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Solar distillation; design, fabrication and characterization of a double sloped solar still for household use along the Kenya coast

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Abstract: In an attempt to find sustainable solutions, a low cost double sloped solar still is designed, fabricated and characterized based on Kenyan coast climatic conditions using locally available materials. Solar radiation is free, clean and available. Solar stills are not available in Kenyan local market and if imported they are not designed for similar climatic conditions and could also be expensive. Double slope solar still uses solar energy and the principle of evaporation and condensation to produce distilled water. The fabricated solar still had a basin area of $1m^2$ and glass cover inclined at 15^0. Materials used were block board and normal window glass. Ambient temperatures, solar irradiation, relative humidity and water output were recorded hourly and analyzed using Excel to evaluate the efficiency. Linear correlation and regression with metrological data were used to determine characteristics of the still. The fabricated double solar still is able to produce 1.652 liters per day per square meter during the period which the study was conducted. The still was found to be able to sustain clean and safe drinking water to an individual with a fabrication cost of Kshs 9,350 and payback period of six months. The still is therefore recommended for use to the local household, county government and other willing investors.

Keywords: Distillate, double slope solar still, solar irradiation, water desalination, water quality, payback period, efficiency

Introduction

All desalination methods require fossil fuel or electrical energy but solar distillation is one of many processes that can be used to produce fresh water by using the heat of the sun directly in a simple equipment to purify water. The equipment, is commonly called a solar still (Tiwari and Tiwari, 2007).Solar desalination could be one of the most successful applications of solar energy in most of the hot climate countries having limited resources of fresh water(Argaw, 2001).Coastal region are hot and humid and in constant demand of fresh water. Brackish water and Sea water desalination has been considered as a long-term freshwater source. It is considered as a viable solution to drinking water all over the world and Kilifi County where this study was based is not an exception.

Kilifi County has encountered persistent water problems due to many factors like rapid population growth and poor maintenance of existing water supply networks. Although the area is geologically rich in groundwater which is often seen as an option, exploitation is limited due to salinity because of seawater intrusion (Musingi *et al.*, 1999). Ground water exploitation is also curtailed by pollution from numerous pit latrines and septic tanks in the towns. In fact it has been revealed that more than 50% of all the diseases reported in the county are associated with lack of access to clean or good quality water and inadequate wastewater management (Munga, 2002).

Kilifi has an outstanding solar energy potential which is always maximum during the hot season when freshwater demand is high hence using solar energy to solve water scarcity is rather an obvious approach. Solar energy is clean, unlimited and very economic source of energy available to residents free of charge. Neither is sea water scarce in Kilifi due to its proximity to the Indian Ocean nor brackish water from boreholes and wells due to high water table levels hence salt water intrusion. It is worth noting that the new excise duty act, number 23 of 2015 which came to effect 1st December 2015 (www.kenyalaw.org) increased the price of water by Kshs 10 per liter.

Although, setting up a county desalination plant is the best solution to water crisis, it is a capital intensive and it takes time to construct. The persistent water problems, national grid power blackout in Kilifi County calls for the residents to take care of their water needs at household level and stop relying on water service providers who are unreliable. The present study suggests that an individual permanent solution to water shortages in Kilifi is to invest in solar still desalination which is environmentally conducive and cost efficient.

Other cities and towns have addressed this water problems using solar stills eg Baghdad, California and Faryab in Afghanistan (Kolstand *et al*,, 2011). In Baghdad for example, three solar stills were tested. All had black basins, and two of the stills had additionally jute wicks and in Faryab three solar still types namely single slope ,double chamber ,double sloped solar still and wick type solar still were tested and evaluated(Kolstand *et al*,, 2011). The solar stills were found to be an efficient and promising solution to water shortages (Al-Karaghouli *et al.*, 1995).

Theory

The stills operates by principles of evaporation and condensation and are classified into two groups; Passive and active solar stills, (Fath, 1998).This basic principle is simple and replicates the natural process of water purification (Badran, 2007). Evaporation of water requires energy. The sun, through direct, diffuse and reflected radiation, supplies this energy to the solar still. A solar still is an air tight basin that contains saline or contaminated water (i.e. feed water). Usually the basin of the still is filled with brackish or sea water, the incident solar radiation is transmitted through the glass cover and is absorbed by a black surface (basin).

From a radiation point of view the following happens inside the distiller unit: the part of the solar radiation that is not reflected nor absorbed by the cover is transmitted inside the solar still, where it is furthered reflected and absorbed by the water mass. The amount of solar radiation that is absorbed is a function of the absorptivity and depth of the water. The remaining energy eventually reaches the blackened basin liner, where it is mostly absorbed and converted into thermal energy. Some of this energy might be lost due to poor insulation of the sides and bottom (Tiwari and Singh, 2004). At this stage, the water heats up, resulting in an increase of the temperature difference between the cover and the water itself. Heat transfer takes place as radiation, convection and evaporation from the water surface to the inner part of the cover. The evaporated water condenses and releases latent heat. (Tiwari and Singh, 2004).

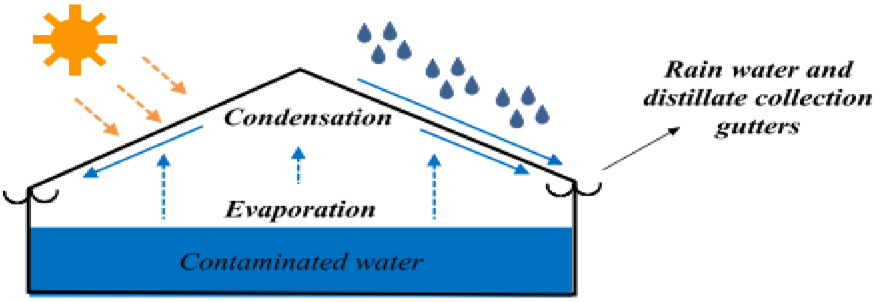

Figure 1: Passive solar still, as it operates solely on sun's radiation *(*Murugavel *et al.*, 2008*).*

To maximize incoming radiation, the inclination of the glass and latitude should be the same. This will give maximum received radiation in a whole year. In the summer period, the declination angle of the sun is at its highest, due to the tilt of the earth on its axis of rotation , thereby, having a lower inclination of the glass will increase incoming radiation to the still in the summer period (Al-Hinai *et al.*, 2002). As the water is heated, the bonds that are keeping the water molecules together breaks, making it evaporate. The vapor transfers from the basin, towards the cooling glass by convection and evaporation and condense to water. The condensed water (i.e. the distillate) trickles down the cover and is collected in an interior trough and then stored in a separate basin (Al-Hayek and Badran, 2004; Tiwari *et al.*, 2003).As the vapor condense it releases latent heat (Tripathi *et al.*, 2004).The total amount of energy required to change the water into vapour, is termed as the latent heat of vaporisation (L) and is calculated as (Arnell, 2002):

$$L = 2.501 - 0.0002361\,T\ [\mathrm{MJ\ kg^{-1}}] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 1$$

As seen in the equation, the energy required is dependent on temperature. The air above the water surface has to be unsaturated, for the evaporation to occur. There will be no evaporation if the air is saturated. The vapor pressure deficit (VPD) refers to the amount of moisture in the air, and how much moisture the air can hold when it is saturated. This value increase with temperature, and when exceeded, the dewing point is reached. For open water surfaces, the evaporation rate increases with the speed of the wind, there by leading the saturated air away, and bringing new unsaturated air to the surface. Together, the humidity and turbidity controls how the water vapor can diffuse into the surrounding (Arnell, 2002).

The salinity of the water also affects the evaporation rate. As the salinity increase, the evaporation rate decrease, because of the salt occupying space in the water, makes fewer molecules available for evaporation. This is why saline water has a higher saturation vapour pressure than fresh water (Arnell, 2002). Ward *et al*, 2000, however found this effect to be small, about 2–3% lower in evaporation rate for saline water over fresh water. Akash *et al.*, 2000 found that increasing the salinity percentage by 10 to 75 %, gave a decrease in output by 1.5 liters/day.

It is important that the still is airtight, due to heat loss to the ambient air. The outcome of a still therefore depends on both weather conditions and the design of the still. Weather conditions such as solar radiation, temperature and wind velocity are important factors that affect the outcome (Murugavel *et al.*, 2008). Radiation, and how it is distributed through the day, is the most important parameter to increase the yield of a solar still (Ray *et al.*, 2011).To estimate the output of a solar still, the following approximation can be used (Twidell and Weir, 2006; Badran and Abu-Khader, 2007):

$$Q = \frac{E * G * A}{L} \quad \text{………..…………………………. 2}$$

Where E = effectivity, L = Latent heat, A = area of still, G= daily/annual global horizontal solar radiation (MJ/m^2), and Q is daily output.

Equation (2) can be used both prior and post experiments, to predict outcome. A solar still normally has an efficiency ranging between 30 – 60 %, depending on materials and design (www.engineeringforchange.org). The efficiency of the still can be calculated after the experiments, but some assumptions can be made to get a prediction on the daily output of the still.

The productivity of a solar still is affected by ambient conditions (temperature, the insulation, and the velocity of the wind),operating conditions (depth of the water, the orientation of the still and the inlet temperature of the water) and design conditions (material selection for the still and cover, slope of the cover, gap distance and the numbers of covers used)

The objectives of this study was to design, fabricate and characterize a cost efficient double slope solar still using locally available materials in Kilifi County for small scale household use.

Materials and Methods

The study was carried out in Kilifi County which lies between latitude 2° 20’ and 4° 0’ South of the Equator and between longitude 39° 05’ and 40° 14’ East of the Greenwich Meridian, (SOK, 2012). The County is located in Kenya’s Coast region and borders Kwale County to the south west, Taita Taveta County to the west, Tana River County to the north, Mombasa County to the south and Indian Ocean to the east. It covers an area of 12,609.7 km^2. Kilifi town is the County headquarters and data was collected at Mtwapa agro-metrological station.

Designed Double slope solar still

The fabricated solar still consist of a basin made of block board which is painted black with an absorbing plate made of damp proof polythene paper. The block board consisted of channels attached to it and a tap to drain the concentrate brine after desalination using solar energy. The double slope solar still has a glass cover which is made of ordinary window glass of 4mm thickness.

In the design of the double slope solar still latitude was considered. Latitude is one of the factors that determine whether single or double slope still should be used. At latitudes higher than 20°, single slope stills with equator facing cover are recommended (Murugavel *et al.*, 2008). For the study area, which is located at latitude of 4°, double sloped solar can be successfully used. When the cover is placed with an inclination equal to the latitude angle, it will receive the sun rays close to normal throughout the year (Kabeel and El-Agouz, 2011; Khalifa, 2010). In this way, maximum interception is achieved. However, fundamental in the design is that the distillate condenses on the top cover as a film rather than as droplets. Droplets might otherwise drop back into the feed water and represent a loss of output. To prevent this from happening, the cover should be set at an angle of 10º .This has been observed experimentally by various investigators that the minimum inclination of the glass cover should be at least 10^0, to avoid the drop back of the condensate (Meukam *et al.*, 2004). However, Samee *et al.*, 2007, found 15 degrees as the best cover inclination. This may be due to several reasons such as the area allocated to condensing will be increased, so the area of the glass (condenser) will be a larger, which allows a better exchange of heat between the cover and the ambient air, thus; the difference between the water temperature and the glass temperature will be increased so that the condensation increases. In addition, the condensed drops on the inner surface of the glass are going to drain channel without falling at the basin again, because of higher gradient of the glass inner surface. In this experiment the design angle of inclination was 15 degree. This catered for latitude, giving maximum sun radiation absorption, avoiding the droplets to fall back and allows easier cleaning of the sloped surface.

The performance of a still is considerably affected by the depth of the water in the still. When the level of the water in the still is low, it has a lower thermal capacity and this increases rate of increase of the water temperature which directly results in higher outputs. Therefore the lower the water levels the higher the output. When there is low solar energy available in the earlier times of the day, water depth becomes important as you need to heat water quickly to produce fresh water. Solar stills with a water depth of 0.02m resulted to have the highest annual yield (Kabeel and ElAgouz, 2011; Tiwari and Tiwari, 2007; Nafey et al., 2000). Brackish water depth used for study was 0.02m which allowed easier evaporation

The preferred material for the top cover is glass with a thickness of 3 mm (Kabeel and El-Agouz, 2011). Glass has a higher solar transmittance and a longer lifetime compared to plastic, which is advised to be used for the short-term use only (Murugavel *et al.*, 2008). At the same time, glass is more expensive and fragile. Glass of 4mm thickness was used as cover. This was hard enough to avoid breakage when lifting the glass cover.

A glass cover that is no more than 5 to 7cm from the water surface will allow the still to operate efficiency. Conversely, as glass-to-water distance increases, heat loss due to convection becomes greater, causing the still's efficiency to drop. Some important stills have been built following the low slope design concept for the glass cover; yet using a short, steeply sloping piece of the glass at the rear (Connor, 1980).The distance of glass cover from water surface was set as 9cm.

Capture of solar energy is also affected by the ratio of the length to width of the still base (R). Effective insolation increased with R but the increase was insignificant for values of R>2.0 for both the double sloped solar still and single sloped solar still at a low latitude (Madhlopa, and Clarke., 2011). Aspect ratio R was greater than 2

Various approaches for increasing the basin absorptivity have been tested and found effective in increasing the daily yield of a solar still. These include the use of charcoal (Naim; *et al.,2003)*, black, and violet dyes, which were found to be more effective than other dyes (Valsaraj, *2003* .Polythene paper that is used as damp proof In construction of houses foundation was tested. The absorbing materials and the basin were painted black

The rate of evaporation of water in the solar still is proportional to the surface area of absorption of water (Velmurugan *et al.,* 2008).The productivity increases with the increase in the exposure area of the water. The inner surface of the basin is usually blackened to increase the efficiency of the system by absorbing more of the incident solar radiation (Tiwari *et al.,* 2003).The absorbing area was length of 1500mm by 790mm width and was painted black

The stills basin is a wooden box made of block board which is a good insulator, with dimensions of approximate 1.5m long and 0.76 m width height of 150mm. The total height of the still was 244 mm, including the glass cover. The frame of the box is glued with silicon several times from inside to prevent leakage. The bottom and sides of the basin was polished and painted black. The glass cover was double sloped and 4 mm thickness with an inclination of 15°.

The condensed water is collected with the help of a plastic channel which is installed underneath the lower side of the glass. It is used to collect the fresh water into the channel and is connected to an external storage bottle with a plastic pipe/hose pipe. Vapor leakage was minimized by use of a sealant (silicone).

Experiment and data collection

The following parameters were measured in order to characterize the double sloped solar still: Intensity of solar energy, the output of a solar still, solar radiation, sky temperature, wind velocity ,ambient temperature and time of the year. The study uses experiment to collect data and reviewing of existing secondary data. Pyrometer, Thermometer, graduated flask stop watch and a clock are some of the research instruments used. Gunn- Bellani Radiation Integrator as a pyranometer was used to measure solar irradiance. Accuracies of the instruments used are shown in the table1

Table 1: Accuracies of the instruments

Instrument	accuracy	Range	% error
Thermometer	$\pm$ 1^{o}C	0-100 ^{o}C	0.25
Measuring jar(1000ml)	$\pm$ 10ml	0-1000ml	10
Anemometer	$\pm$ 1m/s	0-15m/s	10
Measuring jar(100ml)	$\pm$ 1ml	0-100ml	1.00
Gunn- Bellani radiation integrator(MJ/m^2/day	$\pm$ 20 W/m^2	0-25000W/m^2	0.5

The study was conducted for four weeks with data collection done during the day (Hourly measurements of radiation, water output and temperatures were recorded between 08:00 am and 4:00 pm, and between 4:00 pm to 8.00 am output of water were measured in total at 08:00 am). The solar still was facing North-South direction and was filled with salty water up to a level of 20 mm. Microsoft Excel as a statistical tools and software was used to analyze statistically the data collected i.e linear regression and correlation was used which gave various properties of solar stills. For example linear regression model was developed to estimate expected output (response) when ambient temperature increased with 1˚C in the double slope solar stills. The data obtained was used to develop a linear correlation which can be used to get the output considering the data obtained from the metrological departments that are near Kilifi County.

Results and discussion

The data was gathered from 19.09.2016 to 19.10.2016 under the local weather conditions of Kilifi County. The double slope solar stills was refilled with water through the refilling hole 4.00 pm, up to a level of 20 mm. Output during 4:00 pm to 08.00 am was measured in total at 08:00 am. Between 08:00 am and 4:00 pm hourly measurements was registered. The solar still was facing North-South direction orientation (figure 2).

Figure 2: Double slope solar still in north south orientation

Water output (Yield) from the double slope solar still

The daily output of a solar still depends on weather conditions and the amount of solar energy available. The fabricated double solar still is able to produce 1.652 liters per day per square meter during the period which the study was conducted (September and October 2016).An extract of the data on 21st September, 2016 is shown table 2.

Table 2: Typical data collected on 21st September 2016

Time	cumulative solar sill outputs(ml)	still output (ml)	Cumulative solar sill outputs (ml)	solar irradiation(MJ/m^2)	cumulative solar irradiation (MJ/m^2)	dry bulb temperature	wind velocity(m/s)	relative humidity	weather-sky	Rainfall (mm)
8.00	25.50	318.75	318.75	8.94	8.94	26.3	4	66	sunny	nil
9.00	0.00	0	318.75	8.86	17.8	27.5	8	60	sunny	nil
10.00	1.20	15	333.75	11.43	29.23	28	6	59	sunny	nil
11.00	4.30	53.75	387.5	12.02	41.25	28	8	60	sunny	nil

12.00	9.90	123.75	511.25	11.21	52.46	28.6	3	59	sunny	nil
13.00	17.60	220	731.25	12.5	64.96	28.7	6	56	sunny	nil
14.00	17.30	216.25	947.5	11.9	76.86	29	10	55	sunny	nil
15.00	15.00	187.5	1135	10.59	87.45	27.8	6	62	sunny	nil
16.00	10.50	131.25	1266.25	9.59	97.04	27.8	6	62	sunny	nil

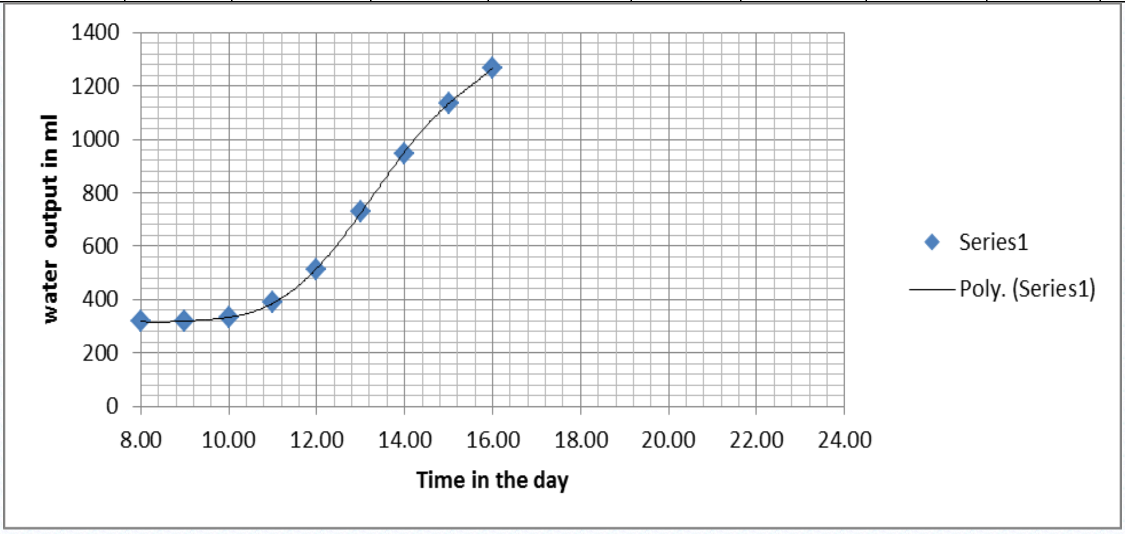

Figure 3: Cumulative Solar still output in millimeters versus time of the day

The data collected was for 21st September 2016 and shows cumulative solar still output in mm versus time. From the graph it is evident that volume increase from 8am to 4pm.

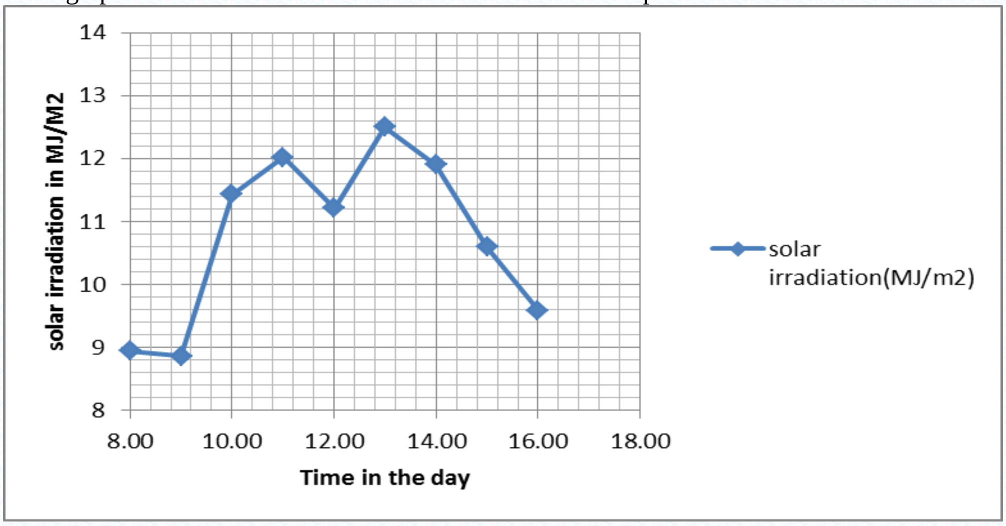

Figure 4: Solar irradiation versus time of the day

For data collected on 21st September 2016 (whole day sunny) it is evident that the graph exhibits the same type of curve for all the days with increase from 8am to maximum solar irradiation at the 1pm and decrease of solar irradiation from midday to 4pm .

Correlation and regression analysis

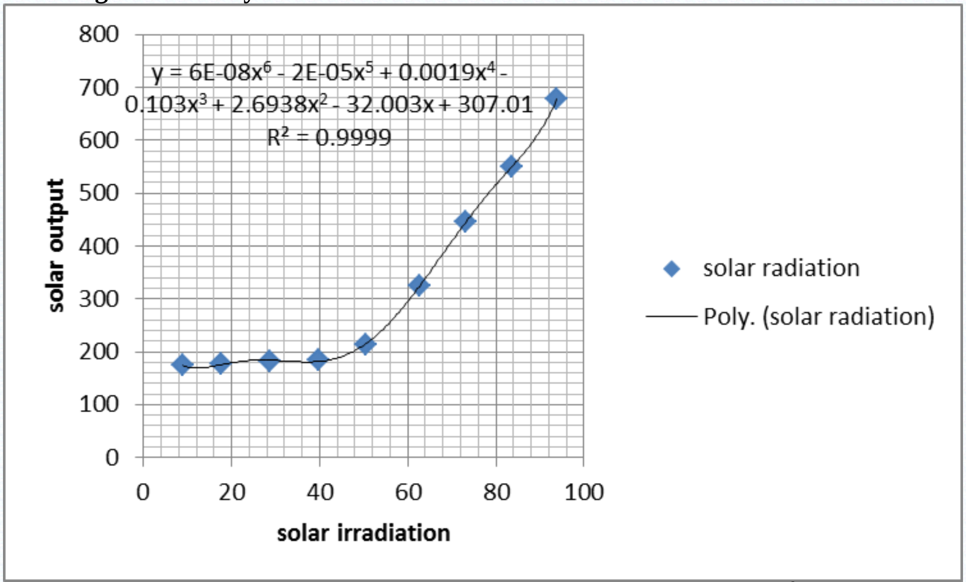

Figure 5: Solar still output versus solar irradiation for data collected on 27th September 2016

Table 3 gives the water output ,efficiency and correlation between output and solar radiation for various days.

Table 3: Correlation between water output and solar irradiation, efficiency and weather conditions

Date	Water output in milliliters (Q)	Efficiency (E) %	Correlation Rsq (%)	Weather
19th September	1072	13.51	99.94	Cloudy and sunny
20th September	726	9.15	99.96	Cloudy and sunny
21st September	1266	15.95	94.58	Whole day sunny
22nd September	771	9.72	99.82	Cloudy and sunny
23rd September	1652	20.82	89.98	Whole day sunny
24th September	958	12.07	86.38	Cloudy and sunny
25th September	998	12.58	96.53	Cloudy and sunny
26th September	635	8.00	99.82	Cloudy and sunny
27th September	504	6.35	99.99	Cloudy and sunny
28th September	1003	12.64	99.99	Whole day sunny
29th September	1008	12.70	99.51	Cloudy and sunny
30th September	212	2.67	99.01	Cloudy and sunny
1st October	884	11.14	97.47	Cloudy and sunny
2nd October	805	10.14	98.34	Cloudy and sunny
3rd October	7725	97.34	99.93	Rainy and sunny
4th October	938	11.82	99.93	Cloudy and sunny
5th October	517	6.51	99.89	Cloudy and sunny
6th October	948	11.95	99.54	Cloudy and sunny
7th October	210	2.65	99.03	Cloudy and sunny
8th October	588	7.41	96.21	Cloudy and sunny
9th October	228	2.87	96.5	Whole day rainy

From the table it is evident that there is a strong correlation between solar still output and solar irradiation and the equation y= $0.103x^3+2.6938x^2-32.003x+307.05$ (Valid during the day) where Rsq is 99.9% can be used to approximate solar still output where cumulative radiation is known. This cumulative solar irradiation is available in metrological stations all over the country and various counties.

An increase in correlation is found when excluding rainy days, (23rd and 24th September, 2016 and 3rd October 2016) with value of R square greater than 90%. An increase in output is due to rainy periods, where water droplets entered the distillation channel via small gaps in-between channel and glass cover, contributing to a lower correlation with solar irradiation (3rd October 2016). Double slope solar still water output and solar irradiation are correlated, which is to be expected, as evaporation rate increases with an increase in amount of solar energy available. Cloud cover also affect the availability of solar irradiation thus to greater extent affects the output and correlations.

During the first days of testing the output gave off a light smell and taste. This was reduced during the experiment. It is assumed that the taste and smell is due to off-gassing from the paint, glue and silicone. However, exposing the basin in the sun for some period of time, without attaching the glass cover, will probably decrease this problem, by having the paint off-gas to the surroundings before making the still airtight.

Occasionally drops backs were observed during the day, usually in context with change in weather, when the ambient temperature decreased or the wind increased, which again increased the condensation resulting in drop backs and lower outputs.

Efficiency

The efficiency is calculated for the day by taking the annual global horizontal radiation set to be 5.5 kWh/m^2/day (19.8 MJ/m^2/day), area 1 m^2 and latent heat of evaporation is 2.494MJ/kg.The total amount of energy required to change the water into vapour, latent heat of vaporisation (L) is calculated using equation (1) and the efficiency using equation (2) Where T is dry bulb temperature in degree Celsius which is taken as Mean temperature in a day (21st September, 2016 mean temperatures is 27.97^{o}C)

For 21st September, 2016;

L=2.494MJ/kg *and E*=15.95%

Table 4 shows mean dry bulb temperature ,water output ,efficiency and weather condition during the day the data was collected

Table 4: Mean dry bulb temperature, double slope solar still output, efficiency and weather conditions

Date 2016	Mean dry bulb temperature	Water output in milliliters (Q)	Efficiency (E) %	Weather
19th September	27.56	1072	15.83	Cloudy and sunny
20th September	26.78	726	9.15	Cloudy and sunny
21st September	27.97	1266	15.96	Whole day sunny
22nd September	27.71	771	9.72	Cloudy and sunny
23rd September	27.44	1652	20.82	Whole day sunny
24th September	27.9	958	12.07	Cloudy and sunny
25th September	27.83	998	12.58	Cloudy and sunny
26th September	27.9	635	12.78	Cloudy and sunny
27th September	28.07	504	8.54	Cloudy and sunny
28th September	26.08	1003	12.64	Whole day sunny
29th September	27.8	1008	13.71	Cloudy and sunny
30th September	27.74	212	2.67	Cloudy and sunny
1st October	28.28	884	11.14	Cloudy and sunny
2nd October	27.7	805	10.14	Cloudy and sunny
3rd October	28.07	7725	9.73	Rainy and sunny
4th October	28.7	938	11.82	Cloudy and sunny
5th October	28.46	517	6.51	Cloudy and sunny
6th October	28.47	948	11.95	Cloudy and sunny
7th October	28.24	210	2.65	Cloudy and sunny
8th October	28.96	588	7.41	Cloudy and sunny
9th October	27.98	228	2.87	Whole day rainy

The designed Double sloped solar still has efficiency that range between 12 % and 20 % for a whole day sunny and below 12% if cloudy. On 19th of September the weather was cloudy and rainy with occasionally sun gaps, and is therefore it is receiving reduced amount of radiation. Clouds also reduce amount of solar irradiation reaching the solar still. On 9th October the whole day was rainy .It is also evident that at average temperature of 28^{o}C and the whole day is sunny the double slope solar still has high efficiency and high production with highest production on 23rd September 2016 .On 3rd October the production is high due to presence of rainy water that trickled to collection point.

Cost estimations

When choosing materials for the solar stills, the availability and price has been considered. Block board, silicone, glue PVC pipes, garden hose, Paint, wood, polythene and glass were all easy to obtain in Kilifi County. An overview over material cost and total cost for the double slope solar still is tabulated in table 5

Table 5: material cost estimates

Sno:	Material	KSHs	USD$
1	Block board	3000	29.13
2	Labor costs-carpenter	2000	19.42
3	Damp proof Polythene paper (100mm width ,3m length and 0.7mm thickness)	500	4.85
4	Ordinary Glass 4mm thickness	3000	29.13
5	Paint 2litres	500	4.85
6	Collecting jar	100	0.97
7	Glue and silicone	150	1.46
8	Plastic,distillation channel/garden hose	80	0.78
Total		**9350**	**90.78**

1 $ usd =ksh 103(as at 19th, January2017 Central Bank of Kenya)

For cost effectiveness analysis, no consideration was made for certain costs such as Packaging and transport cost to the site. Other costs such as that of raw water and concentrated salt disposal are not included (assumed to be zero). The total cost is 90.78$ USD and the cost could be lower when produced in large quantities for commercial purpose.

Calculation of simple payback Period

Daily distilled water production per unit area (mean) = 0.962 L/m^2/day
Cost of distilled water in Kenyan market = kshs 50/L
Saving on distilled water produced everyday (gain) = 0.962 x 50 = Kshs 48.1/ day
Initial cost of present still = Kshs 9350/ m^2
So pay-back period of still is = 195days =0.5years

Conclusions

The daily output of a solar still depends on climatic, weather conditions and the amount of solar energy available. The fabricated double solar still is able to produce 1.652 liters per day per square meter during the period which the study was conducted (September and October 2016).Double slope solar still output increase from 8am to 4pm as radiation, temperature and wind velocity increases. There is a strong correlation between double slope solar still output and solar irradiation and the equation y= $0.103x^3+2.6938x^2-32.003x+307.05$ *(valid during the day)* where Rsq is 99.9% can be used to approximate solar still output where cumulative radiation is known. This cumulative solar irradiation is available in metrological stations all over the country and various counties. The double slope still has an efficiency that range between 12 % and 20 % for a whole day sunny and below 12% if cloudy.

The total cost of the double solar still is 90.78 USD and the cost could be lower when produced in large quantities for commercial purpose and has a pay-back period of 0.5years which is 195 days to recover initial investment cost. The results presented above shows that the use of a double slope solar still using brackish water is an economical viable and feasible measure for the improvement of the water quantity and quality in Kilifi and the surrounding coastal counties.

Finally, it is concluded that the double slope solar still is able to produce clean and safe drinking water and can be installed to address water scarcity in coastal and arid regions.

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