the section, there is a hole which accommodates the channel for the collection of the distillate. The base of the basin is covered with black leather or aluminum painted black. This serves the purpose of absorbing solar energy and also to prevent leakage which may occur due to expansion. The stand which is attached to the base has cross limbs held firmly together with bolt and nut. Figure 1 shows the prototype of the solar still.



No	Item
1	glass
2	window
3	stand
4	basin
5	channel

Figure 1: Prototype of a solar still

Mode of operation and test procedure

Brackish water is fed into the Still through the top window on the side of the Still. The water occupies a portion of the basin. The Still is exposed to solar energy from (900 - 1700) hours and as the water is heated by the sun's heat, evaporation takes place. The vapour rises and condenses on the underside of the glass cover and the condensed water runs down into the u-shaped channel which is collected in the distillate trough.

Two different materials were used as an absorber. The first material, black leather, was used as test I. The second material is Aluminum which was painted black and was used for test II. A measuring cylinder (graduated) was used to measure the daily collection (distillate). A thermometer (10^o – 600^oC) was used at every hour to measure the outer and inner glass surface and water temperatures respectively. Some quantity of brackish water was collected and the salinity determined. After the distillation process, salinity of the distillate was determined. The titrimetric method was used. The procedure for this method is as follows:

(i) 10ml of the distilled water was taken and
(ii) 3 drops of potassium chromate as indicator was added.
(iii) It was titrated with silver nitrate and
(iv) the titer value was calculated after a color change was attained.

Experiments were performed on the Solar Stills during the months of March 2009 and April 2010, for seven days.

RESULTS AND DISCUSSION

By following the above test procedures using absorber – black leather and aluminum painted black, daily readings of 3rd – 9th March, 2009 and 12th – 19th April, 2010 were taken and recorded as shown in Tables 1 to 7 and 8 to 14. The results obtained from salinity test are shown in Table 15. A comparison of the distillate yield for the different materials used, are shown in Table 16.

Table 1: Readings of 3rd March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp ^oC	Temp ^oC	Temp ^oC	Output (ml)
1	900	33.0	38.0	32.0	
2	1000	37.0	39.0	35.0	
3	1100	48.0	51.0	40.0	
4	1200	51.0	52.0	39.0	
5	1300	54.0	53.0	41.0	
6	1400	56.0	52.0	41.0	
7	1500	55.0	52.5	40.0	
8	1600	51.0	48.0	37.5	
9	1700	49.0	46.0	36.5	565

Table 2: Readings of 4th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp ^oC	Temp ^oC	Temp ^oC	Output (ml)
1	900	30	32.5	32.0	
2	1000	30.0	32.5	32.0	
3	1100	35.0	34.0	33.0	
4	1200	42.0	41.0	37.0	
5	1300	49.0	48.0	44.0	
6	1400	54.0	52.0	41.0	
7	1500	56.0	53.0	41.0	
8	1600	49.0	45.0	33.0	
9	1700	47.0	43.0	31.0	448

Table 3: Readings of 5th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp ^oC	Temp ^oC	Temp ^oC	Output (ml)
1	900	30	29.5	28.0	
2	1000	35.0	36.0	35.0	
3	1100	44.0	43.0	37.0	
4	1200	52.0	51.0	38.0	
5	1300	56.0	54.5	42.0	
6	1400	56.0	55.0	41.0	
7	1500	58.0	54.0	40.0	
8	1600	55.0	52.0	37.0	
9	1700	48.0	46.0	35.0	610

Table 4: Readings of 6th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	31.0	34	34.0	
2	1000	38.0	38	36.0	
3	1100	44.0	43	37.0	
4	1200	46.5	45	38.0	
5	1300	45.0	43	34.5	
6	1400	50.0	49	39.0	
7	1500	55.0	52	37.0	
8	1600	55.0	51	37.0	
9	1700	51.0	47	33.0	490

Table 5: Readings of 7th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output(ml)
1	900	29.0	33.5	34.0	
2	1000	36.0	37.0	38.0	
3	1100	42.0	44.0	43.0	
4	1200	49.0	50.0	40.5	
5	1300	52.0	50.0	38.0	
6	1400	58.0	54.0	46.0	
7	1500	58.0	56.0	41.0	
8	1600	57.0	54.0	39.0	
9	1700	55.0	52.0	36.0	590

Table 6: Readings of 8th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	30.5	32.0	32.0	
2	1000	36.0	37.0	38.0	
3	1100	40.0	40.0	47.0	
4	1200	44.0	42.5	38.0	
5	1300	51.0	50.5	48.0	
6	1400	57.0	53.0	44.0	
7	1500	58.0	53.0	42.5	
8	1600	57.0	50.0	39.0	
9	1700	53.0	49.0	34.0	560

Table 7: Readings of 9th March, 2009

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	31.0	37.0	39.5	
2	1000	37.0	41.0	41.0	
3	1100	42.0	41.5	38.0	
4	1200	47.5	45.0	41.5	
5	1300	50.0	48.5	42.0	
6	1400	52.0	49.0	38.0	
7	1500	53.0	49.0	40.0	
8	1600	50.0	45.0	35.0	
9	1700	48.0	46.5	35.5	500

TEST II

Table 8: Readings of 12th April, 2010.

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	32	34	34	
2	1000	42	34	34	
3	1100	42	39	39	
4	1200	44	41	40	
5	1300	50	44	41	
6	1400	51	46	41	
7	1500	52	48	41	
8	1600	43	40	33	
9	1700	43	40	32	559

Table 9: Readings of 13th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	32	34	34	
2	1000	40	35	34	
3	1100	43	41	39	
4	1200	52	50	43	
5	1300	56	52	46	
6	1400	58	54	42	
7	1500	58	55	42	
8	1600	50	44	38	
9	1700	48	40	36	458

Table 10: Readings of 14th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	32	34	34	
2	1000	40	38	36	
3	1100	50	46	44	
4	1200	56	50	48	
5	1300	60	56	52	
6	1400	60	56	50	
7	1500	56	50	48	
8	1600	52	46	44	
9	1700	46	40	38	615

Table 11: Readings of 15th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	32	34	34	
2	1000	38	36	35	
3	1100	50	46	44	
4	1200	58	52	48	
5	1300	60	56	50	
6	1400	60	56	50	
7	1500	62	58.5	54	
8	1600	54	50	38	
9	1700	46	40	36	619

Table 12: Readings of 16th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	30	32	32	
2	1000	40	38	34	
3	1100	42	38	34	
4	1200	50	46	40	
5	1300	54	48	44	
6	1400	54	48	43	
7	1500	56	52	40	
8	1600	57	54	44	
9	1700	52	48	42	585

Table 13: Readings of 17th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	36	37.5	34	
2	1000	44	38.5	36	
3	1100	46	40	38	
4	1200	54	50	42	
5	1300	58	54	46	
6	1400	56	48	44	
7	1500	54	48	42	
8	1600	52	46	38	
9	1700	46	38	34	564

Table 14: Readings of 19th April, 2010

S/No	Time	Water	Inner glass	Outer glass	Distillate
	Hr	Temp °C	Temp °C	Temp °C	Output (ml)
1	900	36.5	34.5	34	
2	1000	44	40	38	
3	1100	50	48	44	
4	1200	60	54	50	
5	1300	62	58	52	
6	1400	60	56	50	
7	1500	60	56	54	
8	1600	54	50	44	
9	1700	50	44	42	622

Table 15: Result of salinity test

Parameters	Who's Max	Who's Max	Results	
	Accept Limit	Allowable Limit	After Dist.	Before Dist.
Salinity Mg /L	200	600	3.33	626.66

Table 16: A comparison of distillate yield for the two materials

Day	Yield (ml)	
	Black leather	Aluminum painted black
1	565	559
2	448	458
3	610	615
4	490	619
5	590	580
6	560	564
7	500	622

It is observed generally from the table of values that the peak temperatures is usually between the hours of (1300 – 1600). The water gained enough heat energy and the water temperature rises above the inner and outer glass temperatures. The tables of values show that the distillate yield was higher for those days having higher temperature. The distillate yield ranges from 400 to 622 mililitres (ml) over the 8-hour period. According to Murugavel et al (2008), production capacity for simple type still are usually low, a number of methods such as the use of additional condensers or use of some materials along with the saline water are however available for improving the effectiveness of stills.

The Still operation with painted aluminum absorber shows a better performance due to its higher water and inner glass temperatures which resulted in higher distillate yield compared to still operation with black leather absorber material. Thus the type of absorber material employed has an effect on the solar still performance, this is also confirmed by the work of Murugavel et.al. (2008).

Table 15, shows the salinity test result. The salinity of the water was reduced from 626.33 to 3.33 mg/l. The salinity has been brought within the maximum acceptable limit of World Health Organisation (WHO) standard of 200mg/l. This means the water is fit for drinking purpose.

CONCLUSION

The performance evaluation carried out on the fabricated Solar Still has shown that it can be used for the desalinization of salty water. The results have shown that a high enough temperature was attained which produced evaporation and the distillate produced was confirmed fit for drinking by the salinity test conducted. The Still has a capacity of 80465cm^3 and produces an average yield of 0.51 litre per day. The daily temperature and type of absorber materials are factors that can influence the distillate yield. The cost of production for the still is thirty-three thousand, two hundred and fifty naira. The low cost of production is as a result of the materials employed in the fabrication.

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