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Research Paper

Water Purification by Heating Using Solar Power as Fuel

Engineering

KEYWORDS :

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ABSTRACT

Purification by heating is one of many processes available for water purification, and sunlight is one of several forms of heat energy that can be used to power that process. Sunlight has the advantage of zero fuel cost but it requires more space (for its collection) and generally more costly equipment.

To dispel a common belief, it is not necessary to boil water to 100oC to purify. Simply elevating its temperature, short of boiling, will adequately increase the evaporation rate. In fact, although vigorous boiling hastens the purification process it also can force unwanted residue into the bottom, defeating purification. Furthermore, to boil water with sunlight doesn't require more costly apparatus than is needed to distill it a little more slowly without boiling.

Many levels of purification can be achieved with this process, depending upon the intended application. Sterilized water for medical uses requires a different process than that used to make drinking water. Purification of water heavy in dissolved salts differs from purification of water that has been dirtied by other chemicals or suspended solids.

For people concerned about the quality of their municipally-supplied drinking water and unhappy with other methods of additional purification available to them, solar distillation of tap water or brackish groundwater can be a pleasant, energy-efficient option.

Solar purification systems can be small or large. They are designed either to serve the needs of a single family, producing from ½ to 3 gallons of drinking water a day on the average, or to produce much greater amounts for an entire neighborhood or village. In some parts of the world the scarcity of fresh water is partially overcome by covering shallow salt water basins with glass in greenhouse-like structures. These solar purification plants are relatively inexpensive, low-technology systems, especially useful where the need for small plants exists.

Solar purification of portable water from saline (salty) water has been practiced for many years in tropical and sub-tropical regions where fresh water is scare. However, where fresh water is plentiful and energy rates are moderate, the most cost-effective method has been to pump and purify.

1.1 INTRODUCTION

Purification using Solar power is not only cost-effective but a natural source and eco-friendly causing no harm to the process.

- This is always a myth when it comes to solar power, it's installation cost, maintenance and efficiency.
- As we are in the age of Renewable Energy, which is the current need to phase out deterioration of earth.
- Earlier process was through boiling which is the conventional and least cost process for purification of water.
- Advancement of Science and Technology, leading to the development of various process like UV filteration, Reverse osmosis, Distillation and many other gradually increased the price of water which was initially available at free of cost .
- With the help of the Solar power, purification made in this process can be used for residential as well as commercial purposes.
- This process requires a very cheap investment and low maintenance.

1.2 Aim and objective

- To provide pure water free of cost.
- The goal is the purify the water using renewable energy and environmentally friendly manner.
- Advancement of Science and Technology, leading to the development and deterioration should only fall towards development in natural and efficient way.

CHAPTER 2
2.Overview of the SETUP

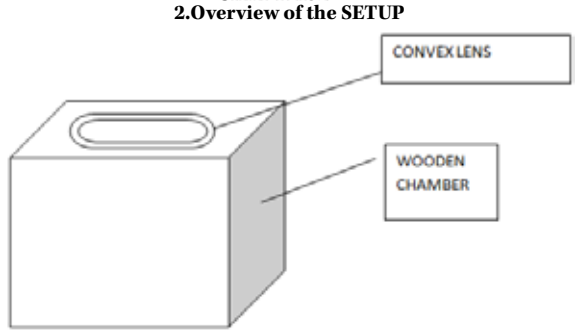


Figure: 1

2.1 CURRENT DESIGNS & THEIR PROBLEMS

We will use a cylindrical single stage solar still design. The basic improvement that we suggest is to use better conducting materials and better heat holding capacity inside the wooden chamber. This will greatly affect the rate of evaporation and

there. As we have already stated above the rate of heating is dependant. After going through the various existing designs of solar stills there are a few facts that come to picture:

1. The efficiency of single stage still is around 25%.
2. Mostly people use three staged stills because for more stages the cost outweighs the utility.

3. Most of the losses can be attributed to heat transfer losses.

4. Thermal losses are mostly in form of conduction and convection and very little by
radiation – owing to low temperatures. So we can assume radiative losses to be
negligible.

Also the cost of a solar still which produces reasonable amount of purified water is high. The

cost of water produced by the still is high. This fact attributes to almost negligible

penetration of solar stills in Indian villages.

While perusing and pondering about the ways to reduce costs the first factor that comes to

mind is why not increase the efficiency. But as we all know this is much easier said than

done. After giving it a considerable thought we came up with a design that can greatly

improve the efficiency of a solar water distillation system by minimizing thermal losses.

The equations governing the heat transfer rates are:

a. Conduction
Q = - k A dT / dx
b. Convection
Q = h A (Tsurface- Tambient)

Both the losses are greatly dependant on the area and temperature difference between the medium i.e., water and ambient. Hence if we can reduce temperature of the whole system we can reduce the heat loss and hence improve the efficiency.

But reducing operating temperature will come at the cost of lower rated of evaporation and consequently lower rated of condensation leading to slower distillation. So now the problem boils down to increasing the rated of evaporation at lower temperature.

(Mass loss rate) / (Unit area) = (Vapor Pressure - Ambient Partial Pressure) * sqrt (

(Molecular Weight)/(2*pi*R*T))

(from Zemansky and Dittman, Heat and Thermodynamics, McGraw Hill, copyright dates from 1937 to 1981).

The Vapor Pressure of a liquid at a given temperature is a characteristic property of that liquid. Vapor pressure of a liquid is intimately connected to boiling point.

Vapor Pressures are influenced by Temperature logarithmically and this relationship is defined with the Clausius Clapyron Equation:

Log P2 / P1= Delta H vaporization [1 / T1- 1/T2] / 2.303 (R)

where: R = universal gas law constant = 8.31 J/mol-K = 8.31 X 10-3 Kj / mol-K

P1 and P2= vapor pressure at T1and T2

T1and T2= Kelvin Temperature at the initial state and final state

At 373K the pressure is 1 atm.

We all know that boiling takes place when the ambient temperature equals that of the vapor

pressure of the liquid. This means that we can increase the rate of evaporation by reducing

the pressure of the vessel. This will ensure higher rates of evaporation even at low

temperatures.

Here we will present our design.



Fig 2

2.2 Design
As stated already, we need to reduce the cost and to increase heating time inside the chamber to increase the rate of purification at lower temperatures and hence increase efficiency. One more additional feature in this model that we are proposing is that it would use the latent heat which is released during condensation to heat up the water at lower temperature. This is achieved by using an cylindrical square design.

The basic arrangement of the system can be described as follows

General arrangement
1. The system will serve for one person.

2. Average requirement of water per person in a house is assumed to be around 1.5 liters/day. Also considering the requirement for cooking we roughly evaluate net water consumption per household is around 30 liters/day which can also be implemented with a larger hold.

3. The solar constant equals 1.3 kW/m2 but owing to losses incurred while passing through atmosphere we can consider the solar irradiation to be 1kW/m2.

Some other important data required for design is given below.

Specific heat of water = 4.2 kJ/kg
Latent heat of vaporization = Latent heat of condensation = 2260 kJ/kg

In the design we have fixed a tempered convex lens glass which is a simply to increase the heating rate and to increase efficiency of the system. We are looking at operating conditions of about 60°C to ensure low heat transfer losses. At this temperature the vapor pressure of water is 20 kPa.

For the purpose of design we will assume a very low conversion efficiency of around 28%.

This will ensure that water is available in excess and also when there is not ample sunlight.

Given the highly erratic supply of sunlight which depends greatly on weather conditions we have to over design it for high factor of safety. In real life we expect the efficiency to be higher than 40%.

1. Tempered Convex glass lens
Glass has the property of selectively allowing only the higher energy radiation to

pass through and blocking the longer wavelengths. This particular property aids

in the upper part as it captures most of the incoming higher energy radiation but

does not allow it to radiate back. This also serves as a condensing surface being

open to atmosphere it will always be at a lower temperature than the water

inside. It is made slanting so that any water droplets that are formed finally move

along the gradient where they finally deposit the condensate into collector.

2. Top water reservoir
Water is stored on top just under the glass plate. This water needs to be

recharged everyday. The floor of the container is painted black to maximize the

irradiation capture. The paint needs to be not water soluble and dried in sun before use to prevent any sort of oil or volatile contents. The side reservoir walls

are insulated and the bottom is conducting.

Chapter 3
MECHANISM
3.1 HEATING MECHANISM
Heating is done using the solar radiation through a convex lens which increases the intensity of solar radiation entering into the cylindrical tub and thus increasing the efficiency.

At a given temperature and pressure, substances with higher volatility (water in this case) vaporizes more readily than the substances(solid impurities) with lower volatility. The water vapor is then directed to a cool region which condenses the water vapor back to liquid state, leaving all the non-volatile solid impurities such as salts, sediment, pathogenic microorganisms and heavy metals behind. However, the distilled water may not be suitable for drinking since it may still contain some volatile organic compounds. The rate of vaporization is proportional to the vapor pressure, fluid surface area and the fluid temperature.

3.2PURIFICATION
This purification process of water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi; and a range of dissolved and particulate material derived from the surfaces that water may have made contact with.

Iodine used for water purification is commonly added to water as a solution, in crystallized form, or in tablets containing tetraglycine hydroperiodide that release 8 mg of iodine per tablet adaptation to chronic tetraglycine hydroperiodide. The iodine kills many, but not all, of the most common pathogens present in natural fresh water sources. Carrying iodine for water purification is an imperfect but lightweight solution for those in need of field purification of drinking water.

A solar still can be used to prepare safe drinking water from usually unsuitable water sources, such as one's own urine, or even sea water.



Fig 3

To improve the efficiency of solar water purification system, reflective surfaces can be used to intensify the solar radiation toward the contaminated water. Another way to improve the system performance is to increase the fluid temperature. According to study, if water temperatures exceed 50°C, one hour of exposure is sufficient to obtain safe drinking water. This is when the solar energy comes in place. A portion of the thermal energy collected from the solar energy collector is directed to the heat up the bottled water.

3.3 WITH SOLAR ENERGY COLLECTOR
The evaporation rate can be calculated as below

$$Q = \frac{\eta_{channel} \cdot S + \eta_{still} \cdot A \cdot G}{HeatOfVaporization}$$

where

- heat of vaporization is heat of vaporization of water = 2.27 MJ/L
- Q is the daily output of water (Liters/day)
- is the efficiency of the still, as the fraction of the energy transfered to the water to the total absorbed solar energy. The typical efficiency for single basin solar stills approach 60 percent.
- nstill and nchannel is the efficiency of the flow channel

to the water to the energy collected from the solar radiation.

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collected from the solar radiation.

- G is the daily global solar irradiation (see solar insolation) (MJ/m^2). The typical solar insolation at the Earth's surface is approximately 1,000 [11] [12] watts per square meter for a surface perpendicular to the Sun's rays at sea level on a clear day. Based on the assumption of 5 hours of sunlight per day, the daily solar irradiation is approximately 18 MJ/

m^2.

- A is the still surface area (perpendicular to the sunlight).
- S is the thermal energy obtained from the solar energy collector. It can be calculated using Enthalpy(ΔH):

$$\delta H = H_f - H_i = \dot{m} \cdot C_p \cdot (T_2 - T_1)$$

where

- δH is the enthalpy change.
- H_{final} is the final enthalpy of the system, expressed in MJ.
- $H_{initial}$ is the initial enthalpy of the system, expressed in MJ.
- $\dot{m}$ is the mass flow rate out of the air flow (kg/s).
- C_p is the specific heat of air (MJ/kg/K).
- T_2 is the flow outlet temperature of the solar energy collector in Kelvin scale.
- T_1 is the flow inlet temperature of the solar energy collector in Kelvin scale.

A simple calculation can be done as follow:

Assumption:

- Daily hours of sunlight = 5 hours/day = 5 hours/day x 3600 sec/hour = 18,000 sec/day
- $\eta_{still} = \eta_{channel} = 60\%$
- Daily global solar irradiation (G) = 1.0 kW

$$Q = \frac{60\% \cdot 0.0012MW \cdot 18,000sec/day + 60\% \cdot 1m^2 \cdot 0.001MJ \cdot 18,000sec/day}{2.27} = 10,33L/day/m^2$$

The International Association for the Properties of Water and Steam (IAPWS) listed the vapor pressure for water as a function of temperature as taken from the latest formulation for general and scientific use:

Table 1

Temperature		Vapor pressure	
Celsius	Fahrenheit	Mega pascals (MPa)	Pounds per square inch (psi)
.01	32	.000612	.088 763
25	77	.00317	.536 639
50	122	.01235	1.791 216
75	167	.0386	5.598
100	212	.1014	14.706

Solar Heat Energy KWh/day

Chennai	70.86995
Mumbai	68.619257
Delhi	79.473161
Kolkata	64.71404

Chapter 4

4.1 CONCLUSION

Water sources must be tested for the Physical and chemical water quality(turbidity, oxygen and color) and microbiological water quality (pathogenic microorganisms) before treatment since it can not change any chemical quality of the water and the solar still is not capable of filtering volatile organic compounds.

But in the view to get purification with results more than expected this will match the need for cooking and other secondary usages.

4.2 APPLICATION:

Project application is not only restricted to residential, it can be applied mainly applied in large scale water purification such as

- First process in desalination after screening.
- For filling water in swimming pool.
- Coolant usage.
- Washing purposes.
- Government spends a lot of money in chlorination for the domestic supply, this will help to replace the process making it very cheaper and harmless.

4.3FUTURE ENHANCEMENT;

In real life application this project can be implemented with specifications such as

- Adding solar collectors.
- Adding solar panels hence serving dual purposes (POWER and WATER PURIFICATION).
- Addition of this system to water supply from domestic and commercial water tanks.
- "These renewable technologyis here now and they're going to be more prevalent in the future, so everyone needs to get on board and be able to support these systems,"

REFERENCE

1) Dwayne Brown, "Guide to Solar power", JAN 2013 edition . | 2) Andy Walker, "Solar technology",AUG 2013 edition . | 3) Solar water Purification, ENGenious Case study Manoj sharma, Karthik Srivatsa, IIT Madras, 2004. | 4) Solar Still Basics by Solaqua | 5) Solar Disinfection System Manual by EAWAG and SANEC. |