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DESALINATION OF WATER USING CONVENTIONAL BASIN TYPE SOLAR STILL

Strictly as per the compliance and regulations of :

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S.M.Abdullah Al Faruq [α], Md.Shaheen Akter [σ], Md.Alamin [ρ] & Md.Zohrul Islam[ω]

Abstract - Solar distillation is a simple treatment of brackish (i.e. contain dissolved salts) water supplies. Distillation is the processes that can be used for water purification and can use any heating source.Solar distillation is used to yield drinking water or to yield pure water for lead acid batteries, hospitals, laboratories and in generating commercial products such as rose water.In this study, a basin type solar still (BSS) is designed, constructed and field experiments have been carried out to check the productivity of the still. The field experiments of the BSS are carried from June 07, 2011 to June 09, 2012. The maximum daily distilled water production is obtained as 3.76 lit/m2-day in July 31, 2011. Also maximum hourly distilled water production is observed as 0.46 lit/m2-hr. The average daily and hourly production rates are found as 1.80 lit/m2-day and 0.20 lit/m2-hr, respectively. The production cost of distilled water is calculated as 0.33 Tk/lit.

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I. Introduction

Fresh water is a basic necessity of man along with air and food. Man has been reliant on lakes, rivers and underground water reservoirs for fresh water necessities in domestic agriculture, life, and industry. However, practice of water from all sources is not always possible or desirable on account of the presence of large amount of harmful organisms and salts (Tsilingiris, 2011). Also in the south western region of Bangladesh, shallow aquifers contain arsenic, exce-eding the allowable limit for Bangladesh standard (0.05 mg/l) and highly saline water exists in deep aquifers. Salinity and arsenic in water poses a serious problem for the development of appropriate water supply system. In these areas desalination techniques could be applied to meet fresh water demand produced from brackish or saline water. Most desalination techniques such as reverse osmosis, electro-dialysis, multi-stage flash etc. consume a huge amount of external energy e.g. fossil fuel/electricity (Nayak et. al., 2000).

Therefore, finding methods of using renewable energy to power the desalination process is desirable. Solar distillation is a simple desalination technique in which only solar energy is needed. A basin type solar still (BSS) is the most popular method of solar distillation compared with others due to its simplicity and longer design life. It could be one of the viable options for providing drinking water for a single house or a small community in arid, remote and coastal regions. On the other hand, uses of water from underground and surface water sources are not always desirable or possible because of the presence of large amount of salts especially in coastal areas. Excessive salinity causes various health hazard and diseases in coastal region. In these areas basin type solar still (BSS) could be a suitable technique for supplying potable water. The method will serve the community with fresh water reducing the harmful effect. Desalination or desalinization denotes to any of several processes that remove extra salt and other minerals from water. Generally, desalination can also denote to the removal of salt and other minerals from water. Solar distillation is a the simple treatment of brackish that contains dissolved salts. Solar distillation has been in practice for a long time. Tripathi and Tiwari (2005) have proposed a thermal modeling of passive and active solar stills for different depths of water by using the concept of solar fraction. In this experiment, it is observed that the internal convective heat transfer coefficient decreases with the increase of water depth in the basin due to decrease in water temperature. Tanoak and Nakatake (2006) conducted an experiment on effect of inclination of external flat plate reflector of basin type still in winter. They proposed a new geometrical method for calculating the solar radiation reflected by the inclined external reflector and then absorbed on the basin liner. Elsarrag (2008) conducted an experiment on evaporation rate of a novel tilted solar liquid desiccant regeneration system. In this study a corrugated blackened surface is used to heat the desiccant and an air flow is used to regenerate calcium chloride solution. In this study, a basin type solar still (BSS) is designed, constructed and field experiments have been carried out on the roof of the Civil Engineering building of Khulna University of Engineering & Technology (KUET) from June 07, 2011 to June 09, 2012 to check the productivity of the still.

II. Desalination Practice in Bangladesh

Due to scarcity of fresh water and presence of excessive arsenic in ground water in Bangladesh increases the demand of alternative source of drinking water. On the other hand surface water is not usable

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due to large scale of salinity. Thus solar desalination is one of the alternative options available for water supply in the arsenic affected areas. The water produced by solar desalination is completely free of salinity and can be mixed with tube well water to increase the volume of water for drinking water supply. The technology cannot produce an adequate quantity of water as a result of cost. The system required further development for use in water supply in rural areas. Gani and Shama (1993) conducted an experiment on basin type solar still from August to October. They used Ferro-cement basin with glass plate cover for storing saline water. The average daily production rate was found as 457 ml/m^2.Mahmood and Rahman (1994) studied on basin type solar still. They used Ferro-cement basin with glass plate cover for storing saline water. The highest average daily output rate was found as 487.81 ml/m^2 in the month of May. Jafor (2011) studied on basin type solar still. He designed and constructed a basin type solar still (BSS) for solar desalination purpose which has an airtight rectangular Ferro-cement basin (90cm$\times$60cm$\times$5cm). The average daily and hourly production rate was found as 2.88 lit/m^2-day and 0.233 lit/m^2-hr, respectively.

III. Methods of Desalination

a) Solar Distillation

Solar stills should normally only be considered for removal of dissolved salts from water. If there is a best between polluted surface water and brackish ground water, it will usually be inexpensive to use a slow sand filter or other treatment method. If there is no fresh water, the majorre placements are rainwater collection, desalination and transportation. Solar distillation has been used for many years for relatively small plant outputs. Although solar stills are comparatively easy to operate and build, there are few, if any, economies-of-scale linked with larger plants. For example, the largest solar stills yet tested have produced only a few thousand gallons of water per day. A well designed solar still can produce 2 to 4 liters of water per square meter of basin area. A sketch of a solar still is shown in Figure 1.

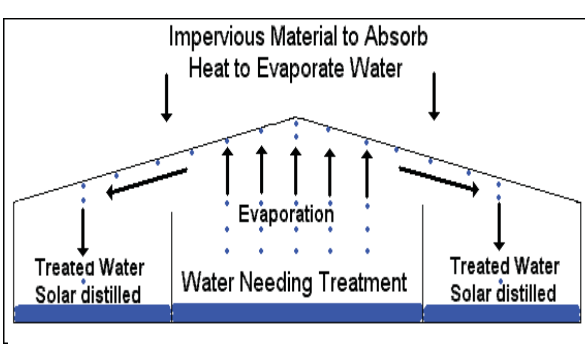


Figure 1 : Section of a typical solar still

b) The Basin Type Solar Stil

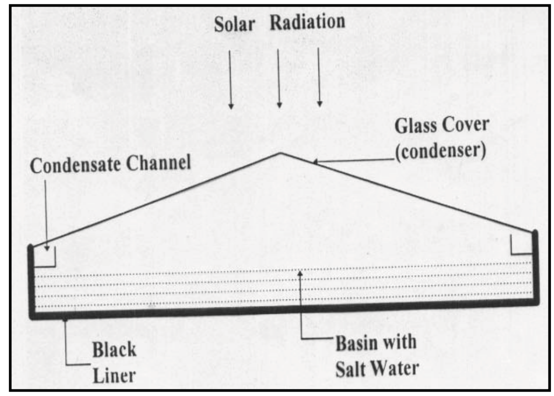
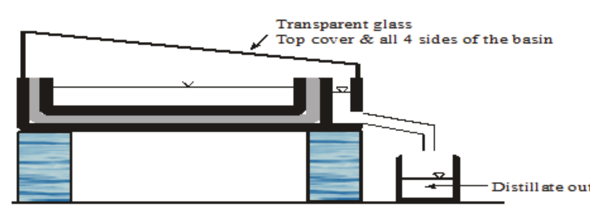


Figure 2 : Section of a typical basin type solar still

IV. Design of Basin Type Solar Still

A conventional basin type solar still (BSS) is designed and constructed in previous year using locally available materials. The still is 100cm long, 70cm wide, 10cm deep and made of 2.5cm thick Ferro-cement materials which is covered with transparent glass of thickness 5mm as condensation surface. The inclination of the glass is 10°with horizontal. The four sides of basin are covered by glass with lower and upper height is 7.5 cm and 22.5 cm, respectively. The still have rectangular basin 90cm long, 60cm wide, 5cm deep and also made of 2.5cm thick Ferro-cement materials. Inside surface and bottom of the basin are insulated by Styrofoam (known as cork sheet) of thickness 2.5cm for protection of heat transfer. To increase the productivity of the still the lower and upper heights are reduced by 2 inch in February 25, 2012. Figure 3 shows the schematic diagram of the BSS.



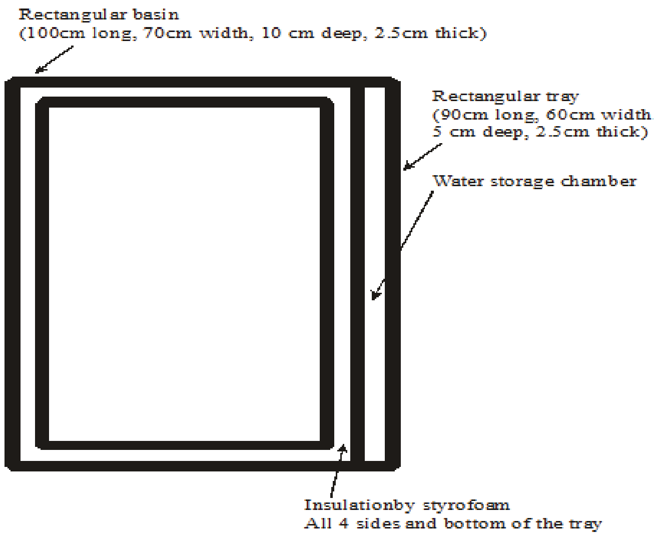


Figure 3 : Schematic diagrams of the BSS

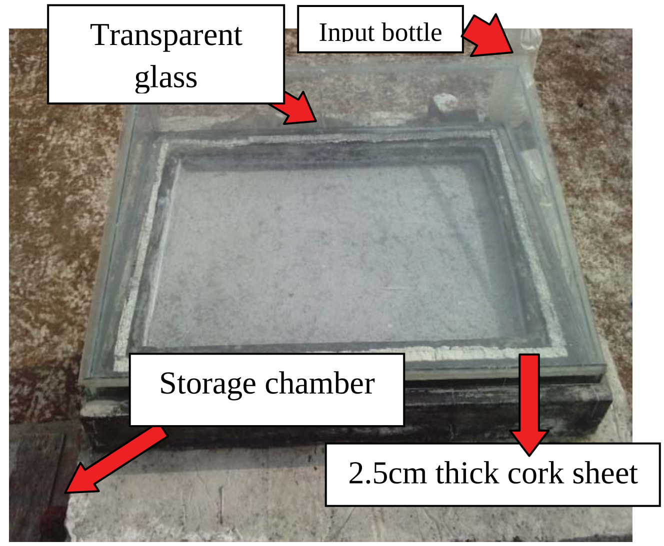


Figure 4 : Photograph of field experiment

V. Field Experiment

The field experiment on the constructed BSS was carried out on the top roof of Civil Engineering building from June 07, 2011 to June 09, 2012. The daily production of distilled water was collected into a bottle everyday approximately two hours after the sunset. Hourly production and ambient air temperature for May 20, 21, and 22 in 2012 were measured during the day time. Figure 4 shows the photograph of the field experiment.

VI. Data Collection

Daily production of distilled water was measured approximately two hours after sunset and tabulated in Table 1. Hourly production and ambient air temperature for May 20, 21, and 22 in 2012 were also measured during the day time and given in Table 2.

Table 1 : Daily distilled water production from June 07, 2011 to June 09, 2012

Day	Daily distilled water production (ml/day)									
	Year (2011)					Year (2012)				
	June	July	September	November	December	February	March	April	May	June
1	-	285	-	-	520	-	1300	1730	-	950
2	-	510	-	-	610	-	1010	1750	-	1125
3	-	464	-	-	645	-	1240	1745	-	1735
4	-	1076	-	-	580	-	1325	1695	-	1670
5	-	1180	-	-	540	-	1125	1795	-	1365
6	-	1100	1050	-	580	-	1250	1250	-	1245
7	2080	1410	980	-	530	-	1305	1710	-	1490
8	1489	975	755	-	690	-	1415	1605	-	1580
9	1927	800	390	-	710	-	1270	1000	-	1610
10	1705	1393	780	-	530	-	-	1468	-	-
11	1078	1100	1010	-	425	-	-	1415	-	-
12	602	1300	1105	-	400	-	-	1512	-	-
13	1626	1105	1073	-	150	-	1100	1455	-	-
14	901	1040	928	920	120	-	1225	1670	-	-
15	923	1180	790	450	170	-	1500	1765	-	-
16	647	1020	920	230	160	-	1350	1900	-	-
17	529	980	200	760	210	-	1330	1860	-	-
18	201	1073	830	785	280	-	1260	-	-	-
19	100	420	925	410	190	-	705	-	-	-
20	351	105	1015	500	300	-	1255	-	-	-
21	627	250	1050	710	240	-	1500	-	-	-

22	920	110	970	615	260	-	1640	-	-	-
23	1302	1675	530	670	280	-	1630	-	1705	-
24	781	928	840	430	300	-	1660	-	1735	-
25	407	948	780	510	440	-	1640	-	1745	-
26	177	1575	1025	535	500	-	1610	-	1150	-
27	751	1608	1070	675	540	1210	1650	-	1170	-
28	400	1625	710	600	510	1225	1710	-	1250	-
29	619	1973	605	595	530	1120	1760	-	1040	-
30	867	2027	965	572	560	-	1670	-	1025	-
31	-	2105	-	-	580	-	1780	-	876	-

Table 2 : Hourly distilled water production and ambient air temperature for three typical days of May 20, 21 and 22, 2012

Time of Day	Hourly distilled water production (ml/hr)			Ambient air temperature (ºC)		
	May 20	May 21	May 22	May 20	May 21	May 22
7.00 am	0	0	0	32	32	32
8.00 am	8	10	5	33.5	32.5	33.5
9.00 am	16	30	5	33.5	33.5	34.5
10.00 am	40	34	21	36.5	30.5	35
11.00 am	120	98	46	39	32.5	35.5
12.00 pm	166	140	90	40	34	37
1.00 pm	180	256	187	38	36	37.5
2.00 pm	195	224	222	33.5	34	38.5
3.00 pm	197	223	214	33.5	33.5	38
4.00 pm	189	191	226	33	33.5	38.5
5.00 pm	144	155	167	34	33.5	38.5
6.00 pm	130	135	170	36	33	36.5
7.00 pm	120	115	106	36	32.5	36
8.00 pm	36	51	67	36.5	32	30

VII. Data Analysis

Data collection and measurement in Section 3.3 were used to calculate the daily (June 07, 2011 to June 09, 2012) and hourly (May 20, 21 and 22, 2012) distilled water production per unit surface area of the saline water in the trough for the BSS and given in Table 3 and Table 4 respectively.

Table 3 : Daily distilled water production rate from June 07, 2011 to June 09, 2012

Day	Daily distilled water production (Lit/m^2-day)									
	Year (2011)					Year (2012)				
	June	July	September	November	December	February	March	April	May	June
1	-	0.51	-	-	0.93	-	2.32	3.08	-	1.69
2	-	0.91	-	-	1.1	-	1.80	3.13	-	2.01
3	-	0.83	-	-	1.15	-	2.21	3.11	-	3.1
4	-	1.92	-	-	1.03	-	2.37	3.03	-	2.98
5	-	2.11	-	-	0.96	-	2.01	3.21	-	2.44
6	-	1.96	1.88	-	1.04	-	2.23	2.23	-	2.22
7	3.71	2.52	1.75	-	0.95	-	2.33	3.05	-	2.67
8	2.66	1.74	1.35	-	1.23	-	2.53	2.87	-	2.82
9	3.44	1.43	0.70	-	1.27	-	2.27	1.78	-	2.88
10	3.05	2.49	1.40	-	0.95	-	-	2.62	-	-

11	1.93	1.96	1.80	-	0.76	-	-	2.53	-	-
12	1.1	2.32	1.97	-	0.71	-	-	2.7	-	-
13	2.9	1.97	1.92	-	0.27	-	1.96	2.6	-	-
14	1.61	1.86	1.66	1.64	0.21	-	2.19	2.98	-	-
15	1.65	2.11	1.41	0.80	0.30	-	2.68	3.15	-	-
16	1.16	1.83	1.64	0.41	0.26	-	2.41	3.39	-	-
17	0,96	1.75	0.36	1.36	0.38	-	2.38	3.32	-	-
18	0.36	1.92	1.48	1.4	0.50	-	2.25	-	-	-
19	0.18	0.75	1.65	0.73	0.34	-	1.26	-	-	-
20	0.63	0.19	1.81	0.90	0.54	-	2.24	-	3.1	-
21	1.12	0.45	1.88	1.27	0.43	-	2.68	-	3.19	-
22	1.64	0.20	1.73	1.1	0.46	-	2.93	-	2.99	-
23	2.33	3.00	0.95	1.20	0.5	-	2.91	-	3.04	-
24	1.4	1.66	1.5	0.77	0.54	-	2.96	-	3.1	-
25	0.73	1.70	1.4	0.91	0.785	-	2.93	-	3.12	-
26	0.32	2.81	1.83	0.96	0.89	-	2.88	-	2.05	-
27	1.34	2.87	1.91	1.21	0.96	2.16	2.95	-	2.09	-
28	0.71	2.9	1.27	1.1	0.91	2.19	3.05	-	2.23	-
29	1.1	3.52	1.1	1.1	0.95	2.00	3.14	-	1.86	-
30	1.55	3.62	1.72	1.02	1.00	-7	2.98	-	1.83	-
31	-	3.76	-	-	1.04	-	3.18		1.56	-

Table 4 : Hourly distilled water production and ambient air temperature for three typical days of May 20, 21 and 22, 2012

Time of Day	Hourly distilled water production (lit/m^2-hr)			Ambient air temperature (ºC)		
	May 20	May 21	May 22	May 20	May 21	May 22
7.00 am	0	0	0	32	32	32
8.00 am	0.014	0.018	0.009	33.5	32.5	33.5
9.00 am	0.029	0.054	0.009	33.5	33.5	34.5
10.00 am	0.071	0.061	0.038	36.5	30.5	35
11.00 am	0.214	0.175	0.082	39	32.5	35.5
12.00 pm	0.296	0.251	0.161	40	34	37
1.00 pm	0.321	0.457	0.333	38	36	37.5
2.00 pm	0.348	0.400	0.396	33.5	34	38.5
3.00 pm	0.352	0.398	0.382	33.5	33.5	38
4.00 pm	0.338	0.341	0.404	33	33.5	38.5
5.00 pm	0.257	0.277	0.298	34	33.5	38.5
6.00 pm	0.232	0.241	0.304	36	33	36.5
7.00 pm	0.214	0.205	0.189	36	32.5	36
8.00 pm	0.064	0.091	0.119	36.5	32	30

VIII. Results

Figure 5 shows the variation of the daily production rate throughout the study period. It is observed that the production is higher in summer time (April to June) and lower in winter time. The average production rate is found as 1.8 lit/m^2-day, whereas the maximum and minimum productions are found respectively as 3.76 and 0.21 lit/m^2-day for July 2011 and December 2012.

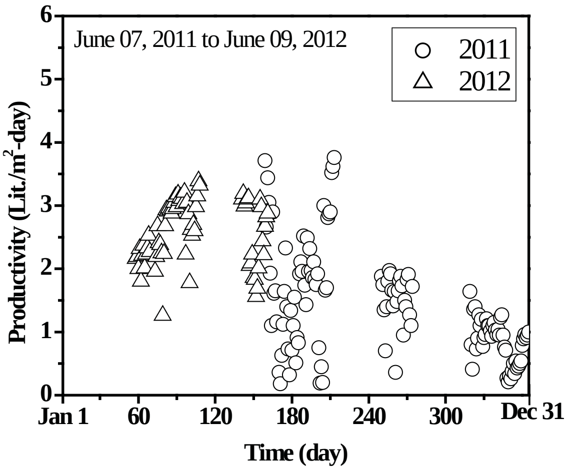


Figure 5 : Variation of production rate of the BSS

Figure 6 shows the variation of the hourly production and ambient air temperature for three typical days May 20 to 22, in 2012. The maximum air temperatures are obtained between 12:00 to 13:00 but the maximum hourly productions are observed between 14:00 to 16:00. The maximum hourly productions are found as 0.35 (15:00), 0.46 (13:00) and 0.40 (14:00) lit/m^2-hr for May 20 to 22 of 2012, respectively.

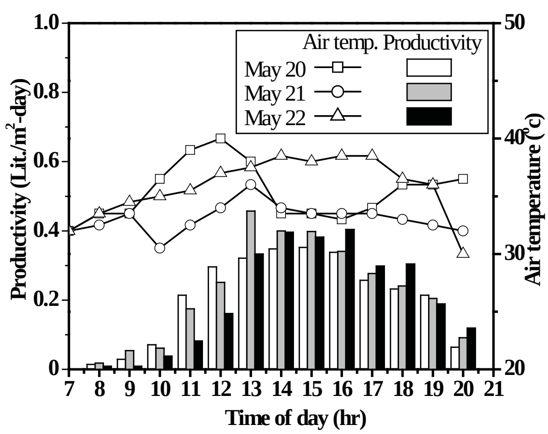


Figure 6 : Variation of hourly productivity and ambient air temperature

Figure 7 shows the average daily production for various months for the study period and given in Table 5. The highest and lowest values are found respectively as 2.87 and 0.73 lit/m^2-day for April and December.

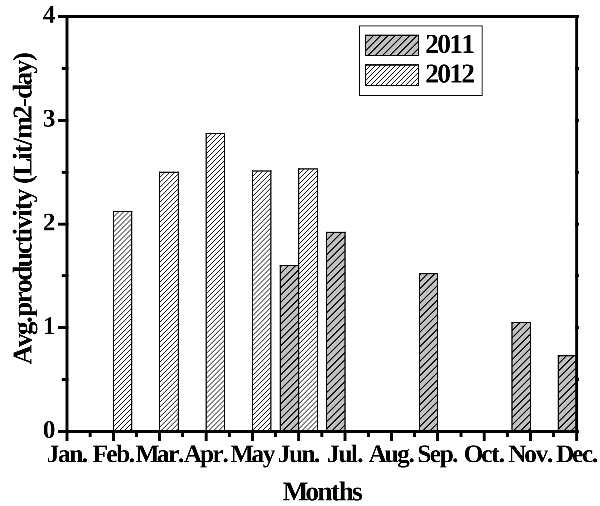


Figure 7 : Comparison of monthly production rates

Table 5 : Average daily production rate for the BSS

Name of months	Average production rate (lit/m^2-day). of conventional BSS	
	Year (2011)	Year (2012)
January	-	-
February	-	2.12
March	-	2.50
April	-	2.87
May	-	2.51
June	1.60	2.53
July	1.92	-
August	-	-
September	1.52	-
October	-	-
November	1.05	-
December	0.73	-

Figure 8shows the comparison of maximum daily production rates for the conventional basin type still with the stepped one (Imran, 2012) throughout the study period and tabulated in Table 6. It is found that the production rates are approximately 16% higher in case of stepped basin type still.

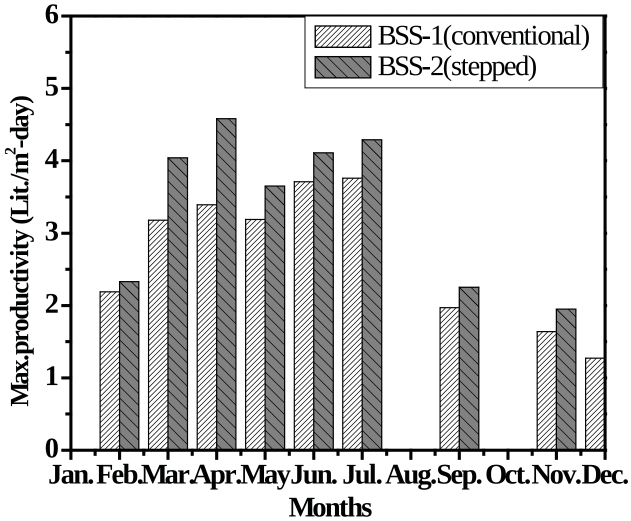


Figure 8 : Comparison of maximum production rates of different BSS

Table 6 : Comparison of maximum daily production rates (June 11, 2011 to June 9, 2012)

Name of months	Maximum daily production rate (lit/m^2-day)	
	Conventional BSS	Stepped
January	-	-
February	2.19	2.33
March	3.18	4.04
April	3.39	4.58
May	3.19	3.65
June	3.71	4.11
July	3.76	4.29
August	-	-
September	1.97	2.25
October	-	-
November	1.64	1.95
December	1.27	1.59
Total	24.3	28.79
Production rates = (28.79-24.3) = 4.49 % of production rates = (4.49 ÷ 28.79) ×100 = 15.6		

IX. Cost Analysis

Table 7 shows the cost analysis for the BSS. The construction cost of the still is estimasted as Tk. 1200 with a design life of 10 years. The production cost of the distilled water is calculated as 0.33 Tk./lit.

Table 7 : Cost analysis for the BSS

Sl. No.	Item Description	Unit	Rate (Tk.)	Quantity	Amount (Tk.)
1	Cement	kg	9	35	315
2	Sand	cft	20	2	40
3	G.I. wire	kg	75	2.5	188
4	Transparent glass	sft	45	8	360
5	Miscellaneous				297
Total =					1200
Design life of the BSS = 10 years Construstion cost of the BSS = Tk. 1200 Operation and maintenance cost = Tk. 0 The average daily production of the BSS = 1.01 lit/day Total production of water in the design life =10×365×1.01 = 3687 lit. Production cost of water = (1200 ÷ 3687) = 0.33 Tk./lit.					

Results

The scarcity of fresh water is increasing day by day in arid, remote and coastal areas. Also in the south western region of Bangladesh, shallow and deep aquifers contain arsenic and high salinity, respectively. Salinity and arsenic in water poses a serious problem for the development of appropriate water supply system. In these areas desalination techniques could be applied to meet fresh water demand produced from brackish or saline water. Among desalination techniques, solar desalination is a simple and low cost technique due to no use of fossil fuel or electricity. A basin type solar still (BSS) is the most popular method of solar distillation compared with others due to its simplicity and longer design life. In this study, a conventional basin type solar still (BSS) is designed, constructed and field experiments have been carried out fromJune 07, 2011 to June 09 2012 on the top roof of Civil Engineering building. The average daily and hourly production rates are found as 1.80 and 0.20 lit/m^2-hr, respectively. The maximum daily and hourly productions are found as 3.76 lit/m^2-day in July, 2011 and 0.46 lit/m^2-hr, respectively. It is observed that the production is higher in summer time (April to June) and lower in winter time. The average daily production for various months with highest and lowest values is found as 2.87 and 0.73 lit/m^2-day for April and December, respectively. It is found that the production rates are approximately 16% higher in case of stepped basin type still. The construction cost of the still is calculated as 1200 Tk. /BSS and the water production cost is estimated as 0.33 Tk/lit with a design life of 10 years.

X. Conclusion

The design, construction and operation of BSS are very simple. Also operational and maintenance cost is very low. Since the initial and water production cost of the still is low, it could be one of the acceptable options for providing drinking water for a single house or a small community in arid, remote and coastal regions.

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