

Experimental Study and Performance Analysis of Sea Water Desalination using Solar Still Method

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ABSTRACT: Pure water scarcity is becoming a social, environmental and economical problem in many countries. Due to climate changes and weather patterns, rain fall is getting reduced each year. With increase in the demand for drinking water, desalination of sea water becomes necessary. Number of water purifications methods has been suggested by researchers, of which most of them are either costly or required high energy. After extensive literature survey, the most economical and easy way for desalination is found to be Solar Still Method.

The purpose of this paper is to design and prepare and experimental setup of a solar still and to evaluate its potential to convert sea water into potable water. The solar still is made up insulated metal tray of 25 litre capacity over with square pyramidal glass cover is placed. The experiment is done over a period of 15 days under heavy sun light. The evaporation rate of salt water and reduction in water depth is noted. The average daily output was found to be 269 ml per day and final salt content is reduced from 3.5% to 0.66%. We conclude that, desalination using solar still is most cost effective method. Additionally the external surface of the solar still can be used for harvesting rain water.

KEYWORDS: Desalination, Square Pyramidal Solar Still, Rain Water Harvesting.

I. INTRODUCTION

Clean water is essential for good health which influences the social and economic development of any nation. People who use contaminated water are prone to waterborne diseases and they cannot effectively engage themselves in economic activities. Moreover, financial resources that could have been allocated to developmental projects are channelled to disease-curing efforts. Consequently, ill health contributes to the retardation of economic growth

More than two-third of the earth's surface is covered with water. Most of the available water is either present as seawater or icebergs in the Polar Regions. More than 97% of the earth's water is salty; rest around 2.6% is fresh water. Less than 1% fresh water is within human reach. Even this small fraction is believed to be adequate to support life and vegetation on earth. Nature itself provides most of the required fresh water, through hydrological cycle.

Water is a basic necessity for sustaining life on the earth. With the passage of time due to technological usage and their waste disposal along with ignorance of human being caused water pollution which led the world to water scarcity.

Due to water pollution the surface and underground water reservoirs are now highly contaminated. The demand of fresh water is increasing with growth in human population. To meet the demand of potable water, scientists have developed various technologies such as reverse osmosis (RO), vapour compression (VC) and electro dialysis (ED). These water purification methods are highly energy and cost intensive. It is well known that desalination plants use electrical energy which have both economical and environmental drawbacks and rely on conventional fuels. Therefore a method is required to use renewable energy, low input cost and less effort for the production of potable water. Solar desalination is a thermal desalination method where solar energy is used to distil fresh water from saline and brackish water.

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II. LITERATURE REVIEW

Muhammad Tauhe Ali et.al. (May 2011) had classified various conventional desalination technologies like Multi Stage Flash (MSF), Multi Effect Distillation (MED), Reverse Osmosis (RO), Membrane Distillation (MD), Electro Dialysis (ED) and listed out recovery ratios. [1]

Hikmets S. Aybar (May 2007) had stated that, Solar still is the simplest device to get potable/fresh distilled water from impure water using solar energy as fuel. The basin type single-solar still can be classified as a conventional solar still system. There are many different designs of solar still system in the open literature. Researchers have modified the conventional solar still system to get a better performance, such as multi-basin, multi-slop solar still systems, and coupled with solar collector to increase the water temperature. Especially, solar stills look like the best choice to obtain fresh drinkable water in remote areas usage. [2]

Muafag Suleiman K.Trawaneh et.al. (Sep 2007) has explained detailed working principle of solar still and concluded that productivity is increased while using pyramidal type than double slope type. He also mentioned that the deciding role of cooling the glass cover was strongly observed on the increased temperature difference ($T_w - T_g$) as well as on the increased water productivity. Higher attention must be spent to the time of applying the cooling method. [3]

Syed Firozuddin et.al.(May 2014) insisted that Solar distillation present a promising alternative for saline water desalination that can partially supported humidity need for fresh water with free energy, simple technology and a clean environment. Producing fresh water by solar distillation can support community living activities, particularly in rural area. The orientation of the glass cover depends on the latitude of the place for northern latitude south facing and southern latitude north facing stills are used. The inclination of cover is optimized for rate of condensation of water on the bottom surface of the cover and to collect it without the mass accumulated drops fall back into the basin. [4]

Ghassan A.Al-Hasan et.al.(Jan 2013) analysed three similar insulated stills basins that were manufactured from metal attached to pyramidal glass with angle 45 degree and tested for saline water. To study the effect of the water depth in basin different amount of water has put inside the solar still. Distillation of water using solar still basin is the most economical method to get portable drink water. The water that is made in these stills is of better quality than bottled water because it is purified using the distillation process, and because the water is slowly evaporated instead of rapidly boiled, the water taste sweeter due to the natural process. [5]

T.Arunkumar et.al.(Apr 2012), in their paper have done, the fabrication of seven solar still designs (spherical, pyramidal, hemispherical, double basin, concentrator-coupled CPC tubular, CPC coupled with pyramid solar still) and their performance evaluation in converting brackish water into fresh water for drinking are presented. From the experimental results, tubular solar still coupled pyramid solar still shows the maximum amount of productivity due to the concentrator effect. The productivity of the solar still entirely depends on the climatic parameters as well as increasing the water temperature. This leads to raise the evaporative and convective heat transfer coefficients in the solar still. [6]

V. Velmurugan et.al. (Oct 2008): The basin area of the still is 0.25 m^2 , fabricated using galvanized iron sheet of 18 gauge thickness. The bottom and sides of the basin are insulated by 5 cm thick fiber-glass surrounded by a wooden frame of 5 cm thickness. The surface of the basin is painted black to absorb maximum solar radiations. On the inside rim of the basin two troughs have been fixed with each one extends along two sides of the basin. The main function of these troughs is to collect the distilled water falling from the glass cover which is fixed above the tray. Each trough is tilted at a small to permit the distilled water to leave the stiller through water to a graded flask. The function of the glass cover is to permit solar radiation to pass to the stiller and elevate the temperature of the hot water in the tray. This enhances the evaporation process of water in the basin, which will condense on the inner surface of the glass covers whose temperature is definitely lower than that of the water. [7]

Ali.F. Muftah et.al. (Apr 2014): This study highlights the factors that influence the output of solar stills. The most important factors include climate, design, and operational parameters. The productivity of the solar still was determined to be directly correlated to total solar radiation, ambient air temperature and wind speed. A lower glass angle generates higher output. [8]

III. EXPERIMENTAL SETUP

- a. **Base Tray:** A square shaped base tray is fabricated from G.I Sheet metal of size 50 cm x 50 cm x 15 cm and 20 gauge thickness. The interior of the tray is painted in black to absorb maximum solar radiation. The exterior of the tray is covered with aluminium foiled faced polyethene rubber insulator of thickness 5 mm.
- b. **Square Pyramidal Solar Cover:** Airtight glass cover is made using 4 isosceles triangular glass pieces joined to form a pyramidal shape of inclination of 45° . The function of the glass cover is to permit solar radiation to pass to the stiller and elevate the temperature of the hot water in the tray. This enhances the evaporation process of water in the basin, which will condense on the inner surface of the glass covers whose temperature is definitely lower than that of the water.
- c. **Collection Trough:** On the inside rim of the base tray, four troughs have been fixed with each one extends along four sides of the basin. The main function of these troughs is to collect the desalinated water falling from the glass cover which is fixed above the tray. Each trough is tilted at a small to permit the desalinated water to leave the stiller through water to a graded flask.
- d. **Collection Tube:** The collection trough is joined at one end and is connected to a 0.5 inch diameter PVC pipe, which extends towards collecting flask which is placed in the bottom of the support stand.
- e. **Graded Flasks:** Two high quality plastic jugs with handle are used as collecting flasks. One flask for desalinated salt water and another for collecting rain water which falls over the external surface of the square pyramid.
- f. **Instruments:** Instruments like digital thermometer, hydrometer and measuring beaker are used to measure and support the experiment

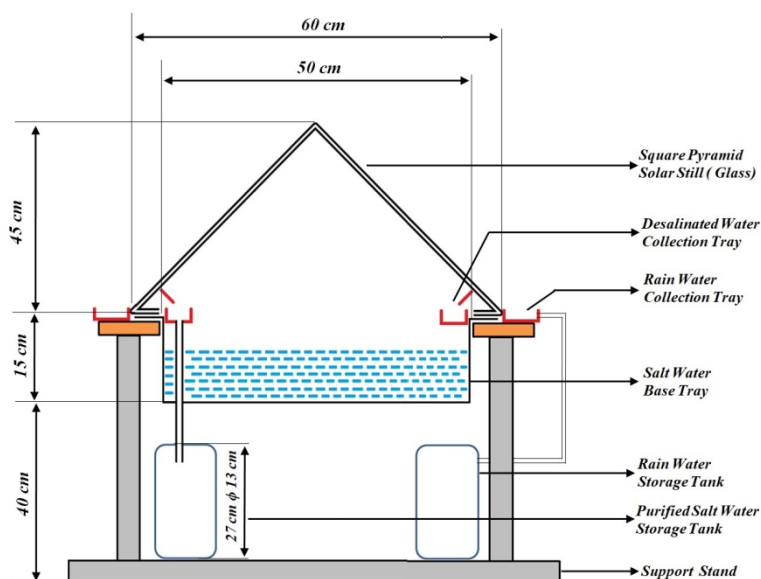


Fig 1: Layout of the Experimental Kit



Fig 2: Actual Image of Experimental Kit

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IV. WORKING PRINCIPLE & EXPERIMENTAL PROCEDURE

a. Working Principle of the Solar Still:

A small-scale hydrological cycle can be created in a well designed solar still. The air tightness and the good insulation, are two essential design parameters that should be highly considered in order to minimize the vapour leak and heat loss tendencies. Solar stills are used to produce fresh water from Salt water by directly utilizing the sunshine.

Construction and operation principle of solar stills are very simple. The black painted absorbing tray contains the saltwater which is directly exposed to the solar energy above the tray. The saltwater is completely enclosed in an air-tight condition, inside the transparent glass pyramidal cover. The incident solar radiation passes through the transparent glass cover and is absorbed by the black-painted G.I sheet, the absorbed heat is then transferred to the water with no significant energy loss. The saltwater starts heating and evaporating, the formed vapour on the water surface start moving in an upward direction due to the driving force (convective currents) due to the temperature difference between the water and glass cover ($T_w - T_g$). When the water vapour comes in contact with the condensing surface, the vapour will condense at different small-size droplets of fresh water. Then the condensate starts moving down along the inclined glass cover due to the gravitational force. Finally, the condensate will be collected from the collecting channel which is connected to the collecting flask.

b. Experimental Procedure:

At the beginning of the experiment, water is filled up to 10 cm level of the base tray such that the total volume becomes 25 litres. Approximately 875 gm of salt is mixed well with the water so as to make it equivalent to sea water which contains 3.5 % of salt. The square pyramidal glass cover is placed over the basin and air tight conditions are ensured. The experiment is commenced after 24 hours of assembling the glass cover, so as to enable the setup to reach the steady state condition.

For each experiment, the glass cover is cleaned in the morning to avoid the dust deposition over the outer layer of the glass. The extensive experiments were conducted for a period of 15 days from 05-Feb-2019 to 19-Feb-2019. The readings were taken from 9AM in the morning till 6PM in the evening at hourly intervals. The variables measured in this experiment are water temperature (T_w), basin temperature (T_b), outer glass temperature (T_g), humidity, and productive efficiency is calculated. Samples were collected once in three days and tested for salinity level, pH and thermal conductivity.

V. OPERATIONAL PARAMETER & SPECIFICATIONS

In a conventional solar still, the base absorbs a large amount of solar radiation, rendering it to be the hottest area of the still. Heat is transferred from the bottom surface to the water via convection and to the outside atmosphere via conduction through the side walls. Hence the base tray is coloured black in inside and insulated outside to provide maximum heat transfer to the water and to prevent heat loss to the external surfaces. Angle of inclination of the glass pyramid plays a vital role in the performance. Various angles like 27°, 36°, 45° are available, but 45° of angle inclination is selected based on literature study. The productivity of the still is inversely related to water depths, thickness of cover, gap distance between water surface, says Ali.F. Muftah et.al. Above mentioned factors are also considered while determining design and operational parameters.

Specification:

Length	Breadth	Height	Water Depth	Volume of Water	Salt content	Solar Still
0.5 m	0.5 m	0.15 m	0.1 m	25 litre	3.5 % per Litre	Square Pyramidal Glass Cover (45°)

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VI. READINGS & TABULATION

S. No	Date	Avg. Temp °C	Avg. Humidity %	Avg. Water Temp °C	Amount of Salt Water Evaporated (ml)	Amount of Desalinated Water Collected (ml)	Efficiency %
1	05-Feb-19	32	61	45	1175	247	21.02
2	06-Feb-19	34	63	46	1264	265	20.97
3	07-Feb-19	34	68	46	1268	268	21.14
4	08-Feb-19	34	67	47	1254	262	20.89
5	09-Feb-19	34	68	46	1260	264	20.95
6	10-Feb-19	34	63	48	1249	260	20.82
7	11-Feb-19	33	68	42	1192	248	20.81
8	12-Feb-19	35	63	45	1305	275	21.07
9	13-Feb-19	35	68	47	1312	278	21.19
10	14-Feb-19	34	64	46	1273	264	20.74
11	15-Feb-19	34	62	46	1267	267	21.07
12	16-Feb-19	36	64	47	1342	284	21.16
13	17-Feb-19	38	64	50	1372	292	21.28
14	18-Feb-19	37	66	50	1357	284	20.93
15	19-Feb-19	36	61	49	1290	271	21.01

VII. RESULTS

Parameters	Unit	Before Experiment	Acceptable Range for Drinking Water	Sample after 3 days	Sample after 6 days	Sample after 9 days	Sample after 12 days	Sample after 15 days
Salinity	gm/k	35	0.5	0.72	0.65	0.67	0.64	0.62
Total Dissolved Solids (TDS)	mg/L	15120	< 1000	452	427	392	388	385
pH	-	8.2	6.0-8.0	6.12	6.15	6.31	6.13	6.21
Electrical Conductivity	μS/cm	65.20	5.0-50.0	7.75	6.13	5.83	5.91	5.82

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VIII.CONCLUSION

We conclude that, solar still method presents a good alternative solution in converting sea water into potable water. Compared with RO and ED systems, thermally driven solar stills are cost effective and provide more output per litre of salt water. Large scale solar stills can be constructed near sea shore and can provide continuous water supply to nearby villages. Except for initial installation costs, Solar stills require minimum operational costs and maintenance costs. From the experimental results it is evident that contaminants such as salts, odour, heavy metals, bacteria, micro-organisms, sand, rust, fluoride etc. are completely removed in the desalination process. The solar stills are appropriate technology because they are site specific, use no electricity to run, require no running water to work, gets rid of contaminants, have a life expectancy of at least 20 years and are easy to use and maintain. However, to decrease fresh water costs, efforts should be undertaken in the following research topics: thermal storage studies, insulation studies, thermo-optical studies for the condensing covers, geometry and design studies.

The experiment was done over a period of 15 days and the average daily output was found to be 269 ml per day and final salt content is reduced from 3.5% to 0.66%.

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