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MODIFICATION OF SOLAR DISTILLATION UNIT TO INCREASE EFFICIENCY IN DRINKING WATER PRODUCTION FROM SALINE WATER

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ABSTRACT

Solar distillation is one of the appropriate methods which could be used to reduce cost of power in the process of water purification. The commonly used single basin solar distillation systems are not efficient in the process of distillation. Therefore, an experiment was carried out to increase the efficiency of the existing single basin solar distillation unit constructed by the NERD center Sri Lanka by incorporating a 2cm thick unsieved river sand layer for heat retention due to its high thermal capacity. It was revealed that, 30% increment of water distillation could be achieved when sand is incorporated to the solar distillation system even though the internal temperatures of the both systems were not significantly different. Average daily production of the solar distillation system constructed by the NERD center was 1557ml/m^2/day at Mapalana (6°3'39"N 80°33' 57"E). The average daily production after the modification was 2017.50ml/m^2/day at Mapalana. The maximum distillation rate of NERD solar distiller was 2150ml/m^2/day and 2780mi/m^2/day for the modified solar distiller during the experiment period. The average inner temperatures of NERD and modified solar distillers were 55.88^{0}C and 56.54^{0}C, respectively when the average ambient temperature was 29.02^{0}C. Evaporation of more water from the modified solar distiller was the reason for insignificant temperature differences between two solar distillers.

***Key words**:* Sand, Solar distillation, Purification

INTRODUCTION

Solar distillation systems are appropriate low cost methodologies to produce drinking water from salaine water. Solar distillation process removes impurities such as salts and heavy metals as well as microbiological organisms. Most of the people near coastal areas may face with the unavailability of fresh water due to sea water intrusion into groundwater aquifers. It has been reported that due to higher fluoride and other ions, people face health problems in North and North Central provinces of Sri Lanka.

The solar energy has been used for many years in obtaining potable water by distillation from contaminated or brackish supplies (Ihalawela and Careem 2007). As early as 1561, Arabs used solar distillers to obtain drinkable water as well as water based fragrances. In 1861, the French used solar stills to produce Brandy from wine. In 1872, in Las Salinas, Chile' a solar still made of 64 water basins constructed from wood with sloping glass covers was used to supply water to animals working in the local mines. Even the United States military includes solar stills in their survival kits (Speirs 2007).

Apart from the solar distillation, there are various technologies such as Reverse Osmosis (RO), Electrodialysis (ED), Ion-Exchange (IE), Mechanical Filters (MF) etc for water purification (Avvannavar *et al.* 2008). However, energy cost and operational and maintenance cost incurred these methodologies increases the production cost of drinking water. (Rodrígueza and Camachob 1999). Production cost without labor charges is around Rs.150/- to Rs. 500/- per cubic meter by Reverse Osmosis and for other methods the cost may be at same range (www.oas.org - 2009).

Use of the solar energy for the distillation of water is one of the appropriate methods to reduce the cost incurred on power when other methodologies are used. The main drawback associated with the solar distillation systems are low distillation efficiency. The solar distiller introduced by the NERD Sri Lanka is a single chamber type and also performing poor distillation efficiency. Therefore, the present experiment was to incorporate a feasible technology to increase the efficiency of the solar distillers. In this experiment the performance efficiency of the 1 m^2 size single basin solar distiller manufactured by NERD center was tested, when sand is placed under the black plated corrugated metal sheet that is expected to increase the thermal capacity.

The intensity of solar energy received by the distiller is the single most important parameter affecting the water production (Happer 2007). The daily distilled water output (M e in kg/m^2/day) is the amount of energy utilized in vaporizing water in the distiller (Q e in J/m^2/day) divided by the latent

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heat of vaporization of water (L in J/kg). Solar distiller efficiency (n) is the amount of energy utilized in vaporizing water in the distiller over the amount of incident solar energy on the distiller (Q^t in J/m^2/ day).Thus solar distiller production and efficiencies could be expressed as below (equation 1 and 2). According to the available data the typical efficiency for single basin solar distiller is reaching only to 60%. (http://www.solaqua.com/ solstilbas.html).

Daily distilled output: $M_e = Q_e / L$ - (1)
Daily distilled efficiency: $n = Q_e / Q_t$ - (2)

Therefore, to increase the production of a solar distiller, area of the solar distiller or heat conversion efficiency should be increased. However, increase in efficiency is more viable approach than increase in distiller size owing to several reasons including cost of production, handling and fixing.

MATERIALS AND METHODS

NERD solar distiller and modification done

The solar distiller manufactured by NERD center is a single basin type and has 3 main parts, glass sheet, top opened rectangular metal case and black painted corrugated metal sheet. The top side of the rectangular shape metal box (125cm X 85cm X 12cm) was covered with a 3mm thick non colored general purpose plain glass sheet and, the corrugated metal plate was fixed within the box. The black painted corrugated metal plate of the solar distiller contains the brackish water which is directly exposed to the solar energy Figure 1. The polluted water is completely enclosed in an air-tight condition inside the solar distiller unit. The incident solar radiation passes through the transparent glass cover which is covering upper side of the distiller and is absorbed by the black painted metal sheet, the absorbed heat is then transferred to the water without significant energy loss. The polluted water get heated and evaporated. The formed vapor on the water surface start moving in an upward direction due to the created driving force (convective currents) and temperature difference between the water and glass cover which is get in to comparatively low temperature due to heat loss by convection. When the water vapor comes in contact with the glass, the vapor will condense to small-size droplets of freshwater. The condensate starts moving down along the inclined glass cover due to the gravitational force, which will be collected from the collecting channel which is connected to the lower side of the inclined glass sheet (Tarawneh 2007).

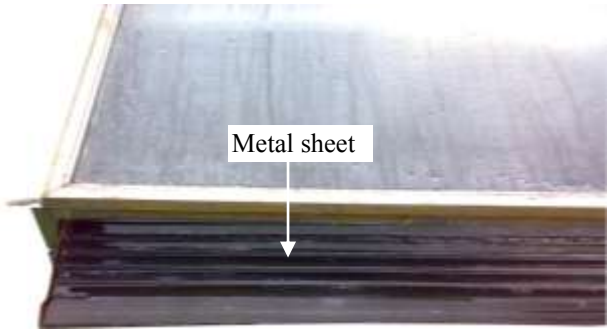

Figure 1: Solar distiller inside view

Modified Sand Layered Solar distiller

Same dimensions and materials used for the NERD solar distiller ware used for the construction of modified solar distiller and only the sand basing was the extra component used in the modified distiller. A 2cm well dried unsieved river sand layer was placed under the water holding corrugated metal sheet of the solar distiller as illustrated in the Figure 2. A rectangular metal basin made of 1 mm thick zinc coated metal sheet with depth of 2.2cm, length of 124.5cm and width of 84.5cm was used to place sand layer. Approximately 8kg of dry sand was evenly applied inside the sand basin. Thereafter, the corrugated metal sheet was placed tightly on sand layer and sealed the edges sheet with the walls of the sand basin using silicon glue.

Meteorological data

Rainfall data of the experiment period were taken from the meteorological station Faculty of Agriculture, University of Ruhuna, Mapalana. Rainfall data were collected at daily basis. The ambient temperature was taken at hourly interval from 8.00 am to 4.00 pm during the experiment. The average ambient temperature during the experiment was 30.2^0C. The observation period was a dry period with less than 2mm average rainfall per day.

Field Validation

Performance of the modified solar distiller by incorporating the sand layer was tested against the existing distiller in the Science Park, Faculty of Agriculture, University of Ruhuna, Mapalana, Sri Lanka during June – July 2008. Both units were placed at 35^0 angle at East-West direction to avoid errors due to the orientation. During the field validation, pipe born water was used and distillers were recharged as it were getting dried. Water distillation rate of the two units was measured at hourly intervals from 8.00 am – 4.00 pm, of the day and internal temperatures of both units were also taken at the time of observations.

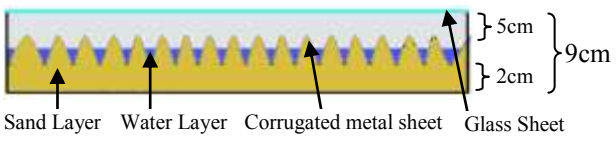

Figure 2: Sand layer beneath the corrugated metal sheet

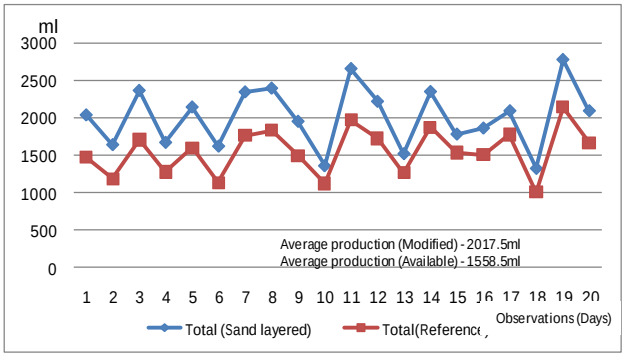

Figure 3: Daily distilled water production. Average production (Modified) - 2017.5ml. Average production (Available) - 1558.5ml

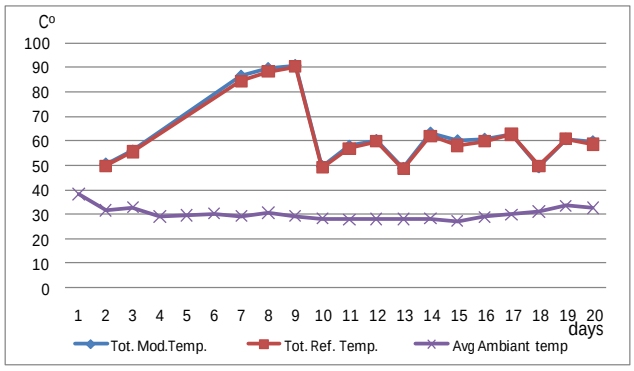

Figure 4: Variation of internal temperatures of distillation units and ambient temperature

RESULTS AND DISCUSSION

It was found that the average production rates of water was 2017.5 ml/m^2/day and 1558.5 ml/m^2/day for modified solar distiller and the conventional solar distiller respectively. The average production difference between two solar distillers was 460.5ml which is a 29.6% increment in production. Results obtained from the two distiller units are given in the Table 1.

Water distillation patterns have closer similarities for both distillers with a distinct percentage increase in the modified distiller. However, the daily production between two units were significantly differed (T test P value $\simeq$ 0.000) and production difference is increasing with the increase production at an accelerated rate.

The internal temperatures of both units were not sigificantly differed (T test P value > 0.05) and it has been fluctuated in the range of 48^{0}C to 91^{0}C. It was evident that there is no significat effect on production rate of two distiltion units by difference in internel temperatures of two units withing the 5 percent confidence level. In the other hand, ambient temperature is significantly correlated to the distillation rate of the both distiller units (P value <0.05) controlling for internal temperatures. Therefore, it is evident that the ambient temperature is effecting to the production rate of the both distiller units.

Table 1: Water production, temperatures and rainfall statistics

Date	Total water production (mm)		Production difference (%)	Internal temperature of the distiller (^{0}C)		Average Ambient temp (C^O)	Rainfall (mm)
	Mod	Ref		Mod	Ref		
08-06-11	2045	1480	38.18	-	-	38.2	0.1
08-06-12	1650	1190	38.66	50.7	49.8	31.7	0.1
08-06-13	2370	1715	38.19	56	55.6	32.8	5.7
08-06-14	1680	1280	31.25	-	-	29	1.3
08-06-16	2150	1605	33.96	-	-	29.7	0.7
08-06-17	1630	1140	42.98	-	-	30.3	3.3
08-06-19	2350	1770	32.77	86.4	84.4	29.3	1.3
08-06-20	2400	1840	30.43	89.6	88.3	30.7	0
08-06-21	1960	1500	30.67	90.8	90.5	29.3	11.1
08-06-25	1370	1130	21.24	49.6	49.1	28.3	4.4
08-06-27	2660	1975	34.68	57.9	57	27.9	0
08-06-30	2225	1730	28.61	60.2	59.9	28	1.4
08-07-01	1530	1270	20.47	48.9	48.6	28	0
08-07-02	2355	1880	25.27	63.2	62.1	28.3	0
08-07-03	1790	1540	16.23	60.1	58.1	27.3	0
08-07-04	1870	1510	23.84	60.8	59.8	28.9	0.3
08-07-05	2100	1780	17.98	62.6	62.6	29.9	2.7
08-07-07	1335	1015	31.53	49.4	49.7	31.1	3
08-07-09	2780	2150	29.30	60.8	60.9	33.6	0.9
08-07-10	2100	1670	25.75	59.7	58.7	32.7	3.6
Average	2017.5	1558.5	29.6	62.9	62.2	30.2	2.00

CONCLUSION

The efficiency of the water distillation from the conventional solar distillation unit of 1m^{2}could be increased by 29.6% when 2cm unsieved river sand bed is incorporated under the corrugated metal sheet to increase the heat absorption and transferring capacity. The additional heat absorbed by the sand layer from the solar radiation contributes to distill more water from the evaporator which helps to reduce the expansion of the evaporation surface to increase production.

The modified solar distillation unit with 1m^2 area produced about 2100ml of water per day under the prevailing climatic conditions of Mapalana during June – July 2008.

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