International Journal of Scientific and Technical Advancements

ISSN: 2454-1532

Experimental Investigation for Drinking Water Production through Double Slope Solar Still

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Abstract-Drinking water supply will become a great challenge for whole world in the new era, because pure drinking water is a primary component for life & good health and it is integral part of our life. It may cause of spreading of diseases, if it in-hygienic or contaminated or improperly handled and stored. A lot of research is going on for the development of sustainable and cost effective technology to produce the drinking water, which will be free from harmful impurities. Suspended solids can be removed easily but arsenic, lead, chromium and excess fluoride contents are few major problems in sustainable supply of drinking water. So to provide the pure drinking water to everyone is becoming a challenging task. For getting pure water, electro dialysis, reverse osmosis and solar distillation *etc* can be used. Although every technology need the energy input to operate the purification device but reverse osmosis and electro-dialysis are intensive energy techniques while solar distillation is an attractive process to produce drinking water using cost-free solar energy. In this paper the experimental investigation of the fabricated double slope solar still has been presented.

Keywords- Drinking water; scarcity; brackishness; solar still.

I. Introduction

It is estimation that only 4 percent of the total natural reserve is in the form of fresh water and frozen water and rest amount is existing as salt water. Only some fraction of this available fresh water is in the reach of human being. Even this small fraction is believed to be adequate to support life and vegetation on earth. The distribution of the water through various sources is controlled by nature. Nature provides most of the required fresh water, through hydrological cycle. The permissible limit of salinity in water is 500 ppm according to world health organization (WHO) but most of the water available on earth has the salinity up to 10,000 ppm whereas seawater normally has salinity much more than this limit, in the form of total dissolved salts.

Excess brackishness and contamination like arsenic or fluoride causes the problem of taste, stomach problems and various acute diseases like brain, endocrine system, thyroid, pineal gland, immune system, reproductive system and organ systems. Some options are suggested for providing arsenic-free water to the affected rural population, like (i) tapping a deeper third layer beyond 100-150 meters below ground level, which is found to be arsenic-free. (ii) Adopting arsenic removal technique through domestic filters, oxidation, coagulation, absorption, ion exchange and reverse osmosis. The Government of India also introduced an 'Arsenic Sub-mission' in 1994 under the Rajiv Gandhi National Drinking Water Mission to tackle the arsenic problem between the centre and the state. On the other hand developing countries are facing so many problems due to presence of fluoride in the drinking water. Human exposure to fluoride has mushroomed since World War II, due to not only fluoridated water and toothpaste but to the environmental pollution by major industries, where fluoride is a critical industrial chemical as well as a waste-by product. We need to develop an efficient technology to control the exposure of this excess fluoride [1]. As the available fresh water is limited on earth and its demand is increasing day by day due to increasing population and rapid increase of industries, hence there is an essential and earnest need to get fresh water from the saline or brackish water present on or inside the earth [2-4].

When two or more than two components are in the same system and they have different boiling points, then this technique works. It is one of the processes that can be used for water purification by using any heating source. Solar distillation is a simple technique, in which water is evaporated using the energy of the sun, and then the vapour condenses as pure water. This process removes salts and other impurities [5], [6]. Distillation has long been considered a way of making salt water drinkable and purifying water in remote locations. The first modern solar still was built in Las Salinas, Chile, in1872, by Charles Wilson. It consisted of 64 water basins (a total of 4,459 square meters) made of blackened wood with sloping glass covers. This design has formed the basis for the majority of stills built since that time. During the 1950s, interest in solar distillation was revived, and in virtually all cases, the objective was to develop large centralize distillation plants. In our country it is yet in developing phase [7].

Apart from common basin type solar stills, different designs have been studied such as the double basin still, the diffusion still, and the multiple effects still. The limitation of the diffusion type was found to be its operational and maintenance problems and the difficulty to be adapted to the field application [8], [9]. Numerous theoretical and experimental studies have been done to study the performances of single and double basin, and several concepts

Suresh Kumar Patel, Dhananjay Singh, Rahul Dev, and G. L. Devnani, "Experimental investigation for drinking water production through double slope solar Still," *International Journal of Scientific and Technical Advancements*, Volume 2, Issue 1, pp. 45-47, 2016.

such as tilted tray, tilted or vertical wick and some other designs have emerged [10], [11]. Various design shapes and different materials of construction have been attempted to maximize the productivity of drinkable water. The development started from the simple conventional solar stills of high thermal capacity to the designs of systems of low thermal capacities such as tilted-wick still, multiple-ledge tilted still, cascade tilted still, and those that recycle heat such as multiple-effect diffusion still, multiple-effect tilted still and multiple-effect basin type still.

Some of the stills recycle energy through the latent heat of condensation either in counter-current flow of an air-vapor mixture with the inlet feed or directly to another solar still, like in double-basin solar stills. Solar stills that reject the heat of condensation to the atmosphere are termed as single-effect solar stills, but those that provide the reuse of latent heat of condensation to some or more extent, are termed as multiple-effect solar stills [12-14]. The objective of this study is to investigate the performance enhancement of a solar still improve the new design configurations.

II. PARAMETERS

There are a number of parameters which affect the performance of a solar still. These parameters are Climatic, design and operating parameters.

A. Climatic parameters: Solar radiation, ambient temperature, outside humidity, sky conditions, wind speed

B. Design parameters: Water depth in basin, bottom insulation, orientation of still, inclination of glazing

C. Operational parameters: The operational parameters considered in solar still are water depth, rate of algae growth, salinity of water and colouring of water.

III. EXPERIMENTAL SET UP AND PROCEDURE

A double slope solar still (distillation unit) has been fabricated with fiber reinforced plastic (FRP) as shown in figure 1. The overall size of the inner basin is 2.0 m × 1.0 m × 0.10 m. The outer basin is made up of FRP. The top is covered with two glasses of thickness 4 mm inclined at 15° on both sides using FRP frame. The condensed water is collected in the V-shaped drainage provided below the glass lower edge on both sides. The condensate collected on both side of the still is continuously drained through flexible hose and stored in a jar. A hole in the basin side wall allows inserting the thermocouples for the measurement of the basin water, still and condensate temperature. The hole is closed with insulating material to avoid the heat and vapour loss. A thermocouple is exposed to atmosphere to measure the atmospheric temperature. Another hole is provided for water inlet. A small tube is inserted through this hole to supply raw water continuously to the basin from storage tank through a flow regulator. Thus the mass of water in the basin always kept constant.

The experiment was carried out in the Department of Chemical Engineering, Institute of Engineering and Technology, Lucknow, Sitapur Road, Uttar Pradesh, INDIA. The observations are taken for 24 h duration starting from 7 am. The temperature of the atmosphere, basin water and the condensate are noted for every 60 min. The energy meter reading and condensate collected on both side of the still are also noted. The experiments were conducted with a layer of 1 cm of water in the still basin. The condensate temperature is taken as the temperature of the glass cover. The temperature indicator along with the thermocouples, measuring cylinders, gallons and thermometers were used to conduct the experiments.

Fig. 1. Double slope solar still.

IV. RESULTS AND DISCUSSIONS

The variation of water temperature (*T*w), glass temperature (*T*g), the difference between the water and glass temperatures (*T*w-*T*g) and production rate (*m*w) for the still with various basin materials regulates the water purification rate [15]. The production rate increases with the difference between the water and glass temperature initially for basin materials. This value is maximum when the water temperature is around 60-80°C during heating. The water production rate increases with the decrease of the temperature difference between the water and glass for certain period. During above period for certain duration, the production rate decreases with the increase of the basin water temperature. When the still reaches the maximum water temperature, the still production rate is lesser than the maximum. The water temperature increases the evaporation rate. This is due the vapour liquid equilibrium, equilibrium in between the vaporisation and condensation of water. The temperature difference between the water and glass increases the bulk motion of the air mixture inside the still which increases the evaporation and condensation. It was found that (conducted in the month of July), the basin as well as water temperatures were maximum at 15:00 pm and these were 74^{o}C and 80^{o}C respectively.

It was found that production rate was maximum around 17:00 hrs. The difference between the water temperature and glass temperature increases the production rate as well as the bulk motion of the air mixture inside the still which increases the evaporation and condensation. This is maximum when the water temperature is around 60-80°C during heating. But for certain period of time the water production rate increases with the decrease of the temperature difference between the water and glass and decrease of the basin water temperature.

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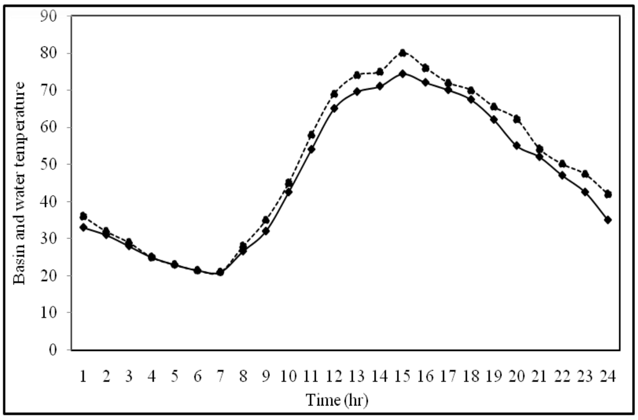

Fig. 2. The basin (solid line) and water temperature (dashed line) of the solar still.

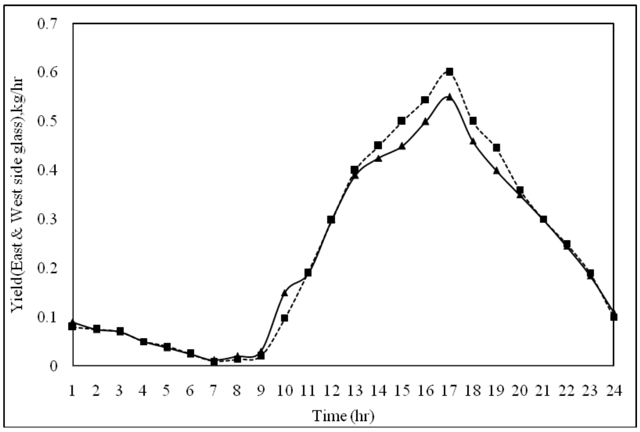

Fig. 3. The east side (dashed line) and west side (solid line) yield with time.

When the still reaches the maximum water temperature, the still production rate is lesser than the maximum. The water temperature increases the evaporation rate. Glass temperature is one important parameter. The east and west side yields are shown in the figure 3 [16], [17].

V. Conclusion

The research in the development of solar distillation units provided a foundation for solar still industries because solar still can provide drinking water supply more economically than any other method. The double slope FRP conventional solar still is the most economical solar still to provide drinking water for domestic applications. This is due to the fact that it is simple in design and fabrication, easy to handle (untrained manpower is sufficient) along with longer life and low cost of water purification per liter of raw water. Further, due to low operation and maintenance cost it is most suitable in rural areas of remote region. The production rate is a complex function of water and glass temperatures, volumetric heat capacity of basin material and solar intensity. Based on the experimental results of monthly average data (conducted in the month of July), it is derived that the basin as well as water temperatures were maximum at 15:00 pm and these were 74^{o}C and 80 ^{o}C respectively. On the other hand the monthly average yields from east and west side glasses are found maximum at 17:00 pm and 0.6 kg/hr and 0.55 kg/hr respectively in the month of July.

Acknowledgment

Authors are thankful to Institute of Engineering & Technology Lucknow, Sitapur Road, Uttar Pradesh, INDIA (Dr. Abdul Kalam Technical University Lucknow, Uttar Pradesh INDIA), for providing financial assistance for this work.

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