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Design, Fabrication and Working of Solar Distillation System

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***Abstract*— Water scarcity is a major environmental issue in our daily life. So in-order to overcome this issue, we have to take steps to reuse the contaminated water. One of the effective measure is the distillation process using solar energy. The purpose of this project is to analyze a solar water distillation system that can purify the waste water and saline water and other contaminated waters. A working model is prepared by using a systematic arrangement having low manufacturing cost and work based on renewable solar energy. The contaminated water is first passed through a filter unit in-order to remove suspended solids and other impurities. Then it is passed through a copper coil solar water heater and then to the distillation still. The impure water is clarified by the solar rays coming into the still and the main process occurring is evaporation and condensation. By the use of this arrangement the contaminated water (Grey water and Sea water) can be made into potable one and shortage of drinking water in our country can be thrown and human hygiene can be saved at a great extent.**

***Index Terms*—Copper coil water heater, Distillation, Distillation still.**

I. INTRODUCTION

Water is an essential element for all life forms. Water is a renewable natural resource of earth and is extremely essential for the survival of all living organism. In nature, more than 97% of water sources are brackish but potable water is not abundant. Therefore, controlling of water quality is one of the essential issues of drinking water management In order to be consumed by people; however, it must be treated to eliminate substances and organisms that could be harmful to human health. Water is the basic necessity for human along with food and air. There is almost no water left on Earth that is safe to drink without purification. Only 1% of Earth's water is in a fresh, liquid state, and nearly all of this is polluted by both diseases and toxic chemicals. For this reason, purification of water supplies is extremely important. Moreover, typical purification systems are easily damaged or compromised by disasters, natural or otherwise. This results in a very challenging situation for individuals trying to prepare for such situations, and keep themselves and their families safe from the myriad diseases and toxic chemicals present in untreated water. Everyone wants to find out the solution of above problem with the available sources of energy in order to achieve pure water. Fortunately, there is a solution to these problems. It is a technology that is not only capable of removing a wide variety of contaminants in just one step, but is simple, cost effective and environment friendly. The process of water purification requires an energy source to separate contaminants from water, and a system that can efficiently use this energy. Distillation is a highly effective method for purification, given that when water changes from liquid to gaseous state it leaves all impurities in the liquid phase However, it is important to note that distillation requires a great amount of thermal energy to evaporate the water. That is use of solar energy. The shortage of potable water is the biggest challenge facing people in arid and remote areas. The use of solar energy in water desalination systems presents the perfect solution of this problem. The simple method using is solar energy. Sea water and brackish water desalination is a promising technique for some countries mainly in the arid regions. It permits to achieve two objectives: drinking water supply and irrigation of agricultural surfaces. The problems encountered at the level of the purification concerning the salinity of the purified waste water. The solar distillation is an interesting technique as it can be easily adapted in the arid regions, it has many advantage as it is simple, it can be easily carried out, not expensive and it is of rustic design. This is why our team of research has chosen this technique. Our study consists of using a solar still prototype of a desalination technique of the purified waste water; the experimental results are very satisfactory concerning the various physico-chemicals parameters. Distillation is the most widely used process for water purification. Different methods of distillation have been used in several countries to resolve the crisis of drinking water. A variety of distillation technologies has been developed over the years on the basis of thermal distillation, membrane separation, freezing, electrodialysis, etc. The conventional water distillation processes consume larger amount of energy to separate a portion of pure water from the saline water.

II. MATERIALS AND METHODS

A. Supply Tank

A supply tank of sufficient capacity is provided at the top of the system at necessary head. The tank capacity, dimension, size etc. are user preferences, i.e. which can be varied. The supply tank should be provided at certain height to obtain the head flow of water from the tank to the bottom through various components. Here a 50liter capacity plastic

circular tank is provided as the supply tank. The tank placed at 6feet from the ground.

Fig. 1 Water supply tank

B. Water filter

A simple type of homemade filter is constructed using the necessary materials in order to filter and remove the suspended and dissolved particles in the raw water.

1) Filter

Plastic pipe is a tubular section, or hollow cylinder, made of plastic. It is usually, but not necessarily, of circular cross-section, used mainly to convey substances which can flow liquids and gases (fluids), slurries, powders and masses of small solids. It can also be used for structural applications; hollow pipes are far stiffer per unit weight than solid members. Here the pipe is used as a filtering unit and 60cm of 6 inch (15.24cm) diameter pipe is adopted for constructing the filter. The filter medium is filled within the pipe layer by layer of certain thickness. Charcoal, sand, gravel, aggregates are used as the filter media. The supply water is provided through the top of the filter unit and the filtered water is collected through the bottom.

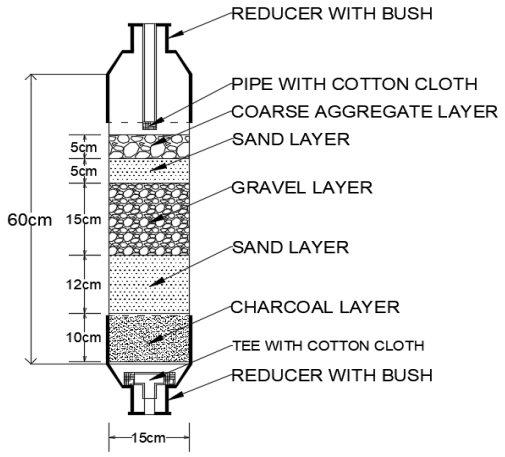

Fig.2 Detailed view of PVC filter unit

A cotton or polyester cloth piece is provided at the top and bottom portion of the filter media inside the pipe. The cloth placed at top act as a screen in order to prevent the entry of larger particles in to the filter. The bottom cloth similarly acts as a barrier for the entry of the filter media along with the filtered water.

2) Charcoal

Carbon filtering is a method of filtering in which a bed of activated carbon removes contaminants and impurities by chemical adsorption. Each particle/granule of carbon provides a large surface area/pore structure, allowing contaminants the maximum possible exposure to the active sites within the filter media. Activated carbon works via a process called adsorption, whereby pollutant molecules in the fluid to be treated are trapped inside the pore structure of the carbon substrate. Carbon filtering is commonly used for water purification, in air purifiers and industrial gas processing Active charcoal carbon filters are most effective in removing chlorine, sediment, volatile organic compounds (VOCs), taste and odor from water. They are not effective in removing minerals, salts, and dissolved inorganic compounds. Typical particle sizes that can be removed by carbon filters range from 0.5 to 50 micrometers. The particle size will be used as part of the filter description. The efficacy of a carbon filter is also based upon the flow rate regulation. When the water is allowed to flow through the filter at a slower rate, the contaminants are exposed to the filter media for a longer amount of time. A 10cm thick media is used.

3) Sand

Most literature recommends that the effective size of sand used for continually operated sand filters should be in the range of 0.15 – 0.35mm, and that the uniformity coefficient should be in the range of 1.5 – 3, although a coefficient of less than 2 is desirable. The sand used for a sand filters should preferably be preferably rounded, and free from any clay, soil or organic matter. If necessary, the sand must be washed before being used. If the raw water is expected to have high levels of carbon dioxide, then the sand must contain less than 2% of calcium and magnesium, calculated as carbonates. This is to prevent the formation of voids in the media if the calcium and magnesium are removed by solution. The sand layer is provided with a thickness of 12cm and 5cm.

4) Gravel

Filter gravel is used as a support media to filter sand and coal in water filters. For maximum efficiency, filter gravel must possess the necessary attributes of hardness and be rounded rather than angular. River Sands Filter Gravel is a hard, round, predominantly quartz aggregate. The filter gravel, like filter sand, contains hard durable particles with a slow breakdown rate. This helps to prolong filter media life. The gravel is screened into three standard sizes which effectively supports the filter media.

5) Aggregate

Although the total volume of aggregate used for filters is relatively small. Filter aggregates generally consist of coarse aggregate or crushed rock. Manufactured aggregates are also occasionally used and these often include blast furnace slags. Aggregates passing through 4.75mm and retaining on 2mm sieve are adopted and provided 5cm thick layer

6) Connections

Reducers, L-Bows, Bents, Tee, 1inch PVC pipe, 3/4th inch PVC pipe are used as the connectors from the supply tank to the filter and the filtered water to the heating unit. The connections are fitted to the filter unit with the use of good quality glues and they should be sealed water tight.

C. Solar water heater

Copper has many desirable properties for thermally efficient and durable heat exchangers. First and foremost, copper is an excellent conductor of heat. This means that copper's high thermal conductivity allows heat to pass through it quickly. Other desirable properties of copper in heat exchangers include its corrosion resistance, bio-fouling resistance, maximum allowable stress and internal pressure, creep rupture strength, fatigue strength, hardness, thermal

expansion, specific heat, antimicrobial properties, tensile strength, yield strength, high melting point, alloyability, ease of fabrication, and ease of joining. Hence a copper coil solar water heater is constructed for pre heating the filtered water before it reaches the distillation still.

1) Copper Coil

40feet (12m) of 1/4th inch copper coils are used as the water heater. Smaller thickness allows the rapid heating and transfer of heat. The coil is painted black in order to absorb more amount of heat and to transfer it to the fluid flowing inside the coil. The coil is fixed on an aluminium sheet or any wood or ply wood piece by using ties. They are also painted black to absorb more heat. The water from the filter is collected in a smaller tank of sufficient capacity and the filtered water is then allowed to pass through the copper coil at one end and the heated water is collected at the other end.

Fig.3 Black coated copper coil assembly

2) Water heater

A 60cm x 60cm x 5cm rectangular box is constructed with the plastic foam board and the joints are tightly sealed using any sealing materials or glues. The whole box should be painted black. Hence the heating of the water in the coil become rapid. Then the copper coil assembly is placed inside the box. Then the top of the box is covered by a 4mm thick glass and the glass is adequately sealed.

Fig.4 Solar water heater

D. Distillation still

PVC foam board, also known as Andy board and Chevron board, is used extensively in both indoor and outdoor applications. Its chemical composition is Poly Vinyl Chloride. It is used in advertising, building and furniture industries. PVC foam board is made of light weight, foamed PVC, which is lightweight, moisture and corrosion resistant. It is resistant to chemicals and has low water absorption. Thickness of the material ranges from 6 mm to 45 mm. The surface of the foam board can be easily engraved, milled, embossed, painted, printed and laminated according to the requirements. Also, they do not decay with time and their colors do not fade for a long time. It is Moisture and corrosion resistant, Shock and noise resistant and Durable but lightweight. 1cm thickness foam boards are adopted for the construction of the solar water heater and the solar still. A rectangular tank with sloping top is constructed using the foam boards. The dimensions of the tank is user defined but the top slope should be in between 15-20˚. Here a tank of 120cm long and 60 cm wide is created with the front height of 15cm and the back height of 35cm. hence the side slope of the top portion comes within the range. The top portion is covered with a 4mm glass.

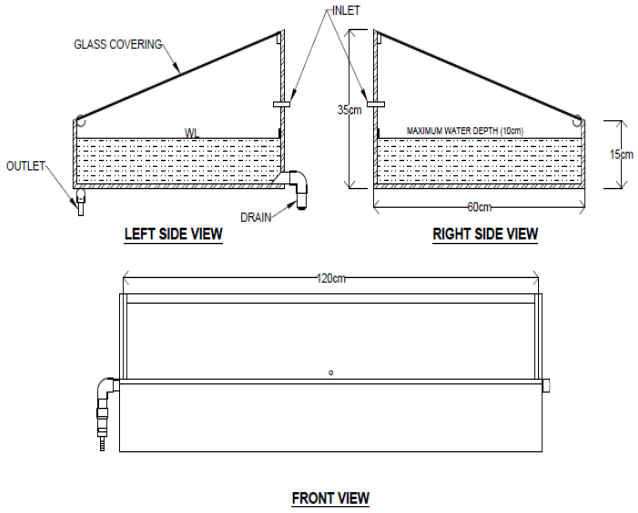

Fig.5 Detailed view of distillation still

The basic principle of the still is evaporation and condensation. Hence a PVC channel is provided at the bottom of the sloping glass to collect the condensed water. The water from the channel is taken out using necessary pipes and connections. The inside of the tank should be painted black in order to absorb more amount of heat. Primer paint coating is done before black painting. The tank should be water tight therefore the evaporation rate will be more. For increasing the inside heat copper pipe filled with PCM (phase change material) can be used and the coil or pipe should be painted black.

The water coming from the preheater or solar water heater is taken into this still by means of an inlet opening. When the atmospheric temperature increases the preheated water in the still get more heated and starts to evaporate. Then the evaporated water stuck on the sloped glass and condensation

occurs. The condensed water flows down through the glass into the channel provided at the bottom of the glass. And the water is taken out and is the distilled water.

Fig.6 Solar distillation system

E. Water sampling

1) Grey water

Grey water is household waste water consisting of waste water coming from the bathing, kitchen uses and washing

2) Sea Water Sample Collection

If collected and prepared properly natural seawater (NSW) is a great alternative to synthetic salts that are available in stores. After all, what would be better than keeping the animals in the same water in which they were born and evolved to survive? Although at first it may seem that this would be ideal and far superior to use over synthetic salt mixes, there are some potential disadvantages and precautions that need to be addressed before the water can be used in a captive environment.

Make sure that the place that you wish to collect the NSW is relatively free of pollutants and runoff from the coastline. It's best to collect the water during high tide when fresh seawater is brought in by the tides. If at all possible collect the water from off shore areas at least one kilometer from shore.

NSW is saturated with organics and plankton. Most of this life can't survive the rigors of life in an aquarium with hazards like changing salinity, pH, calcium, temperature, power heads, filters, protein skimmers etc. If all the plankton were to die off in the tank it could quickly pollute the water and potentially cause an ammonia spike. To prevent this, it's best that you prepare the water before adding it to your tank.

II. RESULTS AND DISCUSSIONS

The water quality parameters mentioned are tested for the different sample solutions. The sample water parameters are checked and are given below. The water samples are distillated and the water quality parameters of the distillated water are also checked.

TABLE I
Water quality parameters of the samples

Sl.No	Parameters	Unit	Value	
			Grey water	Sea water
1	pH	-	3.5	7.5
2	Turbidity	NTU	299.0	1.1
3	T.D.S	Mg/L	1606.0	28600.0
4	Acidity	Mg/L	500.0	48.0
5	Conductivity	µs/cm	2920.0	52000.0
6	Chloride	Mg/L	779.9	10067.8
7	Sulphate	Mg/l	120.0	5000.0
8	Total Hardness	Mg/L	370.0	6680.0
9	Calcium	Mg/L	64.1	340.6
10	Magnesium	Mg/L	51.2	1422.5
11	Iron	Mg/L	0.02	0.05
12	Alkalinity	Mg/L	Nil	180.0
13	Coliform – MPN Ix	MPN	460.0	1100.0
14.	B.O.D	Mg/L	7600.0	520
15	C.O.D	Mg/L	12400.0	1600

The same parameters for the distillated samples are tested and are shown below.

TABLE II
Water quality parameters of the distillated samples

Sl.No	Parameters	Unit	Value	
			Grey water	Sea water
1	pH	-	7.6	7.2
2	Turbidity	NTU	2.1	0.5
3	T.D.S	Mg/L	87.0	127.0
4	Acidity	Mg/L	34.0	28.0
5	Conductivity	µs/cm	127.0	124.0
6	Chloride	Mg/L	173.0	72.9
7	Sulphate	Mg/l	83.1	99.2
8	Total Hardness	Mg/L	118.0	39.0
9	Calcium	Mg/L	42.2	43.1
10	Magnesium	Mg/L	21.7	9.1
11	Iron	Mg/L	0.06	0.1
12	Alkalinity	Mg/L	Nil	72.0
13	Coliform – MPN Ix	MPN	Nil	Nil
14.	B.O.D	Mg/L	3.5	1.8
15	C.O.D	Mg/L	27.0	21.0

TABLE III

Removal efficiency of the distillation system for Grey water

Parameter	Unit	Value		Removal Efficiency (%)
		Sample water	Distillated water	
pH	-	3.5	7.6	-
Turbidity	NTU	299.0	2.1	99.3
T.D.S	Mg/L	1606.0	87.0	94.6
Acidity	Mg/L	500.0	34.0	93.2
Conductivity	µs/cm	2920.0	127.0	95.6
Chloride	Mg/L	779.9	173.0	77.82
Sulphate	Mg/l	120.0	83.1	30.75
Total Hardness	Mg/L	370.0	118.0	68.2
Calcium	Mg/L	64.1	42.2	35.3
Magnesium	Mg/L	51.2	21.7	57.6

Iron	Mg/L	0.02	0.02	Nil
Alkalinity	Mg/L	Nil	Nil	Nil
Coliform – MPN Ix	MPN	460.0	Nil	100
B.O.D	Mg/L	7600.0	3.5	99.95
C.O.D	Mg/L	12400.0	27.0	99.8

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TABLE IV
Removal efficiency of the distillation system for Sea water

Parameter	Unit	Value		Removal Efficiency
		Sample water	Distillated water	
pH	-	7.5	7.2	-
Turbidity	NTU	1.1	0.5	54.5
T.D.S	Mg/L	28600.0	127.0	99.6
Acidity	Mg/L	48.0	28.0	41.7
Conductivity	µs/cm	52000.0	124.0	99.8
Chloride	Mg/L	10067.8	72.9	99.3
Sulphate	Mg/l	5000.0	99.2	98
Total Hardness	Mg/L	6680.0	39.0	99.5
Calcium	Mg/L	340.6	43.1	87.3
Magnesium	Mg/L	1422.5	9.1	99.4
Iron	Mg/L	0.05	0.01	80
Alkalinity	Mg/L	180.0	72.0	60
Coliform – MPN Ix	MPN	1100.0	Nil	100
B.O.D	Mg/L	520	1.8	99.7
C.O.D	Mg/L	1600	21.0	98.7

III. CONCLUSIONS

Energy and water are the basic necessity for all of us to lead a normal life on the earth. Solar energy technologies and its usage are very important for the developing and under developed countries to sustain their energy needs. The use of solar energy in distillation process is one of the best applications of renewable energy for the purification of water. The solar distillation system is also user friendly to the environment.

A solar water distillation kit was successfully fabricated and characterized under actual environmental conditions. The system included five major components; a rectangular Distillation still, copper coil Solar Water heater, filter, supply tank and a collection tank. The system could produce 1.8L of pure water each day by this small unit. This quantity of water is small compared to daily need of potable water. The efficiency of the distillation kit can be increased by using large heat absorber surfaces and increasing number of distillation stills.

Any measure that can occasionally reduce the surface temperature of the glass roof will increase condensation process. Also, using solar concentrators to channel radiant heat to the absorber surface can increase the efficiency of the distillation system. Meanwhile, the solar distillation system can be fabricated with cheap and readily available local materials, such as plastic foam board, PVC pipe, glass etc. The filter and the copper coil water heater can also be constructed using cheap materials like PVC pipe, natural filter media (sand, gravel, charcoal and aggregate), glass and copper coil etc.

It is observed that a high feed water temperature was the most important factor for obtaining higher rates of distillation process. In this work, it is concluded that the productivity of the solar distillation system is significantly affected by the temperature of the feed water.

Salt, bacteria and other impurities can be removed completely in the distillation process. In the experiment it has found that the black coated solar still is more effective when compared with the laboratory distillation. Distillation of water using solar still basin is the most economical method to get potable drinking water.

The solar distillation system is more applicable for saline water or sea water, because the removal efficiency for sea water is about 87% as compared to other type of contaminated water samples. The system removes large percent of turbidity, T.D.S, conductivity, B.O.D, C.O.D, hardness and coliform bacteria. The construction and operation cost of the solar distillation still is lesser when compared to the laboratory distillation apparatus. The main advantage of this system is that it does not require electricity and any mechanically operating parts, hence it is more effective and economical.

The efficiency and the distillate production of this system can be increased using aluminium or copper plating inside the distillation still but may increase the cost of the construction. PCM materials can be used for maintaining the heat in the still for a long duration. The lifetime of this system is more as compared to other systems and is easy to maintain and operate.

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