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Experiments for calculating Properties of Distilled Water from Solar Still and Potable water from Reverse Osmosis Process

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Abstract*: Solar stills absorb solar radiation convert brackish water into distilled water. In this project, a comparative analysis between the properties of distilled water from solar still and potable water from reverse osmosis process has been carried out. Two metals (Aluminium and GI sheet) and Granite stone are used as absorber plates. The water properties collected from three different absorber plates are compared with the potable water that obtained from reverse osmosis process. Based on the amount of water collected, thermal conductivity is analyzed between three absorber plate materials. An analysis on pH value, total dissolved solids, hardness dissolved oxygen between distilled water from solar still and potable water from reverse osmosis process is also evaluated.

***Index Terms*: Solar stills, Osmosis, G.I Sheet, Granite stone, dissolved oxygen**

I. INTRODUCTION

In this paper the solar still is utilized for producing distilled water. This is a typical solar still having a basin consist of saline water in deep area, above with a transparent air tight cover enclosing completely the space above the basin. The different kinds of material viz., Aluminium plate, GI sheet (Galvanized iron), granite stone, are used as absorbing materials. In each case, the quantity of water being collected may be different based on its thermal conductivity, pH value and total dissolved solids, hardness, dissolved oxygen in each distilled water obtained from reverse osmosis process. Used for softening hard water in which a pure solvent passes through semi permeable membrane.

II. HISTORY OF DRINKING WATER

Supply of drinking water is a major problem in undeveloped and in some developing countries as well.

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The basic necessity of human being is Water, Air and Food. Man has been dependent on rivers, lakes by industrial effluents and sewage causes fresh water scarcity in many places near lakes and rivers. The pollution of natural sources of water which is created by humans is turning out to be the single largest cause for fresh water shortage.Surveys show that about seventy nine percent of water cause for fresh water shortage. Surveys show that about seventy nine percent of earth's water contain salts and only one percent is fresh water. Also remaining 20% is brackish many diseases (about eighty percent) afflicting mankind are due to unhygienic water used for drinking; fifty percent children die every year due to dioherra caused by unhygienic water[1].

According to present estimated, over 2000 million people are without satisfactory access to a safe and adequate water supply. Many developing countries (eg. India) at certain places, people travel upto 30km. For fresh water, which takes more than six hours daily. major UN organizations encouraging projects related to Purifications of Water so as to supply drinking water to various Villages in India. Government of India has allocated 2500 million rupees for drinking water in its development plan in a 1991.

Various methods are available for purification of water. Among which distillation method seems to be best. Solar distillation has many advantages, it consumes less energy, it is more economical. Also, the technology adapted in this method is more simple, Maintenance also easy, so it can be installed in any place [2].

III. HISTORY OF SOLAR DISTILLATION

The first work on solar distillation is done by Arab alchemists in the year 1551, after that Mouchot in 1869, later by Malik in the year 1982.

A. Solar Distillation

The basic need for all the human being is quality drinking water. Without drinking water human cannot survive. Also, Fresh water is essential for Industries and Agricultural work. So, purification of water is an essential one. Moving this motive, Solar distillation can be a better choice. In this paper the experiments were done on Solar distillation process. Fresh water which was obtained from rivers, lakes, and ponds in plenty is becoming scarce because of industrialization and population explosion Moreover, these potable water sources are being polluted continuously by the waste coming from Industries and also by sewage wastes. Survey says that currently more than 200 million people are not getting potable drinking water.

This leads to lot of diseases, humans are suffering lot and this stops their further development. Physically they are not fit and suffering a lot. Due to demand in fresh, in 1980 UN declared the years 1981-1990 the decade or water supply and sanitation. Many U.N. organizations like UNDP.

WHO, and the World Bank are now actively involved throughout the world in promoting projects concerning the supply of hesh water for drinking purposes[3,4].

In earlier stage instead of Fresh water, only brackish water was available and arid and semi-arid regions. But now due to industrialization and population arise, the shortage has become prominent. In earlier days when the population was small and people lived near water resources, normally one person consumed 15 to 25 litres of fresh water per day in earlier stage, later in 20th century it increased to 75 to 1000 litres per day. This is happened because of increased demand in fresh water. Industries are using enormous amount of water, in Agriculture for irrigation purpose they are utilizing a lot. Under these much demand, it is very essential to convert brackish water into potable water. Lot of methods are there, some of them are as follows.

a) Desalination: This is the method where saline water is evaporated because of thermal energy, and the resulting vapour is collected and condensed, which is the final product.

b) Vapour Compression: It is the process in which water vapour is collected from Boiling water then it is compressed adiabatically, the compressed vapour is superheated. It initially cooled and then condensed at constant pressure to form fresh water [5,6].

c) Reverse Osmosis: Here saline water is passed at high pressure with the help of special membranes which allows water molecules to pass further excludes the dissolved solids.

d) Electro dialysis: Here water is passed through a pair of special membranes, which is perpendicular to an electric field. The membranes won't allow water to pass on while dissolved solids passes.

Many parts of the world particularly arid and semi-arid areas also coastal areas are having plenty of underground water. But these waters are in a saline (2000 ppm to 3500 ppm) state and therefore not suitable for human consumption. 70.8% of the earth surface is covered by ocean that may be around 1350 million cubic km of saline water which 35000 ppm impurities. Out of this about 28000 ppm is common salt. The maxinum level of salt content in fresh water for human consumption should be only 500 ppm, But we are having more than that. Proper measures should be taken so as to avoid this.

Compare to Agriculture, Industries are very much suited to use more saline water. But moving to human side the usage of fresh water is more. In some industries like modem steam power generation, very pure water with a dissolved solids of only 10 ppm can be used. There water standards available in many countries for drinking, agriculture and industries [7].

Distillation process is considered to be one of the simplest and widely adopted technique for converting sea water into fresh water. More than 90 per cent of the worldwide installed sea water desalination capacity is based on distillation process: The distillation process requires only 120°C of heat, that can easily taken from solar energy and other energy sources. This would be the main advantage of the distillation process, while in reverse osmosis, vapour compression, and electro dialysis processes, some mechanical or electrical energy is used. Distillation devices are divided into four main types of sub processes: (a) (i) single effect distillation, (ii) multiple effect distillation; (b) vapour compression distillation; (c) (i) single stage (ii) multiple stage, and (iii) multiple effect multiple stage flash distillation; and (iv) Solar distillation.

IV. SOLAR DISTILLATION

Solar distillation is to admit solar radiation through a transparent cover in a shallow, covered brine basin as shown in Figure 1. In costal area's there is abundant sunlight that can be made for converting brackish or saline water into portable distilled water[8].

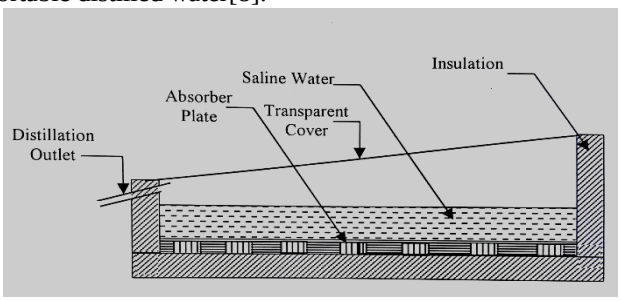

Figure 1: Solar distillation

A. Solar Still

- Solar still can produce 3 to 5 litres of distilled water per square meter on avg. sunny day.
- Solar distillation is to convert brackish water into portable water, small solar still can also fabricated in rural area's.

B. Reverse Osmosis

Osmosis principle is used for softening hard water. Reverse osmosis is a process in which pure solvent passes from a concentrate solution to a dilute solution through a semi permeable membrane[9].

V. QUALITY OF WATER

A. Analysis of water :

The main aim of testing in Laboratory is to confirm whether the potable water supplying to the customers is having the standards are not. The following tests are conducted:

- To determine the quality of raw water
- To determine the treatment processes to be provided
- To ensure that treatment of water is properly done during each phase or stage of treatment
- To examine whether the treated water conforms to standards

Following water properties :

- Amount of solids
- Hardness nature
- Chloride content
- Dissolved gases present
- pH value
- Chemical substances

B. Amount of solids :

Suspended matter and Dissolved matter are the main reasons for solid contents. Each one is found separately and then mixted together. The suspended solids are found by filtering the water is then evaporated and the residue is weighed. This gives the dissolved matter. Total solids in potable water should not exceed 500 ppm and never more than 1000.

C. Hardness Nature :

There are two kinds of Hardness, one is Temporary hardness and the other one is Permanent hardness.

The presence of bicarbonates of calcium or magnesium are the main reason for Temporary hardness. The main reason for permanent type of hardness is presence of sulphates, chlorides and nitrates. Permanent hardness causes.

- Soap Consumption.
- Formation of Scale
- Tasteless solids
- Discolouration of clothing in dyeing industry

Hardness is tested by EDTA (ethylene diamine tetracetic acid) test. For this, the water is titrated against EDTA salt solution using Erio Chrome Black T as indicator. The colour changes from red to blue while titrating.

In another method, hardness is tested by the soap solution test. Standard soap solution is added to the water and vigorously shaken for about five minutes. The difference between the soap solution used and the lather factor gives the hardness. The unit of hardness is the degrees. A unit degree of hardness is given by the soap destroying power of 14-25mg of calcium carbonate in one litre of water. For potable water the hardness should vary between S to 8 degrees or should not be more than 200 ppm.

D. Chloride contents:

The presence of chloride contents ensures that the water is contaminated by sewage. This is because in ground water the sodium chloride is present because of soil. The amount of sodium chloride present in the water is determined by adding silver nitrate of known concentration and potassium chromate to the water to be tested. The solution should be continuously stirred. If chlorides are present, then reddish colour will be formed. The permissible limit of chlorides is 250 ppm.

E. Dissolved Gases present:

Some quantities of oxygen are found dissolved over the surface water which are absorbed from atmosphere. In surface waters, the quantity depends upon the amount organic matter presents. (Hydrogen sulphide, methane, carbon dioxide, chlorine are found dissolved in water rarely and hence not dealt here). The amount of dissolved oxygen is found by exposing the sample of water for four hours at 27°C with potassium permanganate of 10% concentration. The quantity of oxygen absorbed should be between 5 and 10 ppm.

F. pH Value or Hydrogen-Ion Concentration :

The acidity or alkalinity in water that is caused by bicarbonates or hydroxides of sodium, potassium, calcium and magnesium can be found using this Test. Acidity is caused by mineral acids, carbon dioxide, iron and aluminium. This problem can be solved by passing an electric charge into water, it dissociates itself into positively charged and negatively charged ions. Thus, for pure water,

$$H20 \square\square H^+ + (OH)^-$$

The water splits into positively charged hydrogen ions and negatively charged hydroxyl ions.

According to the law of mass action, the product of the two types of ions is always constant. For example, in water, Concentration of H^+ ions x concentration of $(OH)^-$ ions = constant = 10^{-14}

Since water is electrically neutral, the H^+ ion concentration is equal to the $(OH)^-$ ion concentration. Hence concentration of H+ ions is $10^{-7} = 1/10^7$ and concentration of $(OH)^-$ ions a $10^{-7} = 1/10^7$.

The logarithm of the reciprocal of the H^+ ion concentration is called as pH value. Pure water is having the pH value of 7.0. When an acid such as hydrochloric acid is added to the water, the following dissociations happen:

$$H20 <--> H+ + (OH)^-$$
$$HCI <-> H+ + Cl^-$$

It may be seen that the concentration of H+ ions increases, i.e., the value may be say 10's. The pH value thus decreases. Similarly when an alkali such as sodium hydroxide is added,

$$H20 (-) H'' + (OH)$$
$$Na(OH) <-> Na+ + (OH)'$$

The concentration of (OH)' increases, the concentration of H+ decreases and the pH value increases. Thus when an acid is present in water, it decreases the pH value and when an alkali is present it increases the value. Acidity or alkalinity of water is measured by the H^+ ion concentration. It is expressed in ppm.

The pH value is determined by the following two methods:

a) Electrometric method

b) Colourimetric method

a) Electrometric method :

In this method, a potentiometer is used to measure the electrical pressure exerted by the H+ ions. A meter connected to the circuit indicates the pH value directly.

b) Colourimetric method :

In this method, chemical reagents or indicators are added to the sample of water. The colour produced is compared with standard colour waters kept in sealed tubes of known pl! values. This is a simple test and commonly adopted.

G. Fluorides :

This is mainly because of chemical wastes from industries. Water drawn from any geological formations will have high amounts of fluorides. Small amount of 1 ppm Fluorides are good for water. These type of water enhance dental health and avoids formation of dental caries. Excess contents of fluorides in drinking water will cause dental fluorosis, which results in discolouration of enamel and chipping of teeth particularly for children. The presence of fluorides and iodides are determinedwith the help of colouring agents after adding into water and comparing with standard colouring solutions.

H. Metals and other chemical substances :

Iron contents affects the taste of water. It stains clothes, The maximum iron content in potable water can be 0.3ppm. Manganese blocks pipes and discolours clothes. This maximum manganese content is 0.05ppm. The amounts of iron, manganese and other metals in water are found by adding colouring agents to the water and comparing known amounts of the metal contained solutions.

I. Water quality standards :

High salt content in water is not suitable for Agriculture and for some industries. It affects fish and other biological life. In some cases non drinkable is suitable for irrigation purpose. Similarly water that not suitable for irrigation can be used in industries in some cases. But chemical and metal contamination in in water is definitely not good for both cases, but minimum quantity ensures no harm to users.

The criteria levels for drinking water source have to be based upon removability of the constituents at the water treatment plants and available data on the human health. The criteria for the waste Waters generated from industries may be based on the nature of the industry and effects of their constituents on the waters and land. Maintaining criteria is very much important but some modifications can be made if required[10].

Some standards are available to maintain the water quality. The standards can be of two types, one is effluent standards and the other one is Stream standards. The 'effluent standards' are used to check the quality of municipal, industries and agricultural wastes that is discharged into the water. The 'stream standards' and refer to water resources like rivers, lakes, estuaries, oceans of ground water.

VI. INTRODUCTION OF REVERSE OSMOSIS

For the past 30 years the process for purification of water seems to be an essential one. There is a heavy shortage of drinking water around the world. This is due to less water resources and more contaminations. Environmental effects, wastewater disposal, and some climate influences causes contamination. It is financially rewarded if water recycling process is efficient and handling equipment seems to be a challenging one. Considering these effects reverse osmosis and ultra filtration will be best choices. It is a typical process that operates at a pressure of 62 psi with a reduced concentration of salt from 3l to 3.2 mmol NaCl per litre of water. Ultra filtration did not affect the overall ability for the system to remove salt contaminants[11]. Reverse osmosis specifications are shown in Table 1 and 2.

A. Reverse Osmosis Specifications

Table:1 Membrane Rating

Membrane Production	24 gallons nearer per day
Membrane T.D.S. Reduction	95% atleast
System Rating	
Warm Climate Production produces	9.5 gallons nearer per day
Warm Climate T.D.S. Reduction	85%+
Cold Climate Production	6 gallons per day
Cold Climate T.D.S. Reduction	85%+

Table:2 Incoming Water Specifications

Water Pressure Range	40 to 42.5 psi
Maximum Total Dissolved Solids	Max 1500 ppm (T.D.S.)
Water Temperature Range	40 to 85°F
Allowable Ph Range	5 to 8.5
Maximum Hardness	Max 10 grains per gallon or pre soften
Maximum Iron	Max 0.1 ppm
Maximum Manganese	Max 0.05 ppm
Hydrogen Sulfide Restriction	hydrogen sulfide must not present
Chlorine Level	0.2 to 2.0 ppm
Bacteria Restriction	water must be potable

B. *Units Of Reverse Osmosis*

Parts per Million (ppm)

1 ppm is equal to 1 part of $CaC0_3$ which is to equal hardness in 10^6 parts of water.

pH Scale Definition

- Acids give H+ ions.
- H+ ion concentration gives strength of acids.
- Basic give OH- ions in solution. The strength bases depend on OH ion concentration.

pH of a solution is is the negative logarithm to the base 10 of hydrogen ion concentration.

$$pH = -\log_{10}[H^+]$$

Drinking Water

- Municipalities have to supply potable water, water which is safe to drink.
- Drinking or portable water, fit for human consumption, should satisfy the following essential requirements

a. It should be clear and odourless
b. It should be pleasant in taste.
c. It should be cool.
d. Turbidity should not be more than 10 ppm.
e. It should be free from dissolved gases like hydrogen sulphide
f. It should not contain minerals like lead, arsenic chromium and manganese salts.
g. Its salt content should not be high.
h. It should be reasonably soft.
i. The dissolved solids should be lower than 500 ppm.
j. It should not contain Microorganisms that may cause diseases.

Purified drinking water is classifieds 3 stages.
1. Sedimentation 2. Filtration 3. Sterilisation

C. Working Of Reverse Osmosis

Osmosis principle is used for softening hard water. Reverse osmosis is a process in which pure solvent passes them a concentric solution to a dilute one with the semi permeable membrane. Reverse osmosis taken place when the hydrostatic pressure applied on the concentration solution is greater than the osmotic pressure as shown in Figure 2.

In this method, hard water in the inner vessel and soft water is taken in the outset vessel. A semi-permeable membrane separates hard water and soft water.

A hydrostatic pressure is applied over hard water provided that pressure should be greater than the osmotic pressure.

Obviously pure water present in the inner vessel get passes to the outer vessel, excluding dissolved salts.

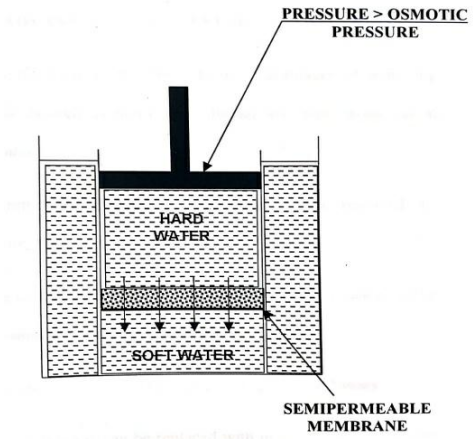

Figure 2: Working of Reverse Osmosis

D. Advantages Of Reverse Osmosis

- Ionic as well as non-ionic colloidal can be removed easily.
- Colloidal silica can be removed which is not removed by demineralization
- The only maintenance cost is at replacing the semi permeable membrane. The life time of membrane is high which may be of 2 years.
- The membrane can be easily replaced within a few minutes.
- The capital and operating cost is very low.

VII. FABRICATION WORK

Single basin solar still was designed. The experimental set up of solar still consists of three absorber plates [G.I. Sheet, (Galavanized iron sheet), Aluminium sheet, granite stone] as shown in Figure 3.. The experimental set up of solar still absorb solar radiation through a transparent cover distilled water is collected at the outlet.

Figure 3: Experimental setup

A. *Design of solar still:*

The total area of the still is 0.9m^2
Length of the still is 0.45m
Breath of the still is 0.45m

Water collecting tank is connected in solar still. 3 sets of readings were taken and all the data's were collected. The data's collected are

Glass plate temperature (T_G)
Absorber plate temperature (Ta)
Solar intensity

The glass plate temperature and absorber plate temperature are taken from the chart [temperature vs millivolts chart].

When sample water is collected through a 3 absorber plates [Granite stone, Aluminium sheet, GI sheet]. GI sheets water collected in 2 days. Aluminium sheet and granite stone sample water collected in two days. Two days, 6 hrs per day can be collected. pH value, ppm of water total dissolved solids (TDS) and hardness, dissolved oxygen were compared and analysed between distilled water from solar still and potable water from reverse osmosis process. Water samples were collected and test was conducted in environmental lab.

Solar still using 3 different absorber plates G.I. sheet, aluminium sheet with granite stone collected distilled waters:

1. G.I sheet (galvanized iron):
a) No. of days collected : 2
b) No. of hours collected : 6 hours
c) No. of litres collected : 1250ml

2. Aluminium sheet
a) No. of days collected : l
b) No. of hours collected : 6 hours
c) Litres collected : 250ml

3. Granite stone
a) No. of days collected : l
b) No. of hours collected : 6 hours
c) Litres collected : 750ml

B. *Water Sample Tests In Environmental Lab*

Table: 3

S. No.	Reverse osmosis Process		Solar still		
	Potable water		Distilled water		
			3 Absorber plates		
	Properties		G.I Sheet	Aluminium sheet	Granite stone
1	pH	6.82	8.90	6.82	7.08
2	TDS	TS – Nil TDS – Nil	TS – 0.6 mg/l TDS – 1.2 mg/l	TS - 3.1mg/l TDS-3.1 mg/l	TS – 60.5 mg/l TDS – 60.5 mg/l
3	Hardness	1 ml	12.80 ml	1.5 ml	2.6 ml
4	Dissolved Oxygen	7 ml	2.6 ml	5.7 ml	3.2 ml

C. *Distilled water sample and potable Water sample tests*

Specimen Calculations:

1. GI sheets properties

a) To calculate total dissolved solids (TDS)

i) Ts

Empty weight (wl) = 16.964 mg/l

After drying weight (w2) = 16.970mg/l

$$Ts = \frac{w1-w2}{Vol.of\ Sample} \text{ x } 1000$$

Since volume of sample = 10ml

$$= \frac{16.964-16.970}{10} \text{ x } 1000$$

Ts = 0.6 mg/l

ii) TDS

Empty weight (wl) = 17.568 mg/l

After drying weight (w2) = 17.580mg/l

$$TDS = \frac{17.568-17.580}{10} \text{ x } 1000$$

TDS = 1.2 mg/l

2. Aluminium sheet properties

Ts = 3.1 mg/l

TDS 3.1 mg/1

3. Grainite stone properties

Ts = 60.5 mg/l

TDS = 59.6 mg/l

4. Reverse osmosis process properties

Ts = Nil

TDS = Nil

VIII. RESULTS AND DISCUSSION

The declining rate in sources of drinking water, and necessity to go for a solar still has been studied solar stills play an very important role in converting brackish water into potable water. By analysing and comparing pH value, ppm of total dissolved solids, hardness, dissolved oxygen we can able to find out the way of obtaining safety potable water. Also solar distillation, desalination and the way of obtaining potable water from reverse osmosis process have been studied. Solar stills converts brackish water into distilled water and reverse osmosis process produces potable water (drinking water). Solar stills using G.I (galvanized iron) sheet, aluminium sheet, granite stones are used as absorber plates. From the 3 absorber plates [G.I (galvanized iron) sheet, aluminium sheet, granite stones] distilled water were collected from solar still. The distilled water and reverse osmosis process water sample tests were conducted in environmental lab. After testing the results of distilled water are better than reverse osmosis process water results.

REFERENCES

1. Amitava Bhattacharyya, "Solar Stills for Desalination of Water in Rural Households" International Journal of Environment and Sustainability, ISSN 1927-9566, Vol. 2 No. 1, pp. 21-30 (2013)
2. Ruchir Parikh, Dr. Umang Patdiwala, "Solar Distillation System With Nano Particle: A Review" PDPU Journal of Energy and Management, Vol. 3, No.1, October, 2018
3. Hiren Patel, Mrs. Pragna Patel, Mr. Jatin Patel, "Review Of Solar Distillation Methods" International Journal of Advanced Engineering Research and Studies, E-ISSN2249–8974 IJAERS/Vol. II/ Issue I/Oct.-Dec.,2012/157-161
4. Farah Ejaz Ahmed, Raed Hashaikeh, Nidal Hilal, "Solar powered desalination – Technology, energy and future outlook" Desalination, Volume 453,1 March 2019, Pages 54-76
5. O. M. A. Al-hotmani, M. A. Al-Obaidi, R. Patel, I. M. Mujtaba "Performance analysis of a hybrid system of multi effect distillation and permeate reprocessing reverse osmosis processes for seawater desalination", Desalination, Volume 470, 15 November 2019
6. K. Tarnacki, M. Meneses, T. Melin, J. van Medevoort, A. Jansen, "Environmental assessment of desalination processes: Reverse osmosis and Memstill", Desalination, Volume 296, 15 June 2012, Pages 69-80
7. Wei Lun Ang, Abdul Wahab Mohammad, Daniel Johnson, Nidal Hilal, "A review of research trends over the past decade", Journal of Water Process Engineering, Forward osmosis research trends in desalination and wastewater treatment: Volume 31, October 2019
8. Jaymin Patel, Bhupendra K. Markam, Subarna Maiti, "Potable water by solar thermal distillation in solar salt works and performance enhancement by integrating with evacuated tubes", Solar Energy, Volume 188, August 2019, Pages 561-572
9. Radha Krishna Lal, Shubham Mishra, J. P. Dwivedi, Harshit Dwivedi "A Comprehensive Study of the Different Parameters of Solar Still", Materials Today: Proceedings, Volume 4, Issue 2, Part A, 2017, Pages 3572-3580
10. S. Varun Raj, A. Muthu Manokar, "Design and Analysis of Solar Still", Materials Today: Proceedings, Volume 4, Issue 8, 2017, Pages 9179-9185
11. Aayush Kaushal, Varun, "Solar stills: A review", Renewable and Sustainable Energy Reviews, Volume 14, Issue 1, January 2010, Pages 446-453

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