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RESEARCH ARTICLE

TO ENHANCE THE PERFORMANCE OF SOLAR STILL WITH REFLECTORS

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Abstract

The solar still is an errorless well spring of freshwater for farming and drinking in far away, widely different areas or islands. There are great numbers of sort of solar stills the least difficult and most put examples on view of is the basin solar still. Observations put examples on view of that the common still has limited amount produced. Researches have taken determinations to make different designs of solar stills to get well the amount produced and got knowledge by reasoning that solar stills incorporated with reflectors are the most efficient and effective Designs The reflectors, either outside or inside, are a good and cheap modification to increase the solar irradiation given direction to the basin liner or the water along with the distillate efficiency of the still. In this paper, a wide measures taking for different solar stills with reflectors has been showed.

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Introduction:-

People existing in isolated areas or islands, where freshwater source by transport is costly, face the problem of water scarcity every day. Solar still offerings specific advantages to be used in these ranges due to its easier production, minimum skills of operation and preservation requirements, and responsiveness to the environment. The clean free and ecofriendly to the environment are two major benefits which strengthen the use of solar stills. The main drawback of solar stills is the low production of freshwater in comparison with the other distillation systems. The production volume for a simple type solar still is only between 2–5 /m²/day. This makes the solar stills uneconomic compared to the other conventional distillation systems [1]. Many researchers have reviewed, comprehensively, the latest work on solar stills such as classification [2], design [3], improvement techniques [4], passive [5], active [6], inclined [7], stepped [8], wick type [9], and condensers with solar stills [10]. There is no specific manageable survey on solar stills with reflectors. Along these lines, this work is to make a documental study on the solar stills combined with external reflectors and internal reflectors.

Conventional Solar Still with Reflectors:-

Internal reflectors are suitable tools to concentrate and transmit solar radiation. They are suggested when sunlight is weak or the local temperature is comparatively low. External reflectors are ideal to be used to change the direction of solar rays to improve the flexibility of the absorber plate configuration such as vertical solar absorber plate which helps to recover the vapor latent heat of condensation. External and internal reflectors are suggested when sunlight is weak or the local temperature is discreetly low shown in Figure no 1.

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Categorization of reflector with solar stills:-

To get high distillation production, scientists introduced many efforts to make different design of solar stills. They concluded the solar still integrate with reflectors is effective and efficient. The reflectors with solar stills can be distributed into three types (1) internal reflectors (2) external reflectors both top and bottom, and combination of internal and external reflectors. To utilize the external and internal reflectors can be an economical method to expand the solar irradiation incident on the basin liner to make high productivity as possible. A simple valuation of different solar stills with reflectors is showed in Table no 1. The evaluation based on location, daily productivity, yield improvement and efficiency.

Internal reflectors (IR):-

The reflectors inside the solar still affect significantly the output of distilled water, which is credited to the centralization of the reflected solar radiation incident on the water. Besides, reflectors decrease the waste heat energy from solar still. Tamimi [11] studied experimentally the performance of a single slope solar still

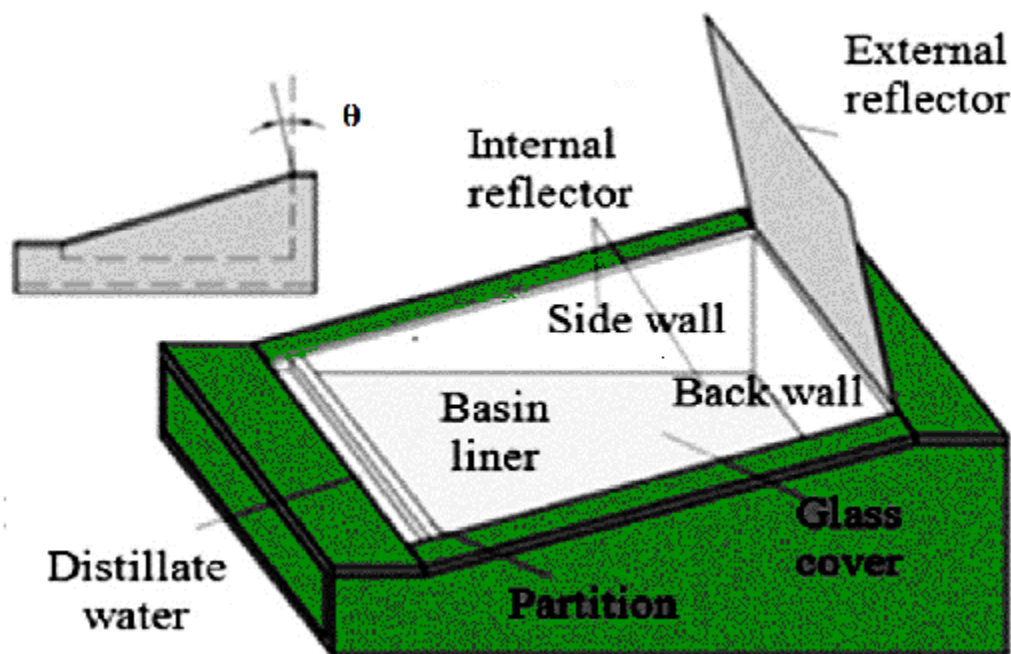


Figure 1:- A Solar Still basin with reflector

Single basin solar still with mirrors installed on the side walls of a still. They concluded that by using mirrors the basin efficiency increases during the whole day. El Swify and Metias [12] used scientific modeling and conducted experiments to find out the effect of internal reflectors on the back and side walls of a single slope solar still with its back wall acting as an additional condenser showed in Figure No.2. They mentioned that the distillation increase of 80% & 20% can be obtained from installing reflectors in the summer and winter season, respectively. New designs of solar still consist of a metallic cylindrical parabolic reflector studied by Minasian et al. [13]. The reflector was design to concentrate incident solar radiation on the black outside surface of a tray located on the focal line of the reflector. The tray was lined with blackened wick, which represents the evaporative surface of proposed still which was shown in Figure no. 3. They showed that the productivity of the latest still was 23–33% greater than that of a conventional basin type solar still. Abdallah et al. [14] provides the modified basin solar still. The design modification was fix the interior reflecting mirrors on the internal walls of the still to minimize the amount of energy lost shows in Figure no 4. The experimental result was shows that the use of internal mirrors improved the system thermal performance up to 32%. The solar still design was modified from flat basin to stepwise basin and the efficiency increases by a normal value of 185%. AlHayek and Badran [15] compared the performances of a double slope basin solar still and a single slope basin solar still. The inside surfaces of complete walls were made of mirrors. They performed their experiments during July and determined that using mirrors on the inside walls of the single slope basin solar still improved the production of distilled water by 18% higher than the double basin solar stills. The effect of an internal reflector on the production of a single slope solar still (during the winter and summer)

was examined experimentally and theoretically by Karimi et al. [16]. They presented a scientific model considering the effect of all walls (east, west, north and south) of the solar still on the amount of received solar radiation to brine. The model was validated with the experimental data. The model can calculate the yield of the still with and without Internal Reflector on various walls. The result shows the simultaneous use of Internal Reflector on front and side walls enhances the solar still efficiency by 16%. Though, installation of an Internal Resistance on the back wall can increase the annual efficiency by 20%. The installation of Internal Resistance on all walls in comparison to a still without Internal Reflector can increase the distillate production at winter, summer, and the entire year by 60%, 20%, and 31%, respectively. Modification of the stepped solar still over installing Internal Reflector on the vertical side which was introduced by Omara et al. [17]. The productivity of the stepped solar still with Internal Reflector was higher than that without the Internal Reflector. The results also indicated that the productivity of the modified stepped solar still with and without Internal Reflector is higher than that of the conventional solar still by almost 70% and 50%, respectively. Also, the efficiency of the stepped solar still with reflectors and without reflectors was 54% and 51% respectively, whereas, the efficiency of the conventional solar still was only 32%. The performance factors of the Corrugated Solar Still (CSS) and Conventional Solar Still (CnSS) were studied experimentally by Omara et al. [18]. The author's view concerns with using both double layer wick material and reflectors composed inside the CSS, Figure no 5. In addition, the influence of saline water depth (1.5, 2.5, and 3.5 cm) on CSS performance was also studied. During investigations, the product of CSS with wick and reflectors is about 146% higher than the CSS at a brine depth of 1.5 cm. In addition, the daily efficiencies of CSS and CnSS were approximately 60% and 35%, respectively. In other experimental study by Omara et al. [19], a hybrid solar distillation system covering of corrugated and wick absorbers of solar stills was combined with an external condenser and internal reflectors to study their performance. They showed that the productivity of corrugated wick still with reflectors and external condenser was improved by about 182% over CnSS at a brine depth of 1.5 cm.

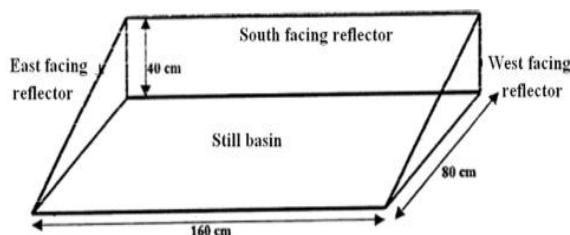


Figure 2:- Double Exposure solar still With Internal Reflectors.

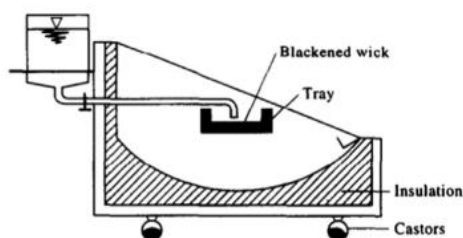


Figure 3:- Basin solar still with cylindrical parabolic reflector.

External reflector (ER):-

The external reflector used in the solar still is made up of greatly reflective materials such as mirror finished metal plate. The diffuse and direct beams transmitted over the glass cover are improved by using the ER. Scientist (Hiroshi Tanaka) is the most concerning to study the effect of reflector on the distillate of stills.

External top reflectors:-

Tanaka et al. [20–22] showed numerical investigation on a tilted wick solar still with a top mirror (vertical [20], forwards [21] and backwards [22]) extending from the upper edge of the still. They displayed geometrical models to compute the solar irradiation reflected from a top mirror and then absorbed on the evaporating wick. They concluded that the top mirror can increase the absorbed solar radiation by evaporating wick, and added, the amount of solar irradiation reflected from the top mirror and absorbed on the wick can be enhanced by inclining the top mirror to be backwards in summer and forwards in winter. A theoretical analysis was used by Tanaka and Nakatake [20] to study the effect of a vertical flat plate External Reflector on the productivity of a TWSS and shows the average increase of

10% in a year. Another theoretical analysis of a top External Reflector with TWSS on a winter was investigated by Tanaka and Nakatake [21]. Their results indicated that the productivity of a still with an inclined reflector would be around 12% or 25% over that with a vertical reflector when the reflector length is a half of or the same as the solar still length. In adding, a theoretical analysis was made on TWSS with external top reflector with the aim of determining optimum inclination for both reflector and solar still for different seasons by Hiroshi Tanaka [22], Figure No 5. Regarding to the results obtained, 30°N latitude was represented as the best inclination angle either for the still or the reflector monthly. In addition, he concluded that for any season the daily productivity of the solar still can be improved by adjusting the inclination of both the reflector and solar still, thus producing around 20% over the traditional TWSS throughout the year. Tanaka and Nakatake [23] displayed another theoretical investigation of one step azimuth tracking TWSS with a vertical flat plate reflector. The TWSS is assumed to be rotated manually just once a day at southing of the sun. They performed numerical analyses of heat and mass transfer in the still to determine the daily productivity of the still on four typical days: the spring and autumn equinoxes and summer and winter solstice days at 29°N latitude. For four days, results indicated that the increase in the productivity of TWSS would be around 40%, and can be accomplished by the simple modification of utilizing a reflector. El-Bahi and In an [24] examined a conventional still integrated with an outside condenser in Figure No 6.

Table 1:- Simple comparison of different solar still with reflectors

No	Categorization	Authors	Locations (Latitude)	Reflector material	- Daily yield (kg/m ² /d) - Improvement - Efficiency	Reflectors effect (%)	Observations in experiment
1. Internal reflectors							
1	Conventional still	El-Swify et al. [12]	Cairo, Egypt (25° N)	Mirrors	3.05–7.2 82.6% in winter 22% in summer –	82.6% 22%	The cooling effect of the back glass cover, back condenser, is improved due to the higher temperature difference as compared to the ordinary one.
2		Minasian et al. [13].	Baghdad, Iraq, (33.33°N)	Stainless steel	1.23–6 25–35% –	25–35%	The productivity of the conventional basin type solar still has been increased by using a stainless steel cylindrical parabolic reflector.
3		Abdallah et al. [14]	Amman, Jordan, (32°N)	Mirrors	1.64 30% ~	30%	Installing internal side mirrors gave better performance because these mirrors make use of the energy reflected on all sides of the solar still.
4		AlHayek and Badran [15]	Amman, Jordan (32°N)	Mirrors	– 20% 11%	20%	Performance characteristics of the stills showed that the temperature at the water surface is increased with decreasing water depth, and by the addition of dye.
5		Karimi et al. [16]	Iran. (30°N)	Mirrors	– 34% –	34%	The installation of IRs on all walls in comparison to a still without IR can increase the distillate production at winter, summer and the entire year by 65%, 22% and 34%, respectively.
6	Stepped solar still	Omara et al. [17]	Kafrelsheikh, Egypt, (31.07°N)	Mirrors	6.35 75% 56%	18%	Productivity of stepped still with and without internal reflectors was higher than the conventional still by 75% and 57% respectively.
7	Corrugated wick solar still	Omara et al. [18] and [19]	Kafrelsheikh, Egypt, (31.07°N)	Mirrors	4.1 145.5% 58%	55%	The yield of Corrugated wick solar still with reflectors when providing a vacuum was enhanced to about 180% higher than the conventional still.

2. External reflectors**External top reflectors**

8	Tilted wick solar still	Tanaka and Nakatake [20]	Kurume, Japan (33°N)	Mirrors	– 9% –	9%	The average daily amount of distillate for four days, (spring and autumn equinox and summer and winter solstice days), peaks when the angle of the still is 20° for the still with the reflector, and peaks at 30° for the still without the reflector.
9		Tanaka and Nakatake [21]	Kurume, Japan (30°N)	Mirrors	4.2 15% –	15%	
10		Tanaka [22]	Kurume, Japan (30°N)	Mirrors	– 21% During the year –	21%	
11	Conventional still coupled with external stainless steel reflector and outside condenser	E1-Bahi and Inan [24]	Ankara, Turkey, (39.6°N)	Stainless steel	–	–	
12	Conventional still	Shanmugan et al. [26]	Tamil Nadu, India (11.30°N)	Mirrors	4.2 – 45	–	The efficiency of the still was as high as 35%, and increased to 45% with the mirror booster. The twin reflector booster has to be reoriented only once in a day at mid-noon. The main advantage of the “V” type solar still is due to center collection and all the condensation are easily directed to the outlet.
13	Conventional still With twin reflector	Srivastava et al. [27]	Rewa India (24.32°N)	Mirrors	79	79%	
14	“V” type solar still	Selva Kumar et al. [28]	India (22°N)	Mirrors	2.7 7.3 12	7.3%	
External bottom reflectors							
15	Double slope single basin solar still	Sebaï [29]	Tanta, Egypt (31° N)	Mirrors	– 19% and 30% summer and winter –	19% and 30% summer and winter	The daily productivity of the double slope single basin solar still with mirrors is higher than that without mirrors, due to the increased basin

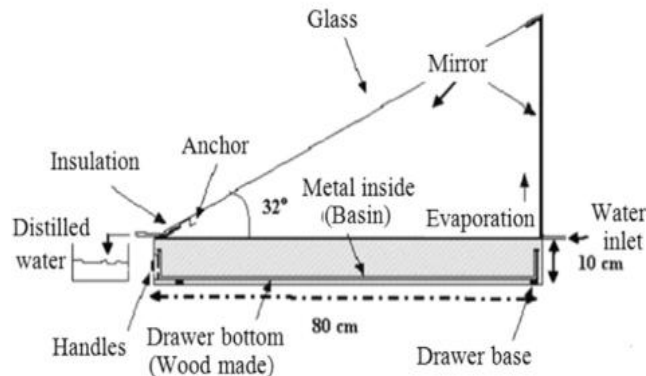


Figure 4: basin solar still with Internal Reflector

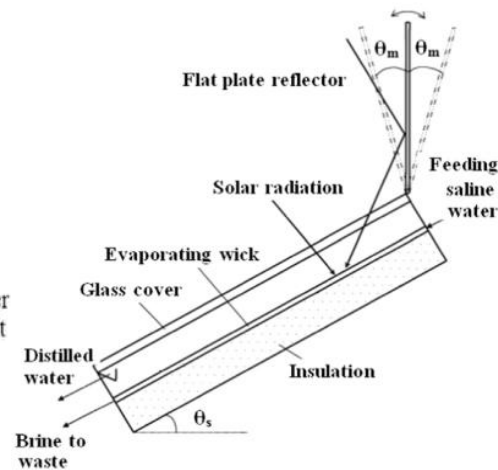


Figure 5: Top reflector with TWSS

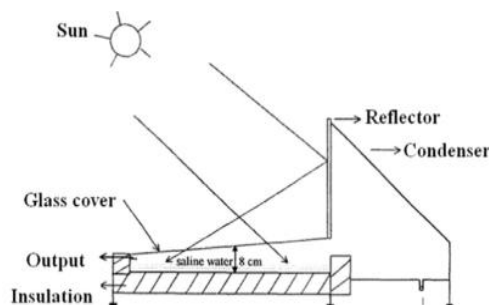


Figure 6:- Conventional Still integrated with top reflector.

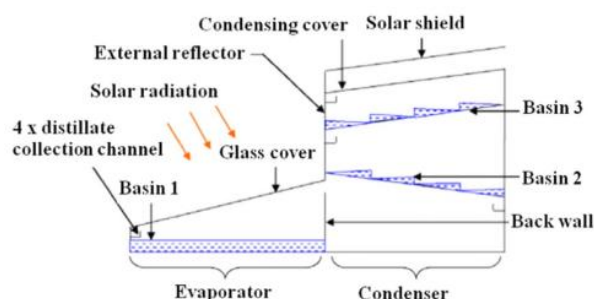


Figure 7:- Basin solar still with reflector and external condenser.

A reflector made of stainless steel was added to the glass cover to reflect the solar radiation into the still basin through the glass cover and to give a shadow for the condenser. The study led to the conclusion that the efficiency of the solar still was enhanced by about 72% and the daily productivity was up to 7 l/m^2 a day. Madhlopa and Johnstone [25] proposed a model to calculate the distribution of solar irradiation inside a conventional still with reflector and external condenser, Figure no 7. The system had one basin in the evaporation chamber and two other basins in the condenser chamber. It had a glass cover over the evaporator basin and an opaque condensing cover over basin 3. Water vapor from the first basin condenses under the glass cover while the remainder flows into the condenser by purging, diffusion, and condenses under the liner of basin 2. They found that distilled freshwater was about 2.1 kg/m^2 a day. The performance of an acrylic mirror boosted solar distillation unit was studied by Shanmugan et al. [26]. The performance of solar still in terms of distilled water collection has been analyzed and a booster mirror (acrylic) was attached just above the glass cover of solar still. The mirror boosting reflects the excess solar radiation to water and it is possible to adjust the booster mirror for perfect reflection depending upon the sun moving angle. The maximum amount of water collected per day was about 4.1 L. The efficiency of the still was as high as 33%, and increased to 43% with the mirror booster. Srivastava et al. [27] performed experiments of a modified solar still with multiple low thermal inertia porous absorbers, Figure no 8. The absorbers were made up of jute cloth and they float on the basin water with the help of thermocol insulation. The surfaces of the absorbers were always wet and hence there were no dry spots. The results showed that the productivity was 66% more than the conventional still and 33% more on cloudy days. The basin water below the floating absorber remained warm during offshine hours, and hence, the distillate was produced even at nights. A twin reflector booster was placed perpendicular to each other on the modified stills. The productivity increased by 77% over the still without booster. The thermal performance of a “V” type solar still with a charcoal absorber was analyzed by Selva Kumar et al. [28]. The main advantage of this type of still is that the distilled water collection was directed towards the central water collection channel as shown in Figure no 9. The production of the outlet distillate water had increased. The overall efficiency was found to be 25% and 12% for the still without and with the boosting mirror, respectively. He also conducted similar experiments which were carried out for the charcoal absorber in the still without and with the boosting mirror which yielded 30% and 14% respectively.

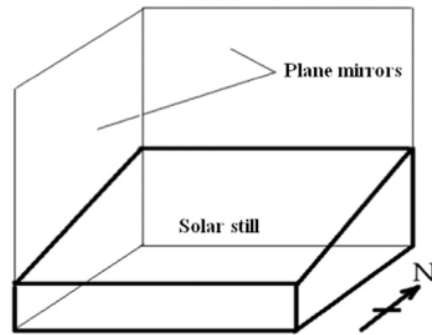


Figure 8:- Twin reflector booster applied to solar still.

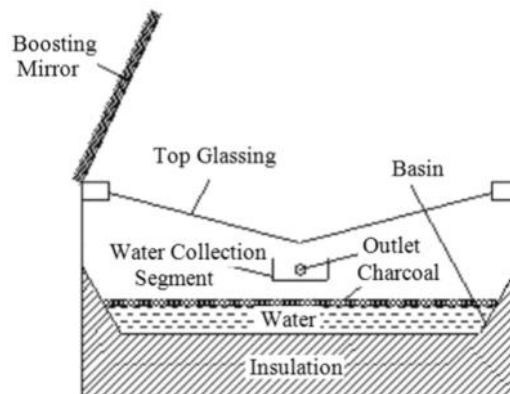


Figure 9:- V type solar still with External reflector.

Scope for further research:-

There are still some problems and challenges on the design of solar stills not being clearly analyzed for performance improvement, including solar stills with reflectors. This paper reviews the studies and developments of solar stills with reflectors. The results from the preceding work done clearly show that the enhancement of solar stills with reflectors performance differs greatly for different techniques due to different experimental conditions. The review represents specific inferences drawn from the analyses of solar stills with reflectors by various authors to pave way researchers to grasp the previous designs and to fabricate new designs with optimum design parameters for higher distillate output.

The following factors may be taken into consideration for further research of solar stills with reflectors:

For active solar still:

- 1.1 Combine solar still with solar water heater in order to increase the basin temperature.
- 1.2 For active solar stills, more research may be carried out with reflectors.
- 1.3 Further studies should be conducted to improve the solar stills productivity, especially in the fields of coupling with heat storage and various waste heat sources.

For tracking system:

- 1.4 Solar still with azimuth sun tracking and just an adjustment of the optimum elevation of the day.
- 1.5 Combine the solar still with sun tracking and the solar water heater.
- 1.6 The sun tracking system is more effective than fixed still and it is capable of improving the distillate output of the still with reflectors.

Conclusions:-

Reflectors are used to enhance the daily amount of distillate of the solar still. The accompanying conclusions can be inferred on the basis of above discussions

- Installing reflectors is more practical in places where solar radiation is weak and the ambient temperature is relatively low.

- Installation angle of the external reflector should be changed with the seasons to enhance the productivity through all the year.
- The external reflector is inclined backwards or forwards according to the month.
- The daily productivity can be increased by adjusting the inclination of both the still and reflector mirror in any season.
- The benefits of both the inclined external top and internal reflectors would be considerably less in summer than in winter.
- For the still with larger angle of the glass cover, the effect of the external top reflector would be smaller.
- The vertical flat plate external reflector would be less effective for the tilted wick solar still than for the conventional still.

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