Performance of Black Granite Basin Solar Still: A Comparative Study

Jadhav Madhav V.
Dept. Physics,S. M. B. S. Thorat College of Arts, Science and Commerce Sangamner, Dist. Ahmadnager-422605, (Maharashtra) India

Abstract
Solar distillation is one of the important methods of utilizing the solar energy for the supply of potable water to small communities where the natural supply of fresh water is inadequate or of poor quality, where sunshine is abundant. Single-basin solar stills can be used for water desalination. They are considered the best solution for water production in remote, arid to semi-arid, small communities, where fresh water is unavailable. The amount of distilled water produced per unit area is somewhat low which makes the single basin solar still unacceptable. The purpose of this work is to study the effect of using two different basin materials in solar still and thus enhance the productivity of water. The experimental results show that the productivity of distilled water was enhanced for black granite basin solar still as compared to iron steel basin solar still. The productivity of the granite basin solar still through the period is averaging 3.784 L/m^2.day, whereas iron steel basin still is 2.358 L/m^2.day which is nearly 38 % higher than the iron steel basin still. Basin water temperature in the granite basin still increased up to 87 ^{0}C compared with iron steel basin still water temperature of about 79 ^{0}C .the productivity of granite basin still is always greater than the productivity of iron steel basin still through out the day. The granite basin solar still is capable of enhancing the productivity.

Keywords: *Solar distillation; Simple single basin still; Granite basin, Iron steel basin*

1. INTRODUCTION

Potable water demand is increasing due to rapid population increase and also due to uncontrolled pollution of the fresh water resources. The fresh water crisis is already evident in many parts of India, varying scale and intensity at different times of the year. The average daily solar radiation varies between 4 and 7 kwh per square meter for different parts of the country. There are on an average 250-300 clear sunny days in a year and it receives about 5000 trillion kwh of solar energy in a year [1]. The conventional desalination technologies like multistage flash, multi-effect, vapor compression, iron exchange, reverse osmosis, electrolysis are expensive for the production of small amount of fresh water, also use of conventional energy sources has a negative impact of the environment. Interest in the simple solar still has been developed due to its simple design, construction, and low operating and maintenance cost, mainly in remote areas. However its low productivity stimulated the development of methods to increase its efficiency [2].

There are many designs for solar stills. 95 percent of functioning solar stills are of the basin type solar still. The performance of basin still depends on the basin, transparent glazing cover, evaporation surface, insulation material and climatic condition. A lot of researcher works on design, fabrication methods, and testing and performance evaluation etc. of solar distillations have been carried out various researchers throughout the world since ancient time. The research works in passive solar stills were carried out by Cipollina et.al. [3] and in this case the water in the basin is directly heated by solar energy. The other design is active solar still in which the water in the basin is heated both directly as well as indirectly and research work carried out by Tripathi & Tiwari [4] reported that with rise in ambient temperature 23^{0}C to 33^{0}C, the daily yield increases by 8.2 %. H.Al.Hinai et.al.[5] reported that the shallow water basin, 23^0 cover tilt angle , 0.1 m insulation thickness and asphalt coating of solar still were found to be the optimum design parameters of simple solar still that produce an average annual solar still yield of 4.15 kg/m^2.day. Samy M & Hassan [6] Solar distillation under climatic conditions of Egypt. The effect of saline water depth, insulation thickness and wind speed on the still productivity were evaluated. The study showed that the productivity of still depends on the solar radiation and ambient temperature. The daily still productivity varies from 1.1 to 5.2 kg/m^2 of basin area. Increasing the wind speed resulted in a relatively small reduction in still productivity. Abdul Jabba et.al. [7] developed a concluding correlation from all brine depth data the correlation showed a decreasing trend in the productivity with the increasing in brine depth and showed that the still productivity could be influenced by the brine depth by up to 48 %. Salah Abdullah et.al.[8] modified conventional solar still, it involves the installation of reflecting mirror on all sides, replacing the flat basin by a step-wise basin, and coupling the conventional solar still with a sun tracking system it improves the system thermal performance up to 30 %, 180 %, 380 % respectively.

S. Nijmeh et.al.[9] , Bilal A.Akash et.al. [10] Studied the effect of different absorbing material in a solar still and shows that the productivity of distilled water was enhanced for some materials. Abdulrahman Ghoneyem [11] were designed, constructed and tested four single effect basin type solar still, three still had a glass cover of different thickness 3, 5, 6 mm and fourth cover plastic reported that the thinnest glass cover had shown the highest production rates up by 15.5 %. Bilal A. Akash et.al. [12] Presented experimental results using basin type solar still with various cover tilt angles of 15, 25, 35, 45 and 55^0. An optimum tilt angle for water production was found to be 35^0 during the month of May. Abdul Jabbar N. et.al. [13] In his study the effect of insulation on the production of a basin type solar still is verified. Solar still with insulation thickness of 30, 60,& 100 mm are investigated and the result are compared with those obtained for a still without insulation and found that the insulation thickness could influence the productivity of the still by 80 %.

G.M.Cappelletti [14] reported an experiment with plastic basin solar still. The greatest quantity of fresh water obtained by the tested solar still was 1.7-1.8 l/m^2.day. The result was achieved in the third weak of July. Mohammed Farid, Faik Hamad [15] fabricated the solar still from galvanized steel sheet, found that the efficiency of the still to be independent of solar radiation. An increase in still productivity was observed with the increase in ambient temperature and decrease in wind velocity. In the present study the two similar simple basin solar still of basin material as black granite and iron steel are used. The experiment was carried out during 3rd May 2010 to 11th May 2010 under the same climatic conditions by keeping water depth of 1cm.

2. EXPERIMENTAL SETUP

Single basin solar still were fabricated and tested under field condition at the testing field of the physics department, S. M. B. S. Thorat College of Arts, Science & Commerce, Sangamner, Dist-Ahmednager (M.S.) India. The one basin solar still consists of a basin liner made up of black granite of 1 x 1 meter with maximum height of 120 mm and thickness 15mm thick. The color of granite is permanent dark black so it will be better to absorb the maximum amount of solar radiation on them and convert it to heat. The granite also has a smooth surface to make it easier to clean. The distillate through made up of green color marble. It absorbs less solar radiation. In the basin there is no metal part so the problem of corrosion is avoided. The basin is made water proof using carpet, M-seal and Veebee (knifing paste filler). The top of the basin is covered with transparent 4 mm window glass inclined by nearly 1^0 angle with the horizontal. There are certain specifications needed for the used glass cover in the still. They are (a) Minimum amount of absorbed heat, (b) Minimum amount of reflection for solar radiation energy, (c) Maximum transmittance for solar radiation energy, and (d) High thermal resistance for heat loss from the basin to the ambient. The spacing between the glass cover and the basin water surface is 70 mm -120 mm. The slope of the glass cover does not affect the rate at which the distillate runs down its inner surface to the collection trough. The glass cover that is no more than 50 to 70 mm from the water surface will allow the still to operate efficiently. Consequently, a glass-to-water distance increases, heat loss due to convection become greater, causing the still efficiency to drop (Horace McCracken et al.2009).The cover is sealed tightly using silicon sealant to reduce the vapor leakage. Two G.I.

pipes of 12mm diameter are fitted to the basin; one for filling the brackish water in to the basin and other for flushing the brackish water out from the basin of the solar still. A condensate channel runs along the lower edges of the glass cover which collects the distillate and carries it out side the still. The total basin of the still is insulated with black foam of 15 mm thickness. The sticking material used is fevicol-SR505 which is synthetic rubber adhesive. The basin finally enveloped by envelops which is prepared by the Galvanized steel sheet.

The second same basin solar still was made only the basin liner made up of galvanized steel. The bottom of the basin is painted with black paint. The distillate through made up of galvanized steel. Both the assembly is placed on the structure made up of M.S. angle. The still is fed with brackish water. The still technical specifications are shown in Table 1, and Fig. 1a shows the geometrical constructions of the solar still used in the experiments. Fig. 1b- shows the black granite simple basin solar still photograph. The solar still is oriented in the E-W direction. The experiments on the still were carried out during 3rd May 2010 to 11th May 2010 under the same climatic conditions. The experiment was carried out keeping water depth of 1cm. During the experiment every day the solar radiation, temperature of water inside the basin and temperature below the glass cover were measured at 1.00 p.m. The day time ambient temperature and day time wind speed were also measured. The feed water was changed and the distilled water product measured at 7.00 a.m. every morning. The hourly distillation rate of steel basin solar still and granite basin solar still was measured on the 11th May 2010. The hourly productivity of fresh water is collected through a graduated flask.

The measuring devices used in the system are as follows:

1. Two mercury thermometer with a range from 0 to 99.9^{0}C are used to measure the temperatures of the various components of the still system.
2. A Sun Meter (Digital Solarimeter) is used to measure the solar radiation. This device measures the instantaneous intensity of radiation in (W/m2), Range 0-1999 Watt/m^2 Resolution-1Watt/m^2.
3. A digital anemometer is used to measure wind speed.
4. A 80 mm steel rule is fixed inside wall used to measure water depth.
5. Max.., Dry & Wet thermometer used to measure Day time ambient temperature.

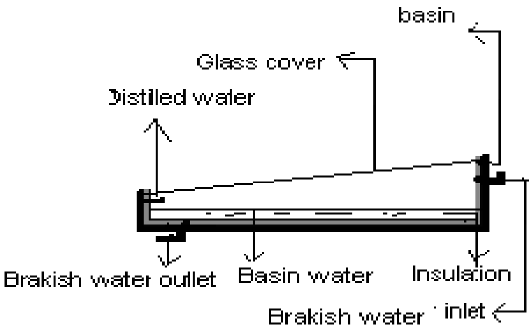

Fig. 1a- Construction of simple basin solar still

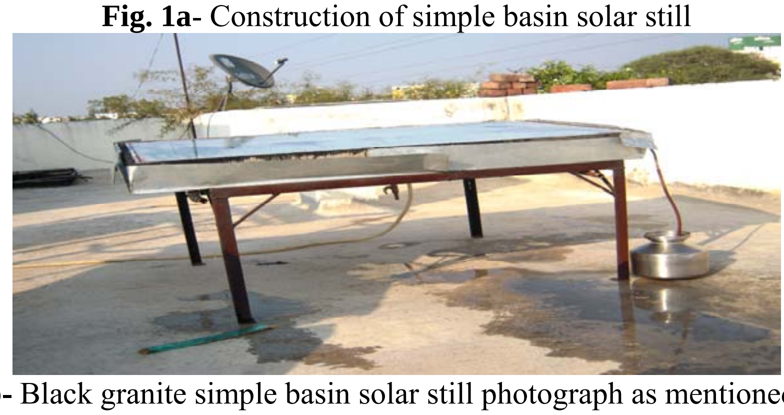

Fig. 1b- Black granite simple basin solar still photograph as mentioned in text

Table-1 Technical specification of the single basin solar still

Specification	*Black Granite basin Descriptions*	*Steel basin Descriptions*
Basin area (m^2)	0.9280	1.081
Black granite/ steel thickness (mm)	15	1
Glass area (m^2)	0.9401	1.123
Glass depth (mm)	4	4
Number of glass	1	1
Inclination angle of glass (in degrees)	$\approx 1^0$	$\approx 1^0$
Transmittivity of glass	75 %	75 %
Black foam (Insulation) depth (mm)	15	15
G. I. pipe diameter (mm)	12	12
Distance between glass and basin water surface (mm)	70-120	70-120

3. RESULTS AND DISCUSSIONS

The results and discussions for the performance of both simple solar stills are presented here in the form of graphs and tables. The experiments have been conducted from 7.00 a.m. to 7.00p.m. under the same climatic conditions. It was covered with a wide range of parameters such as temperatures of basin water, temperature below glass cover, hourly yield, which are reported in the Table.2 and Table. 3. At this particular condition, experiments were conducted for the 7 days to get concurrent results. According to the hourly variation of solar radiation for both the solar distillation system at date May 11th 2010 the results have been illustrated.

Fig. 2 shows the time versus temperature of basin water and Fig-3 shows the time verses temperature below glass cover for the steel basin solar still and granite basin solar still. It can be seen that, the basin water temperature, temperature below glass cover increase continuously to a maximum till the afternoon because the absorbed solar radiation exceed the losses to the environment. From about 2 p.m., temperatures start to decreases due to the heat losses from the solar still which becomes larger than the absorbed solar radiation. It can be noted that the basin temperature, basin water temperature and temperature below glass cover get closer to the each other because of the continuous contact between them which lead to heat equilibrium. Also Fig. 2 and Fig-3 shows, the temperature of basin water and the temperature below glass cover for granite still is always greater than the iron steel basin still because the granite basin is totally black its heat absorbing capacity is more and heat loss is less than iron basin still.

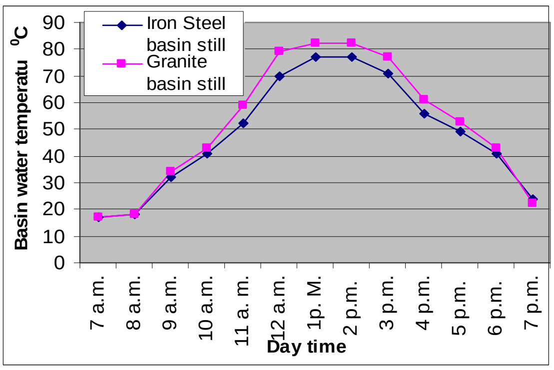

Fig-2 Day time versus temperature of basin water as mentioned in text.

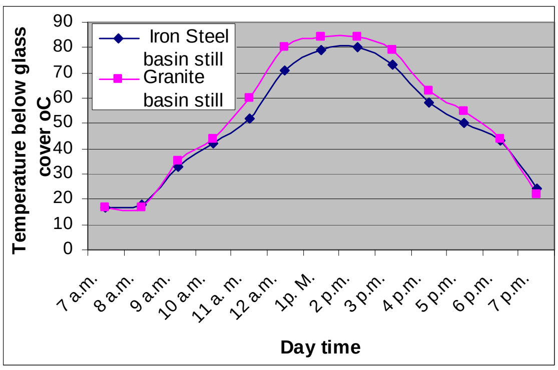

Fig-3 Day time verses temperature below glass cover as mentioned in text.

The productivity rate varies as time passes from early morning until late afternoon. Fig. 4 shows that, the productivity of both still is increasing until it reaches the maximum in the afternoon, then decreases in the afternoon. The productivity of the granite basin solar still increases fast after 10 a.m. and reaches to maximum at 12 a.m. and become nearly constant up to 2 p.m., then decreases. The productivity of iron steel basin still increases linearly and reaches the maximum in between 1 p.m. to 2 p.m., and then deceases .The productivity rate of granite still is considerably greater than the iron still between 11 a.m. to 3 p.m. The granite solar still has given more yield than iron steel solar still, this may because of higher water temperature of granite solar still than iron steel solar still. An overall result shows that, the productivity of modified still is 15% higher than the conventional still.

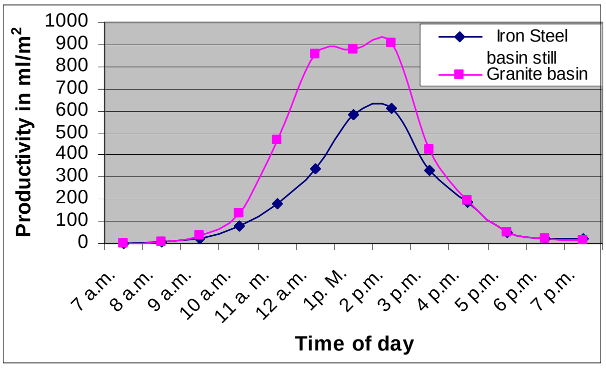

Fig-4 Day time verses productivity as mentioned in text.

The basin water temperature can be taken as one of parameters that have a direct effect on the productivity of solar still. Water temperature is mainly depends on capacity of water inside the basin. Whereas the depth of water increases from 10 mm to 70 mm, the maximum temperature of water gets reduced. 10mm depth saline water reaches the maximum temperature 83 °C of granite solar still and 76 °C of iron steel solar still of water around 12.00 noon to 1.00 p.m. compared to other depths. In the late afternoon, basin water temperature for lower water depths are smaller than the higher depths; this may due to lower capacity basin water release the heat faster than the higher capacity. The productivity of still is highly depends on basin water temperature, from fig-2 when water temperature is high, the productivity is more.

Table-2

Time	*Granite basin solar still*			*Iron steel basin solar still*		
	T_b	T_{bqc}	m_{ex} mL/m^2.hr	T_b	T_{bqc}	m_{ex} mL/m^2.hr
7 a.m.	17	17	0	17	17	0
8 a.m	18	17	7	18	18	8
9 a.m	34	35	34	32	33	25
10 a.m	43	44	139	41	42	80
11 a.m	52	54	470	49	51	182
12 a.m	70	72	855	68	70	335
1 p.m.	82	85	875	77	80	580
2 p.m.	82	84	905	77	81	610
3 p.m.	77	79	422	72	74	330
4 p.m.	61	63	197	56	59	190
5 p.m.	53	55	52	49	52	48
6 p.m.	45	25	25	46	47	23
7 p.m.	22	17	17	24	27	20

Table- 3 solar still productivity

Date	T_{fw}	T_a	G	V_a	Granite basin still			Iron steel basin still		
					T_b	T_{bgc}	$m_{ex}L/m^2.d$	T_b	T_{bgc}	$m_{ex}L/m^2.d$
3/5/2010	17	37	983	3.785	86	88	3.949	79	83	2.450
4/5/2010	17	37	951	3.597	79	81	3.567	73	75	2.115
5/5/2010	17	37	978	3.703	82	85	3.880	76	79	2.410
6/5/2010	17	37	970	3.715	83	85	3.710	76	78	2.374
7/5/2010	17	37	974	3.648	84	87	3.797	78	79	2.386
8/5/2010	17	37	967	3.647	83	86	3.573	75	78	2.290
9/5/2010	17	37	980	3.660	87	88	4.011	79	82	2.480
Mean	17	37	971.85	3.679	83.42	85.71	3.784	76.57	79.14	2.358

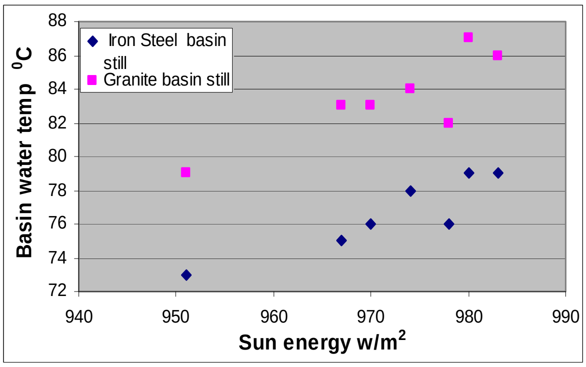

Fig-5 Sun Energy Versus Basin Water Temperature as mentioned in text

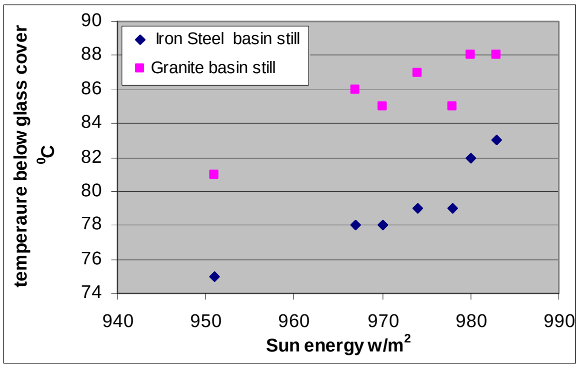

Fig-6 Sun Energy Versus Temperature below glass cover as mentioned in text

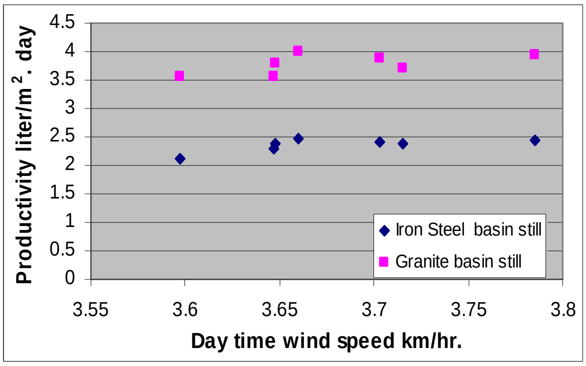

Fig-7 Distilled Water Productivity Versus Day Time Wind Speed as mentioned in text.

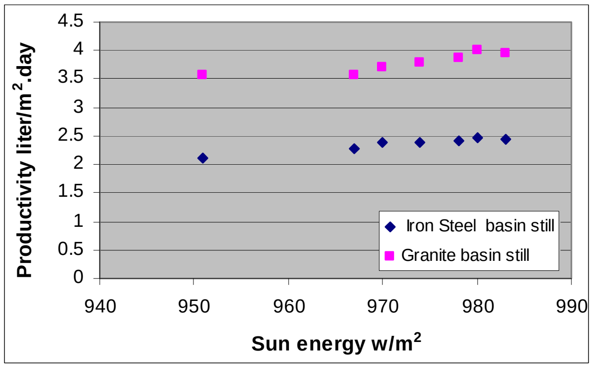

Fig-8 Distilled Water Productivity Versus sun energy as mentioned in text.

Fig-5 and Fig-6, the basin water temperature and temperature below glass cover of granite still reaches to a maximum value of 87 °C and 88 °C respectively at the maximum sun energy of 980 w/m^2, but the basin water temperature and temperature below glass cover of iron steel basin still reaches to a maximum value of 79 °C and 82 °C respectively at the same Sun energy at the day 9th may 2010.Fig-5 and Fig-6 clearly shows that the basin water temperature and temperature below glass cover increases with increase in Sun energy.

Fig-7 shows that when both the sun energy and the wind speed are greater, the distilled water output is less but when the sun energy is greater and wind speed is less; the distilled water output is greater. The still productivity increases with decrease in wind speed.

Fig-8 shows that the still productivity increases with increase in sun energy. The granite basin solar still has a maximum distilled water productivity of 4.011 L/m^2.day when sun energy is 980w/m^2 at the day 9th May 2010. But the iron steel basin solar still has maximum distilled water productivity 2.480 L/m^2.day for the same sun energy.

CONCLUSION

In this present study, several conclusions are obtained: They are as follows,

(a) Basin water temperature in the granite basin still increased up to 87 $^{\circ}$C compared with iron steel basin still water temperature of about 79 $^{\circ}$C .
(b) The productivity of the granite basin solar still through the period is averaging 3.784 L/m^2.day , whereas iron steel basin still is 2.358 L/m^2.day which is nearly 38 % higher than the iron steel basin still.
(c) The increase in either ambient temperature or the solar intensity can lead to the increase of productivity.
(d) The basin water temperature, the temperature below glass cover and the productivity of the granite basin solar still is always greater than the iron steel basin still through out the day.
(e) The effect of wind speed on the productivity is negligible.
(f) The granite basin solar distillation system is an efficient one.

REFERENCES

1. T.V.Arjunan, H.S.Aybar, N. Nedunchezhian, Status of solar desalination in India, *Renewable and Sustainable Energy Reviews*, (2009).
2. Mousa Abu-Arabi, Yousef Zurigat, Year-round Comparative study of three types of solar desalination units, *Desalination* 172 (2005), 137-143.
3. A. Cipolina, Sommariva, M. Giorgio, Efficiency increase in thermal desalination plants by matching thermal and solar distillation: theoretical analysis, *Desalination* 183 (2005) 127-136.
4. R. Tripathi, G.N. Tiwari, Thermal modeling of passive and active solar stills for different depth of water by using concept of solar fraction, *Solar Energy* 80 (2006) 956-967.
5. H. Al-Hinai, M.S. Al-Nassri, B.A. Jubran, Effect of climatic, design and operational parameters on the yield of a simple solar still, *Energy Conversion Management,* Volume 43, Issue 13, September 2002, Pages 1639-1650.
6. Samy M. ELSherbiny, Hassan E.S.Fath, Solar distillation under climatic conditions of Egypt, *Renewable Energy*, Volume 3, Issue 1, February 1993, Pages 61-65.
7. Abdul Jabbar N. Khalif, Ahmad M. Hamood, The verification of the effect of water depth on the performance of basin type solar stills, *Solar Energy*, Volume 83, Issue 8, August 2009, Pages 1312-1321.
8. Salah Abdallah, Omar Badran, Mazen M. Abu-Khader, Performance evaluation of a modified design of a single slope solar still, *Desalination*, Volume 219, Issue 1-3,25 January 2008, Pages 222-230.
9. S. Nijmeh, S. Odeh, B. Akash, Experimental and theoretical study of a single-basin solar still in Jordan, *International Communication in Heat and Mass Transfer,* Volume 32, Issue 3-4, February 2005, Pages 565-572.
10. Bilal A. Akash, Mousa S. Mohsen, Omar Osta, Yaser Elayan, “Experimental evaluation of a single basin solar still using different absorbing materials”, *Renewable Energy*, (1998), Vol.14, No. 1-4. May-August, pp. 307-310.
11. Abdulrahman Ghoneyem, Arif lleri, Software to analyze solar stills and an experimental study on the effects of the cover, *Desalination,* Volume 114, Issue 1-1,December 1997, Pages 37-44.
12. Bilal A. Akash, Mousa S. Mohsen and Waleed Nayfeh, “Experimental study of basin type solar still under local climate conditions”, *Fuel and Energy Abstracts*, (2000), Vol.41, No. 3, May, pp. 163.
13. Abdul Jabbar N. Khalif, Ahmad M. Hamood, Effect of insulaton thickness on the productivity of basin type solar stills: An experimental verification under local climate, *Energy Conversion and Management,* Volume 50, Issue 9, September 2009, pages 2457-2461.

14. G. M. Cappelletti, An experiment with a plastic solar still, *Desalination*, Volume 142, Issue 3, 1 March 2002, Pages 221-227.
15. Mohammed Farid, Faik Hamad, "Performance of single-basin solar still", *Renewable Energy*, Volume 3, Issue1, February 1993, pp. 75-83.

Glossary

T. Temperature (°C)
G. Solar intensity (W/m^2)
A_w. Area of water (m^2)
T_w. Water temperature (°C)
A_s. Surface areas of condensing cover (m^2)
K_g. Thermal conductivity of condensing cover
M_{ex}. Experimental distiller out put
V_a. Wind velocity km/h
T_b. Basin water temperature (°C)
T_{bgc}. Temperature below glass cover (°C)
T_a. Day time ambient temperature (°C)
T_{fw}. Feed water temperature (°C)