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Study of Water Distillation by Solar Energy in India

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Abstract

The purpose of this research is to design a water distillation system that can purify water from nearly any source, a system that is relatively cheap, portable, and depends only on renewable solar energy. From the results of project calculations a truthful estimate was made to prototype the most effective geometries of the distiller and trough concentration system, one that will maximize evaporation/condensation and re capture waste heat to minimize thermal losses. To achieve this goal, a system was designed incorporating a parabolic solar trough coupled with a custom designed distillation device. The incoming solar radiation from the sun is focused and concentrated onto a receiver pipe using a parabolic trough, heating the incoming impure water, at which point it is sprayed into our custom designed distillation device where it evaporates and is re-condensed into pure potable water. Theoretical analysis of the heat and mass transfer mechanisms inside this solar still has been developed. The measured performance was then compared with results obtained by theoretical analysis. The results clearly show that the instantaneous efficiency increases with the increase of solar radiation and with the increase of feed water temperature. The distillation efficiency of the still is 99.64% as compared to the theoretical analysis. Future goals for this project include calculation refinement, material research/testing, and fabrication.

Keywords- *Renewable Energy, Solar PV, Water Distillation, Solar Radiation.*

1. Introduction

The basic principles of solar water distillation are simple yet effective, as distillation replicates the way nature makes rain. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapour rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water cleaner than the purest rainwater.

Water can be purified for drinking purpose by following methods —

1. Distillation
2. Filtration
3. Chemical Treatment
4. Irradiative Treatment

We can rule out few of the above mentioned methods based on the unavailability of materials or costs considering the areas where the technology is intended to be used. Chemical treatment and irradiative treatment are not stand-alone procedures; both can act only to remove some of the specific impurities and hence can only be implemented in combination with other technologies..

2. Solar Water Distillation

Water and energy are the two basic elements that influence the quality of civilized life. Water consumption is increasing all over the world due to rapid increase of population and the agricultural projects. This causes a serious demand on the fresh water. Fresh water is a necessity for the continuity of life. It is also the key to man's prosperity. Although there is a sufficient amount of water on the earth, however it is not always available in the quantity and quality where it is needed for specific purposes. Nowadays, there is growing interest in the developing countries towards the possibilities of utilization of solar energy for purifying water and their practical application in the agricultural sector.

The most important uses of water are in three sectors, namely —

(i) Domestic,
(ii) Agriculture and
(iii) Industrial.

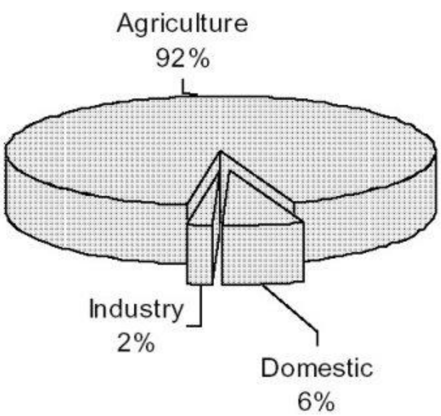


***Fig 1:** shows the percentage of world water use by different sectors for the year 1970 and 2012. In India, major water demands come from the agricultural sector, as it is clear from the above Figure. Domestic sector alone demands 6 per cent of the total demand for water. Solar distillation is the most appropriate process for fresh water supply, especially for small communities in arid zones. {Source: Development and Management of water resources-vol.-II, (2004)}*

The quality of water required generally depends on the type of use. For instance, the public water supply should be free from pathogenic organisms, clear, pleasant to the taste, at reasonable temperature, neither corrosive nor scale forming and free from minerals which would otherwise produce undesirable physiological effects. In view of the wide range of variations in chemical composition of water available in different parts of India, it is hard to prescribe any rigid standards in Indian context. World Health Organization (WHO) has prescribed certain standards, which are given in Table 1.

WHO Test Standards	Permissive	Excessive
Physical turbidity (NTU)	5	25
Appearance		Clear
Chemical odor	Unobjectionable	Unobjectionable
PH	7.0 to 8.5	6.5 to 9.2
Total soloids (ppm)	500	1500
Hardness (ppm)	300	600
Chloride (ppm)	200	400
Nitrate (ppm)	20	50
Iron (ppm)	0.3	1
Alkalinity	-	-

Table 1: WHO Standards for Water
{Source: Development and Management of water resources-vol.-II, (2004)}

2.1. Passive Distillation

Fig. 2(a) shows the simplest form of a solar passive still which is the single-slope, basin-type. This design combines easy manufacturing with low material costs (use of local or recycled material possible); the disadvantage is its low distillate output of two to six liters per day per square meter - depending on the location and applied energy-augmentation measures. This design is viable for locations with latitude greater than 20°; for locations below this latitude, the design of the double-slope, single basin solar still, as depicted in figure 2(b) is recommendable to use, due to the higher solar elevation angles (Murugavel et al. 2008). This type of solar still only has slightly higher material costs, as it requires the use of a bigger number of glass sheets. For practical reasons (water supply for entire communities), this type of still frequently is constructed as a deep-basin still on ground level with water depths between 10 and 50 centimeters, whereas the single-slope still having a water depth of only a few centimeters mostly serves as purification unit for small-scale domestic purposes.

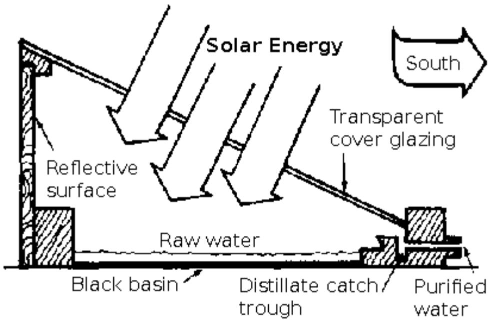


Fig. 2(a): Single-slope, basin-type solar still designs for passive distillation
{Source: Mc Cluney, (1984)}

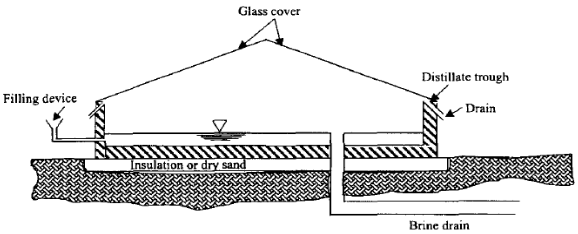


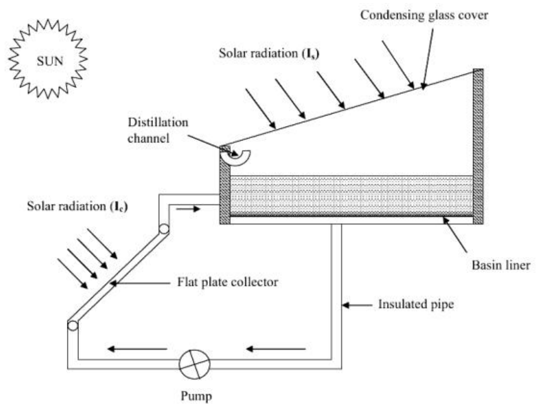
Fig. 1(b): Double-slope, basin-type solar still
{Source: Goosen et al., (2000)}

The overall energy efficiencies of the two types of solar stills vary between 25 and 45% for commonly built models (The Schumacher Centre for Technology & Development, 2008; McCracken and Gordes, 1985), with the single-slope still generally having a 10% higher efficiency than the double-slope still (Al-Hayek and Badran, 2004). In particular cases, efficiencies of up to 60% have been reached.

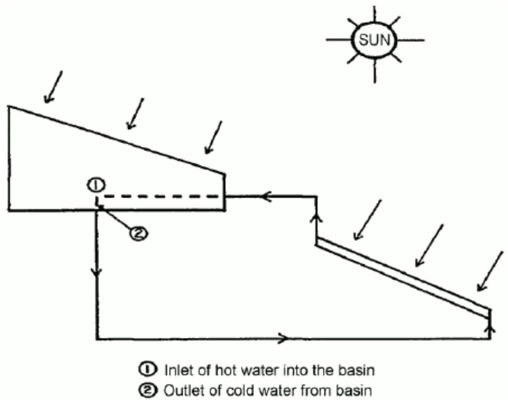
2.2. Active Distillation

The additional energy required for the process of active solar distillation is obtained from other sources, the most common one being an additional solar (water) collector, connected to the evaporation basin. The overall distillate output is raised by approximately 35 to 50% by the usage of pre-heated raw water raises, which also raises the evaporation rate compared to a single-basin solar still. Evaporation temperatures are higher than in passive distillation, about 70 to 80°C. Usually, there are two working principles of the additional hot water collectors:

1. Thermo siphon mode: Due to the temperature difference between hot and cold water, the water circulates from the evaporation basin to the collector and vice versa by force of gravitation and gradients in water density.
2. Forced circulation mode: An additional pump connected between evaporation basin and collector, guarantees a constant flow rate and faster raw water warming.



(a) Forced-circulation mode.
{Source: Tiwari et al.,(2009)}



(b) Thermo siphon mode.
{Source: Lawrence and Tiwari, (1990)}

***Fig.3**: Active distillation systems coupled with flat-plate water collector.*

2.3 Basic Concept of Solar Water Distillation

The solar water distillation principles are simple yet effective. The sun's energy heats water to the point of evaporation. As the water evaporates, water vapor rises, condensing on the glass surface for collection. This process removes impurities such as salts and heavy metals besides eliminating microbiological organisms. The end result is clean water. A passive solar distiller Sol Aqua needs only sunshine to operate. There are no moving parts to wear out.

The distilled water from Sol Aqua does not acquire the "flat" taste of commercially distilled water since the water is not boiled (which lowers pH). Solar stills use the rainwater process which is natural evaporation and condensation. This allows for natural pH buffering that produces excellent taste as compared to steam distillation. They can easily provide enough water for family drinking and cooking needs.

Solar distillers can be used effectively to remove many impurities ranging from salts to microorganisms and are even used to make drinking water from seawater. Sol Aqua stills have been well received by many users, both rural and urban, from around the globe. They are made of quality materials designed to stand-up to the harsh conditions produced by water and sunlight. Operation is simple: water should be added (either manually or automatically) once a day through the still's supply fill port. Excess water will drain out of the overflow port and this will keep salts from building up in the basin. Purified drinking water is collected from the output collection port.

3. Design Concept and Working Process

3.1 Design Concept

A simple asymmetrical solar still was used as the basis for the design concept. Which has been improved by adding various features from researched patents and periodicals. The idea is to thoroughly improve the efficiency of the basic solar still design. The following features were added:

- To prevent solar energy and heat flow from leaving the device insulated basin and side walls were added.
- For multiple smaller bodies of water to be heated at a faster rate than a single body of water Slotted basin was added.
- To regulate water in basin to the optimal level of 1.5 to 2 cm Float valve was introduced.
- On the side walls of the basin to reflect all incoming solar radiation into the water rather than absorb the energy into the walls. Mirrors were incorporated.
- Input tank that was preheated throughout the day so that less solar radiation is required for evaporation.
- Door that opens to allow for easy cleaning of the basin and removal of salt debris.
- Adjustable feet to ensure proper internal level of water.
- Single appliance design for minimum amount of space.
- Ergonomically sized stand to hold basin.
- Effective water collection and easy access spout to fill containers with distilled water.

3.2 Design Parameters

There are a number of parameters which affect the performance of a solar still which are broadly classified as --

(1) Climatic parameters

(2) Design parameters and

(3) Operating parameters.

[1] Climatic Parameters

Solar radiation
Ambient temperature
Wind speed
Outside humidity
Sky conditions

[2] Design Parameters

Single slope or double slope
Glazing material
Water depth in Basin
Bottom insulation
Orientation of still
Inclination of glazing
Spacing between water and glazing
Type of solar still

[3] Operational Parameters

Water depth

Preheating of water
Coloring of water
Salinity of water

3.2 Working Process

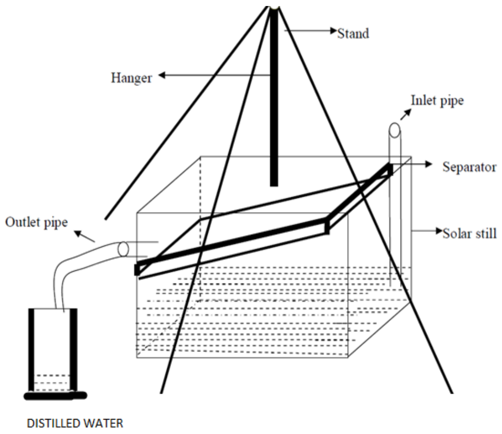


Fig.4 *shows the systematic view of the working. {Source: Anirudh Biswas et al. /VSRD International Journal of Mechanical Auto & Pro. Engg. Vol-2 (5), (2012)}*

Impure water is put in the tank through the inlet pipe and solar still is hanged on the tripod stand in such a way that solar still is on the focus point of the reflector , when sun light is reflected through the reflector.

4. Advantages and Limitations

Advantages:

The advantages of the solar water distillation are listed below —

- It produces water of high quality.
- Negligible Maintenance.
- This process can purified any type of potable water.
- No electricity is required to operate this system and does not involve any moving parts to operate.
- Minimum wastage of water.
- Efficiently produces minimum 2 gallons of potable water per day.
- Can purify water from virtually any source, including the ocean.
- Relatively inexpensive therefore accessible to a wide range of people.
- Easy to use interface.
- Intuitive setup and operation.
- Provides clean drinking water without the need for an external energy source.
- Reasonably portable and compact.

Limitations:

Since we planned to use solar energy for purifying water. The use of solar energy has its limitations like in the rainy season, when it is cloudy and sun does not appear efficiency of water purification will be effected. Water cannot be purified after sun set, so the water needs to be stored during the day time. Solar water distillers do not produce a large volume of potable water, so they will likely never be an effective solution for large communities. The distilled water is missing minerals.

5. Conclusion

In this paper the purpose of water distillation system is described by which we can purify water from nearly any source.

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