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*RESEARCH ARTICLE*

# COMPARATIVE STUDIES ON A SINGLE SLOPE SOLAR DISTILLATION UNIT WITH AND WITHOUT COPPER ELECTROPLATING ON ALUMINIUM BASIN.

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## Abstract

Water is one of the most important resources in the world even though 70% of the earth is covered in water less than 1% of it is in humans reach. Even that much amount of water plays a very crucial role in human life. But due to different human activities the fresh water is getting polluted each and every day so treating it is very important for development. There are many methods to treat waste water among them solar distillation is very important since it uses only solar radiation for the treatment. The basin of a solar distillation unit is very important. It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material have high absorbtivity or very less reflectivity and very less transmitivity. In this paper we studied the performance of a solar distillation unit with and without Copper electroplating on Aluminium basin. We observed that the efficiency had increased from 49.78% to 54.66% by electroplating the aluminium basin with copper.



## Introduction:-

Water is the most abundant and important substance in nature. About 70% of the planet is covered in water, yet all that, only around 2% is fresh water and of that 2%, about 1.6% is polar ice caps and glaciers, 0.4% is drinkable water from underground wells or rivers and streams(Chendake et al., 2015). Water is essential for all life forms on earth-plants, animals and human being, etc. For fresh water requirements humanity is dependent on rivers, ponds, lakes and underground water reservoirs. The available fresh water on earth is fixed, but the demand of fresh water is increased due to population growth and rapid industrialization. Industrial wastes and sewage discharges are mostly mixed in the rivers, so the available fresh water availability is reduced. The provision of fresh water is gradually becoming a more important issue in many areas of the world(Hitesh Panchal, 2015). About 20 percent of the world's people live in regions that don't have enough water for their needs (according to the World Health Organization), With the global population increasing by 80 million each year, a third of the planet will likely face water shortages by 2025( Kabeel et al., 2015). To overcome this problem, there are various methods to produce fresh water from sea water, saline water or brackish water. Desalination processes have received great attention as an alternative solution for fresh water production. Desalination is one of the methods which is suitable for potable water. The demand for reliable and autonomously operating desalination systems is increasing continuously. These systems are meant for a basic need of drinking water and fresh water supply(Naga Sarada Somanchi et al., 2015). A water distiller captures

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the process of evaporation and condensation in a chamber, leaving behind all impurities, such as inorganic materials and chemicals. It can even purify seawater. Distillation is one of the mankind's earliest forms of water treatment, and it is still a popular treatment solution throughout the world today. In ancient times, the Greeks used this process in their ships to convert sea water to drinking water and also to treat water in other area that are fouled by natural and unnatural contaminants. Solar still having the advantage of low capacity and self reliance is best suited as, they can produce pure water by using solar energy only, and do not need other expensive energy sources such as fuel or electricity( Rajamanickam et al., 2012). The process of desalination can be classified into two categories based on the consumption of energy namely; thermal process and non thermal process. Present work is mainly focused on thermal process. Solar stills are classified into two groups in terms of energy supply: active and passive systems. Among active and passive systems, passive solar system is preferred because it is cheaper compared to active solar still. Moreover, in active solar system there is a need of pump which requires electricity for its operation. A single slope solar still is a very simple device used for converting available brackish or saline or waste water into potable water. This is fabricated easily with locally available, materials like wood, aluminium etc. the maintenance is also very cheap and no skilled labour is required. Moreover, it is an excellent solution for solving drinking water or potable water problem (Ravi Gugulothu et al., 2015). A number of studies have examined the effect of cover geometry and inclination in solar stills with the purpose of optimizing the amount of solar radiation captured by the still (Tanaka et al., 2009, Abdallah et al., 2008, . Kumar S. et al., 1998, Singh A. et al 1995). (Tripathi et al., 2004) reported that the change in length for a given height and width of a still does not affect the daily output but the change in the height of the north wall for a given height affects the daily output. Single sloped stills have been reported to give better yield in winter while double sloped stills performed better in the summer(Yadav et al., 1987). On the other hand, for locations with latitude higher than 20°, single-sloped stills are preferable whereas for lower latitudes, double-sloped stills facing north and south directions and having a cover inclination equal to the latitude angle could receive sun rays close to normal throughout the year(Murugavel et al., 2008). A pyramid-shaped cover has also been used but did not improve the productivity(Fath et al., 2003). Other researchers have utilized different cover concepts by changing the basic still configuration using vertical stills(Boukar et al., 2004), spherical stills(Dhiman, 1988), multiple-stage stills(Tanaka et al., 2007), hemi-spherical stills(Nassar et al., 2007), elliptical metallic stills(Ismail, 2009) or transparent tubes as solar stills(Reali et al., 2008).

## Principle:-

The operating principle of a solar still used for water distillation involves phase change water vapour .It permits the separation of the water constituents into salts deposits and distilled water. In fact, the solar flow transmitted through the glass cover achieves the absorber, which in return emits thermal radiations, this fact heats water. Under the influence of heat, the water evaporates successively leaving only water's molecules, a dissolved salt deposit and all other residues in waste water. The obtained vapour condenses and the distilled water streams on the interior face of the inclined slope glass put in drains which drives it into a stocking tank(Hanane Aburideh et al., 2012). A schematic diagram of a solar distillation unit explaining its principle is shown in the Fig 1.

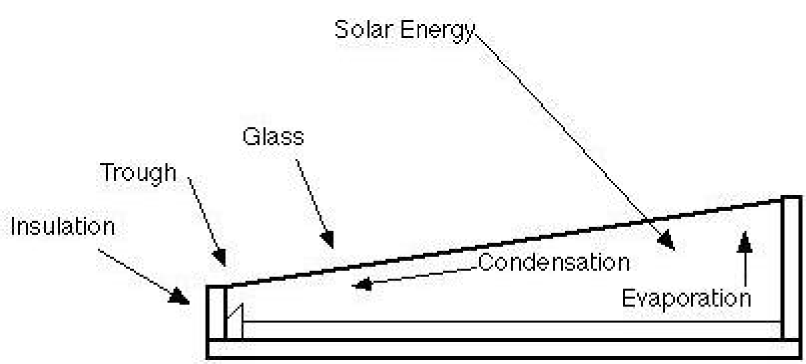


**Fig 1:-** schematic diagram of a solar distillation unit explaining its principle.

## Experimental setup:-

A single slope solar distillation unit consists of a wooden box of length 0.715 m, breadth 0.415 m, height at the smaller edge 0.125 m, height at the longer edge 0.36 m, and thickness 0.01 m. The inside of the box is insulated on all the sides with a 0.02 m thick of thermocol sheets. A metal basin of length 0.64 m, breadth 0.33 m, and height 0.085 m which will hold the waste water is placed on the insulation. The top of the box is covered by a glass sheet of thickness 0.04 m at an inclination of $18^o$and a collector is attached at the lower end to collect the condensate. A rubber stripe is placed on the edges of the wooden box so that the glass won't slip down and helps in reducing the losses by keeping the water vapour inside. The experimental setup constructed is shown in the Fig. 2.

## Details of different parts of the system:-

**Still basin:-**

It is the part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material have high absorptivity or very less reflectivity and very less transmitivity. These are the criteria's for selecting the basin materials. Kinds of the basin materials that can be used are as follows: 1. Leather sheet, 2. Ge silicon, 3. Mild steel plate, 4. RPF (reinforced plastic) 5. G.I.(galvanized iron), 6.Aluminium, 7.cupper. We have used Aluminium sheet and copper electroplated Al sheet ($K_{Al}$= thermal conductivity of Aluminium = 205 W/m.K. $K_{Cu}$= thermal conductivity of copper = 385 W/m.K) (1mm thick).( SIZE:: 64 X 33 X 8.5 cm box of Al and Cu).

**Side walls:-**

It generally provides rigidness to the still. But technically it provides thermal resistance to the heat transfer that takes place from the system to the surrounding. So it must be made from the material that is having low value of thermal conductivity and should be rigid enough to sustain its own weight and the weight of the top cover. Different kinds of materials that can be used are: 1) wood, 2)concrete, 3)Thermocol, 4)RPF (reinforced plastic). For better insulation we have used composite wall of Thermocol (inside) and wood (outside). Size: wood (k= thermal conductivity=0.6W/m$^0$C, 10mm thick, Thermocol (k= thermal conductivity=0.02W/m$^0$C , 20mm thick).

**Top cover:-**

The passage from where irradiation occurs on the surface of the basin is top cover. Also it is the surface where condensate collects. So the features of the top cover are: 1) Transparent to solar radiation, 2) Non absorbent and Non-adsorbent of water, 3) Clean and smooth surface. The Materials Can Be Used Are: 1) Glass, 2) Polythene. We have used glass (4mm) thick as top cover having rubber tube as frame border. (size : 76 x 41.5cm).

**Channel:-**

The condensate that is formed slides over the inclined top cover and falls in the passage, this passage which fetches out the pure water is called channel. The materials that can be used are: P.V.C., 2) G.I., 3) RPF. We have used P.V.C channel (size: 1 inch).

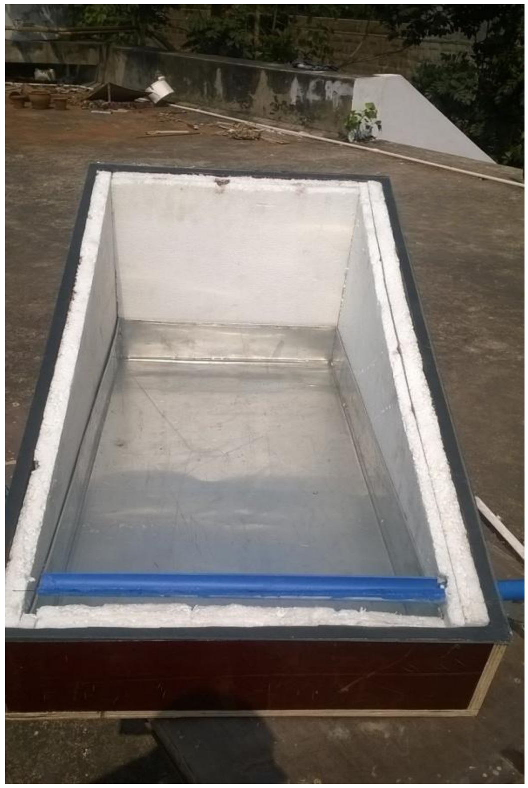
**Fig. 2:-** solar distillation unit with Aluminium basin.

**Experimental procedure:-**

A single sloped solar distillation unit with an aluminium basin is constructed. To determine the optimum direction 2 litres of waste water is taken in basin and distillation unit is placed in the sun light such that the sloped side is directed towards east from 9:30 am to 5:30 pm. At the end of every hour solar radiation is measured using pyranometer, temperature of surroundings, outer surface of the glass, inner surface of the glass, moist air inside the box, water inside the basin and condensate are measured using thermometer and thermocouple. The amount of distillate collected is also measured at the end of each and every hour. Similarly the experiments are conducted in west, south, north and east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm. The direction in which the yield is high is taken as the optimum direction and the remaining experiments are carried in that direction only which is east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm. After fixing the direction the volume of the water is changed (2, 2.5, and 3 lits) and the experiments are conducted again to determine the optimum volume of water. Similarly the experiments conducted by changing the material of the basin with cupper electroplated Al basin. Cylindrical ceramic packing are also used in the basins. A solar distillation unit with copper electroplated Aluminium basin is shown in Fig. 3.

**Fig 3:-** solar distillation unit with copper electroplated Aluminium basin

**Energy balance:-**

The energy balance over the distillation unit is given by

$$I_s A_g/A_b = I_s r_g A_g/A_b + q_{g,s} A_g/A_b + q_{h,g} A_g/A_b + q_{k,air} A_{k,air}/A_b + q_{k,l} A_{k,l}/A_b + q_{k,b} A_b/A_b + (m_{cw} h_{sat,g})/A_b.$$

Where

$I_s$=Solar radiation intensity W/m$^2$ ,$A_g$ Area of glass surface= 0.3154 m$^2$; $A_b$ Area of black surface= 0.2112 m$^2$ ; $r_g$ Reflectivity of the glass cover for visible light=0.04. $A_{k,air}$ Circumferential area of solar still covered by inside moist air,=0.3154 m.$^2$ $A_{k,l}$ Circumferential area of solar still covered by sea water,=0.3154m$^2$. $m_{cw}$=Mass flow rate of condensed water, Kg/m$^2$.sec $h_{sat,g}$=Enthalpy of water at saturation temperature KJ/kg. Considering the heat transfer from the cover to the atmosphere by convection:

$q_{h,g} = h_g (T_g - T_a)$ W/m$^2$

Where $T_g$is the glass temperature,$T_a$is ambient temperature $h_g$ is the convective heat transfer coefficient and is given by the following formula:

$h_g = 5.7+ 3.8w$ W/m$^2$

Where the forced convection coefficient dependent on the wind velocity, w(m/s)=3.75 m/sec.

Radiative heat transfer from the glass cover to the atmospheric air is given by the following formula:

$q_{g,s}=\varepsilon_g C_s [(T_g/100)^4- (T_{sky}/100)^4]$ W/m$^2$.

Where emissivity of the glass, $\varepsilon_g$, is 0.88 for infrared radiation, the constant, $C_s$, is 5.667W/m$^2$K$^4$ and $T_{sky}$ is the sky temperature. Generally for practical purposes the average sky temperature during operations hours can be assumed as about 20°C below the ambient temperature i.e. $T_{sky}$ = Ta- 20°C ;Tg=Temperature of glass K ; Ta=Ambient temperature K .

The conductive heat transfer from the bottom to the atmosphere may be formulated as:

$q_{k,b} = k_b (T_b - T_a)$ W/m$^2$

where $(1/k_b)=(1/h_{in})+(\sum(\delta_i/\lambda_i))+(1/h_a)$ m$^2$ K/W.

$h_{in}$ =Convective heat transfer coefficient at sea water interface, W/m$^2$.

$\sum(\delta_i/\lambda_i)= (\delta_g/\lambda_g)+(\delta_b/\lambda_b)+(\delta_w/\lambda_w)+(\delta_{th}/\lambda_{th})$ m$^2$ K/W.

$\delta_g$Thickness of glass=4mm;$\lambda_g$Thermal conductivity of glass=0.96 W/m.K

$\delta_b$Thickness of basin=1mm;$\lambda_b$Thermal conductivity of basin =205(Al), 385(Cu) W/m.K

$\delta_w$Thickness of wood=10mm ;$\lambda_w$Thermal conductivity of wood=0.17 W/m.K

$\delta_{th}$Thickness of Thermocol=20mm;$\lambda_{th}$Thermal conductivity of Thermocol =0.036W/m.K
$h_a$ = Convective heat transfer coefficient at ambient temperature,$W/m^{2.}$ K.
$T_b$= Temperature of the basin K ; $T_a$=Ambient temperature K.
Considering the heat transfer from the circumferential area of the still by conduction;
From inside moist air to the atmosphere,
$q_{k,air}=k_m\ (T_r - T_a)$ $W/m^2$.
where $(1/k_r) = (1/h_r) + (\sum (\delta_i/\lambda_i)) + (1/h_a)$ $W/m^{2.}$ K
$h_r$=convective heat transfer coefficient at moist air,$W/m^{2.}$
From liquid to the atmosphere,
$q_{k,l}= k_l\ (T_b - T_a)$ $W/m^2$.
Where $(1/k_l)=(1/\infty)+(\sum(\delta_i/\lambda_i))+(1/h_a)m^2.K/W$.

The efficiency of a still can be calculated by the following equation:

$$\eta=\frac{\text{Water output } * \text{Latent heat of evaporation of water}}{\text{Daily solar radiation}} * 100\%$$

$$\eta=\frac{m*2500.7}{I*Ag}*100\%$$

## Results and Discussion:-

For two litres of waste water among the direction like east, west, north, south and east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm the maximum efficiency of 49.78 % is found in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

For Aluminium basin among different volumes like 2, 2.5 and 3litres of waste water the maximum efficiency of 49.78 % is found at two litres and for copper electroplated Aluminium basin the maximum efficiency of 54.66 % is found at three litres

**Hourly variation of temperature at different places in the unit:-**

The variation of temperatures at different places like basin, moist air, inside surface of the glass, outside surface of glass, condensate and ambient temperatures are measure at the end of each and every hour and plotted against time for Aluminium basin is shown in Fig. 4 and for cupper electroplated aluminium basin is shown in Fig. 5.

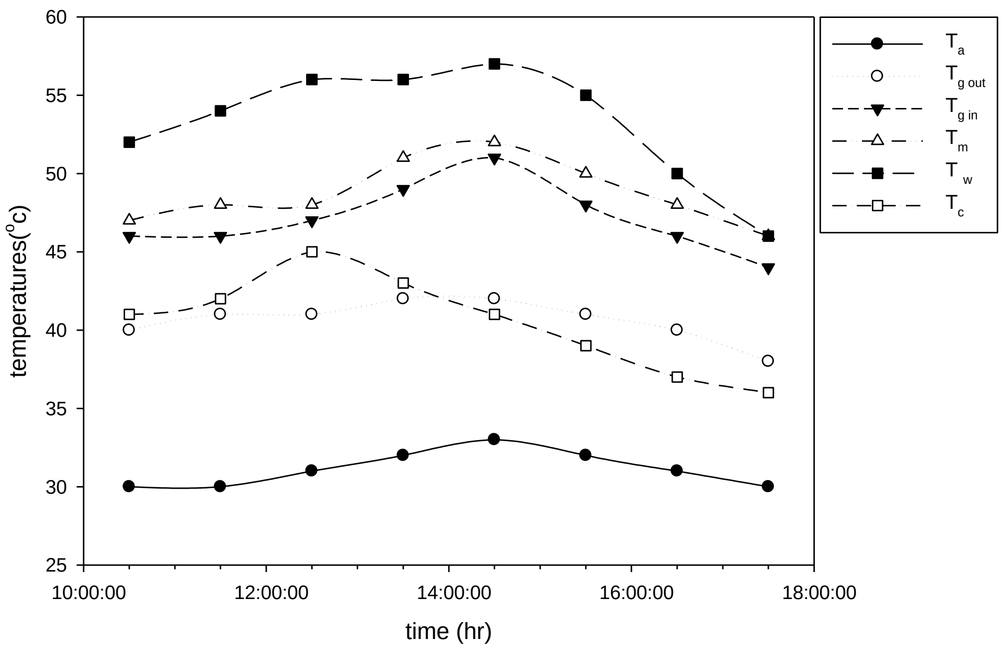


**Fig. 4:-** hourly variation of temperature for Aluminium basin with 2 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

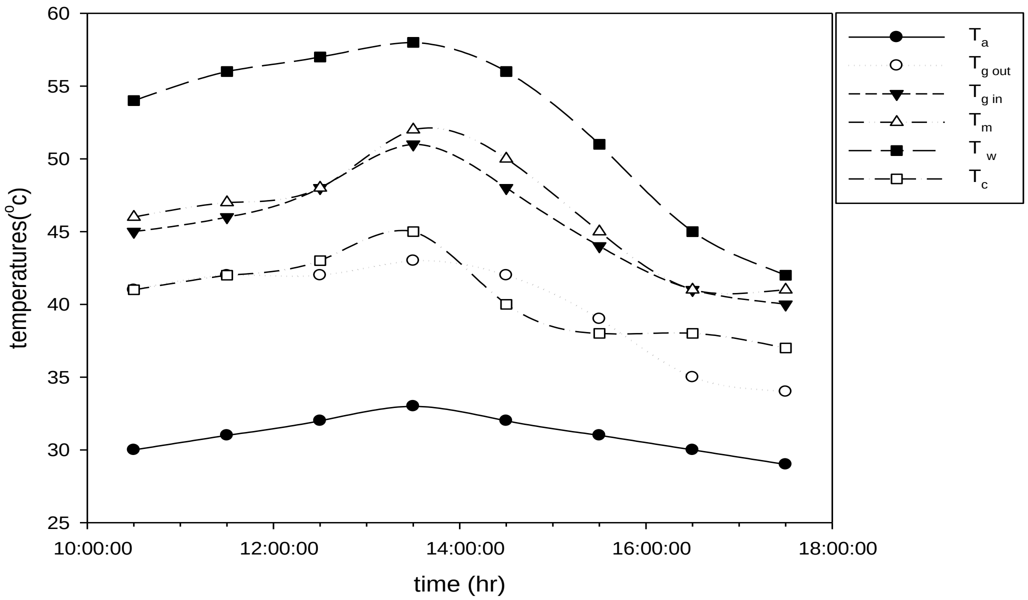


**Fig. 5:-** hourly variation of temperature for copper electroplated Aluminium basin with 3 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

**Hourly variation of distillate collected:-**

The variation of distillate collected with respect to time for Aluminium basin is shown in Fig. 6 and for copper electroplated Aluminium basin is shown in Fig. 7. Maximum distillate is collected around 1:30pm in both the cases but the total amount of distillate collected using cupper electroplated Aluminium basin is higher than the amount collected using Aluminium basin .

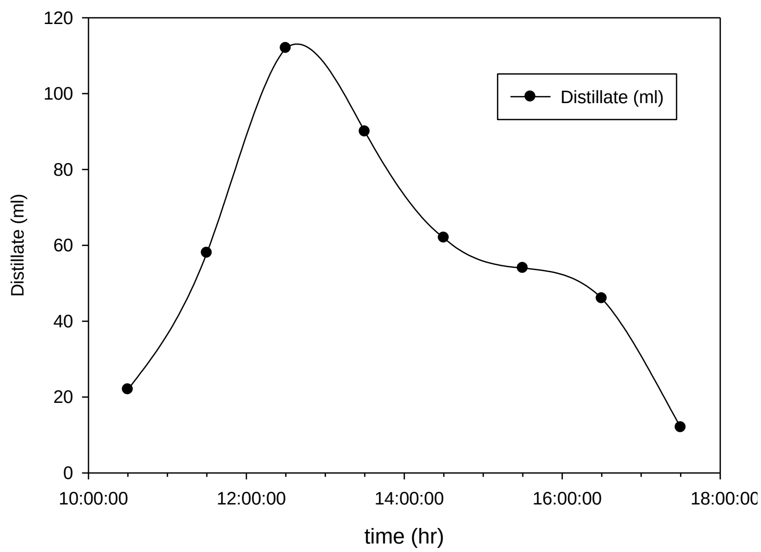


**Fig. 6:-** Hourly variation of distillate collected for Aluminium basin with 2 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

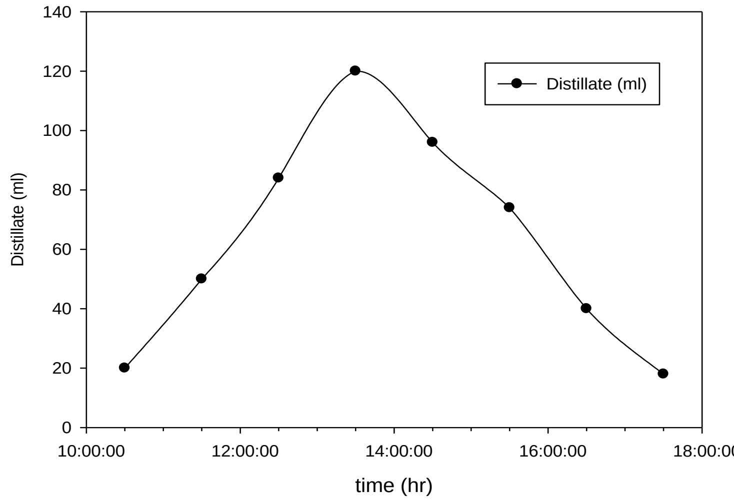


**Fig. 7:-** Hourly variation of distillate collected for cupper electroplated Aluminium basin with 3 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

**Hourly variation of solar radiation:-**

The variation of solar radiation with respect to time during the experiment for Aluminium basin is shown in the Fig. 8 and for copper electroplated Aluminium basin is shown in the Fig. 9.

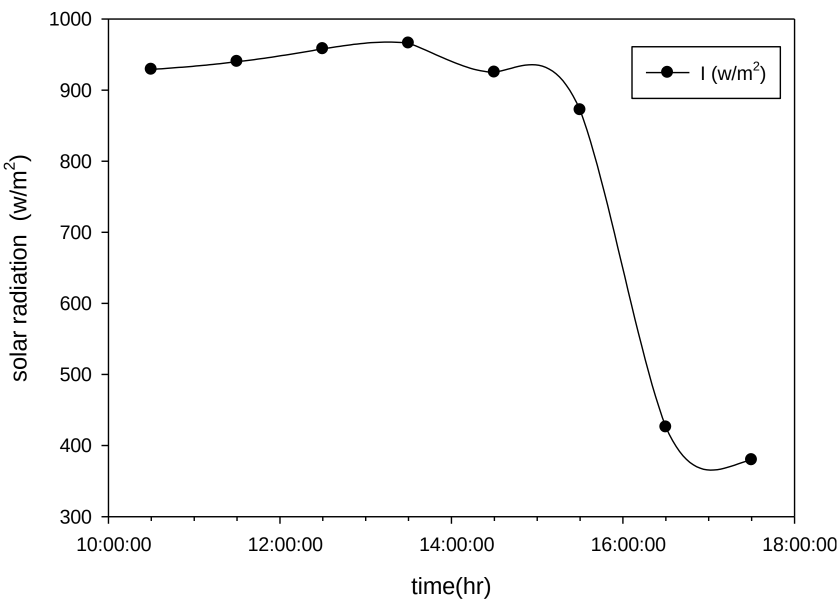


**Fig. 8:-** Hourly variation of solar radiation for Aluminium basin with 2 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

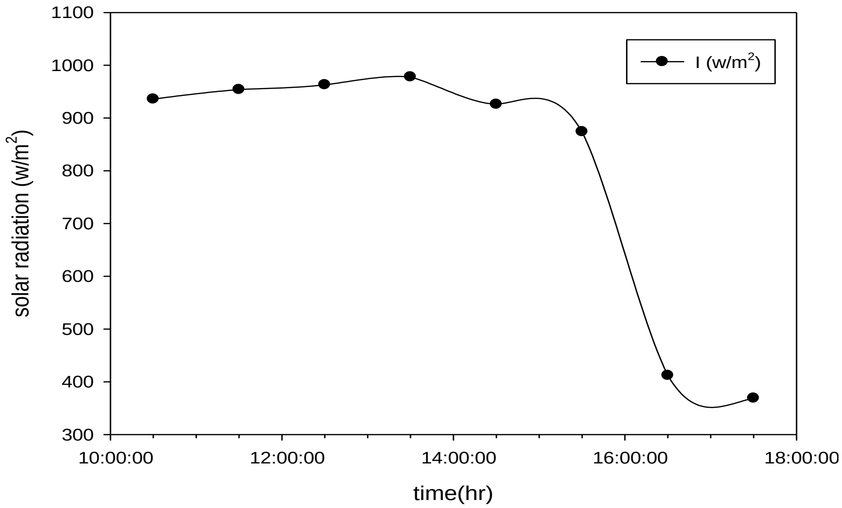


**Fig. 9:-** Hourly variation of solar radiation for cupper electroplated Aluminium basin with 3 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

**Hourly variation of energy input, utilized and lost:-**

The variation of energy input through solar radiation, energy utilized by the solar distillation unit and energy lost with respect to time for Aluminium basin is shown in the Fig. 10 and copper electroplated Aluminium basin is show in Fig. 11.

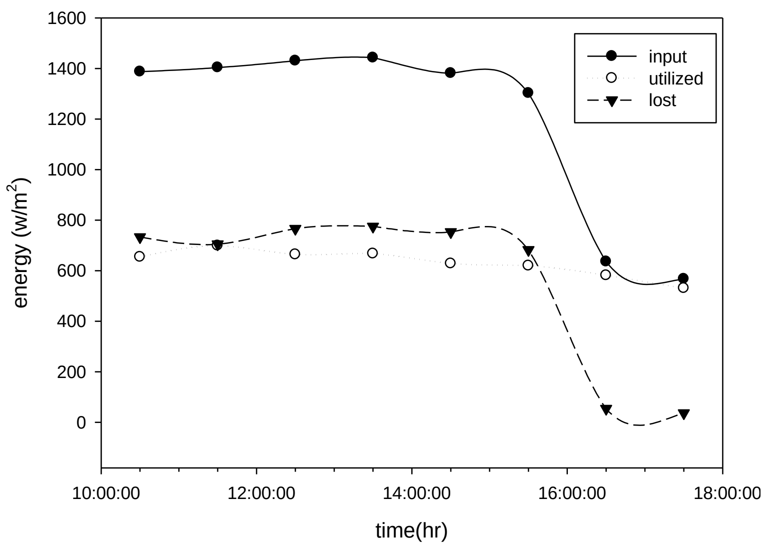


**Fig. 10:-** Hourly variation of energy input, utilized and lost for Aluminium basin with 2 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

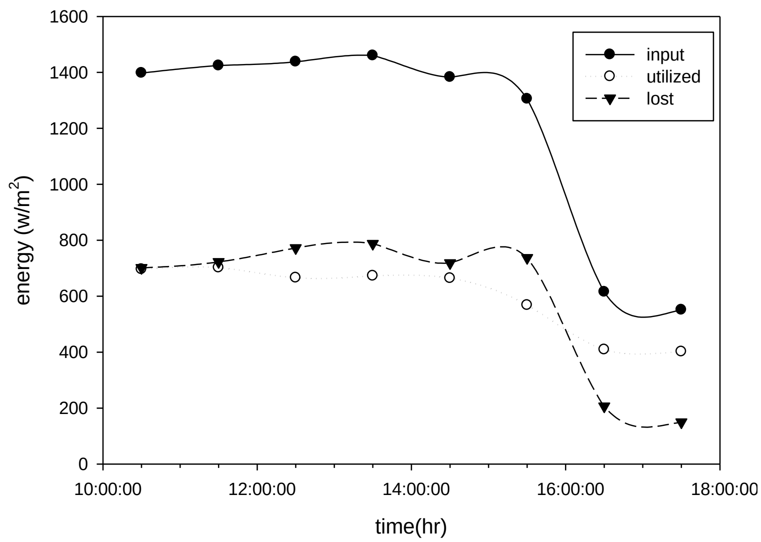


**Fig. 11:-** Hourly variation of energy input, utilized and lost for copper electroplated Aluminium basin with 3 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

**Hourly variation of efficiency:**

The variation of efficiency with respect to time for Aluminium basin is shown in the Fig. 12 and copper electroplated Aluminium basin is shown in the Fig. 13.

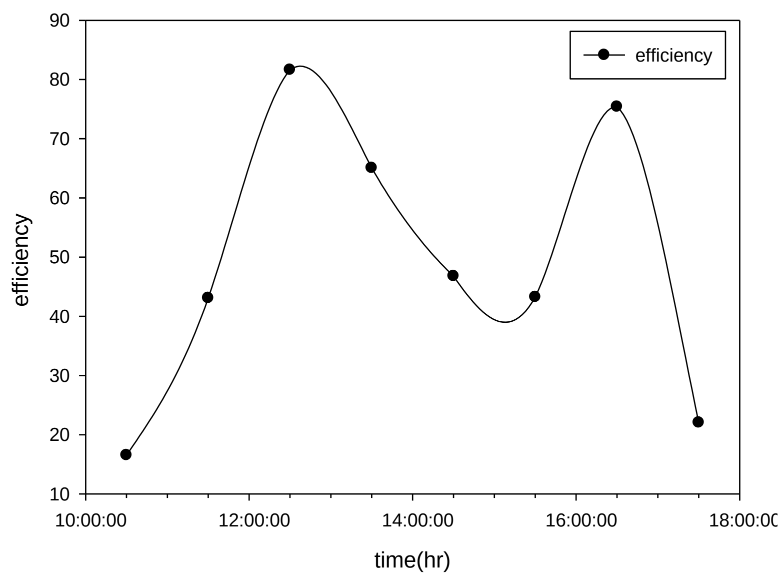


**Fig. 12:-** Hourly variation of efficiency for Aluminium basin with 2 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

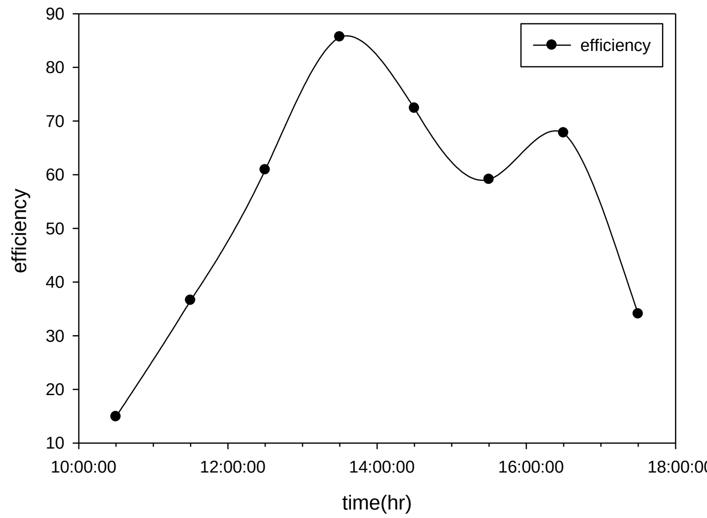


**Fig. 13:-** Hourly variation of efficiency for copper electroplated Aluminium basin with 3 litres of waste water in the direction of east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm.

**Water characteristics:-**

The characteristics of waste water before treatment and after treatment by solar distillation are shown in the table

**Table 1:-** The characteristics of waste water before treatment and after treatment.

| **Property** | **untreated water** | **Treated** |
|---|---|---|
| pH | 6.7 | 7.2 |
| TSS(ppm) | 22620 | 20 |
| TDS(ppm) | 28432 | 15 |
| Hardness(ppm) | 3620 | 10 |
| Chlorides(ppm) | 11360 | 12 |
| COD(ppm) | 600 | 22 |
| BOD(ppm) | 350 | 16 |

## Conclusions:-

Solar distillation is one of the best methods for waste water treatment. For a single slope solar distillation unit east from 9:30 am to 12:30 pm then west from 12:30 pm to 5:30 pm is the direction in which maximum efficiency was obtained. For Aluminium basin 2 litres volume of waste water showed the maximum efficiency where for copper electroplated Aluminium basin it is 3 litres. A Copper electroplated Aluminium basin showed better efficiency when compared to that of an Aluminium basin. The efficiency has increased from 49.78 to 54.66 by replacing an Aluminium basin with a Copper electroplated Aluminium basin.

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