Novel configurations of solar distillation system for potable water production

ARiahi, K W Yusof, N Sapari, B S Singh, A M Hashim
1,2,3,5 Department of Civil Engineering, UniversitiTeknologi PETRONAS, 31750 Tronoh, Perak, MALAYSIA
4Fundamental and Applied Sciences Department, UniversitiTeknologi PETRONAS, 31750 Tronoh, Perak, MALAYSIA

E-mail: ali_riahiupm@yahoo.com

Abstract - More and more surface water are polluted with toxic chemicals. Alternatively brackish and saline water are used as feed water to water treatment plants. Expensive desalination process via reverse osmosis or distillation is used in the plants. Thus, this conventional desalination is not suitable for low and medium income countries. A cheaper method is by solar distillation. However the rate of water production by this method is generally considered low. This research attempts to enhance water production of solar distillation by optimizing solar capture, evaporation and condensation processes. Solar radiation data was captured in several days in Perak, Malaysia. Three kinds of experiments were done by fabricating triangular solar distillation systems. First type was conventional solar still, second type was combined with 50 Watt solar photovoltaic panel and 40 Watt Dc heater, while third type was integrated with 12 Volt Solar battery and 40Watt Dc heater. The present investigation showed that the productivity of second and third systems were 150% and 480% of the conventional still type, respectively. The finding of this research can be expected to have wide application in water supply particularly in areas where fresh surface water is limited.

Keywords – Solar distillation; Solar radiation; Evaporation; Condensation

1. Introduction
One of the most plentiful resources on Earth is water which covers 75% of the planet’s area. Groundwater, lakes and rivers are different types of freshwater which contains just 3% in Earth water [1]. Obtaining fresh water is the most important challenge in the world. Achieving fresh water quality parameters according to WHO standards [2] is required to remove chemicals and heavy metals from natural water resources by using solar distillation system which is the significant factors for producing drinking water. There are some methods for desalination and providing potable water and the simplest one is using distillation system. During the last years, many researchers studied to find the solutions for developing the traditional solar still performance for producing higher value of potable water. This paper emphasized the development of solar distillation still to enhance the potable water productivity and to investigate the relationship between solar radiation in Malaysia and water productivity by adding solar photovoltaic system.

2. Research Background
Solar distillation still is the most commonly used method of producing drinking water in arid, remote and coastal areas in the world. This method is generally the simplest, most flexible and most economical means of brackish water and groundwater treatment. The problem with solar still however, it produces less fresh water [1].

Currently, to raise the productivity of solar distillation systems many types of solar stills were designed, fabricated and tested. Later development in solar distillation stills operation is moving towards the increase of water temperature for reaching high amount of evaporation inside solar still.
The productivity of pyramid shape solar still was increased by 231% and reached to 4.62 L/m².d using solar thermal by treating 18.4 L saline water expose to peak sun radiation between 700 and 1000 W/m² in Jordan [3], while it reached to 6.6 L/m².d by using 2 flat plate collectors combined with a single sloped solar still with maximum solar radiation intensity of 780 W/m² and taking 7 hours to reach the water to 92.3˚C as peak temperature in India [4]. 6.26 L/m².d water productivity obtained by cooling the glass surface cover of double slope solar still using shading screen in Algeria by treating 9.45 L of salty water under 800 W/m² peak sun radiation and 71˚C as peak water temperature [5]. However, the amount of productivity increased by 370% in Saudi Arabia by using 2 AC heaters to reach to 11.9 L/m².day treating 60 L of seawater expose to 1000 W/m² as peak solar radiation intensity, but the problem reported was the high cost of electrical consumption [6]. The water production of solar distillation stills was also improved by using forced convention such as fin, sponges, pebbles, black rubber and sand in solar still, utilizing solar collector coupled with solar still [7].

3. Methodology
In this research, a model of triangular double sloped solar still was constructed by using the materials of steel basin has 34cm length and 20cm width, transparent plastic cover and PVC Pipe for fabricating the frame. A 50 Watt solar panel and a 40 Watt Dc heater were combined as the source of solar energy capture for converting it to electrical energy and transferring to the thermal energy, respectively. Three types of experiments were done by combining 50 Watt solar photovoltaic panel and 12 volt solar battery as an auxiliary system of solar power energy system to the 40 Watt Dc heater inside the trough of solar triangular distillation still.

4. Results and discussion
First experiment was organized by exposing the solar still to only sun radiation on 02.12.2012. The values of solar radiation intensity, ambient and water temperatures obtained in the first experiment as well as the relationship between water temperature and sun radiation intensity are shown in Figures 1 and 2.

The value of 100 ml potable water was produced during 7 hours in UTP, Perak, Malaysia by heating 1.5 Liter of brackish water and exposing triangular solar still to only solar radiation on 02.12.2012. The second experiment was done by using 50 Watt solar panel and 40 Watt Dc heater in Perak, Malaysia on 03.12.2012 is shown in Figure 3. Solar radiation intensity, ambient and water temperatures measured in second experiment as well as the linear relationship between solar radiation and water temperature are shown in Figures 4 and 5. The value of 150 ml distilled water was produced during 4 hours of heating 2 Liter of brackish water in UTP, Perak, Malaysia on 03.12.2012 by using thermal energy of solar radiation and Dc heater. By using 12 Volt solar battery and 40 Watt Dc heater in UTP, Perak, Malaysia the last experiment was done on 06.12.2012. The values of hourly water production, solar radiation intensity, ambient and water temperatures and battery voltage
consumption obtained in third experiment are shown in Figures 6, 7, 8 and 9. A linear relationship can be observed by obtaining the relation of water production and water temperature variations in Figure 8. By considering the above results it can be shown that by increasing the solar radiation intensity, the ambient and water temperature will be raised, thus the high value of water production can be obtained during the day and by decreasing the intensity of solar energy, the reduction of productivity and surrounding temperatures can be observed.

**Figure 3.** The thermal transfer processes in triangular solar distillation still using solar photovoltaic and Dc heater.

**Figure 4.** Solar radiation intensity values versus ambient and water temperatures on 03.12.2012.

**Figure 5.** Relationship between water temperature and solar radiation intensity on 03.12.2012.

**Figure 6.** Hourly water production values versus solar radiation intensity and battery power consumption increase on 06.12.2012.

**Figure 7.** The hourly water production variations versus solar radiation intensity and battery power consumption increase on 06.12.2012.

**Figure 8.** Relationship between average water temperature and hourly water production on 06.12.2012.
However, the increase in water temperature and productivity depends on raising the battery power consumption and sun radiation intensity which can be shown in Figures 9 and 10.

5. Conclusion
The present study of triangular solar distillation still showed that the rate of water production is mostly depended on the values of water temperature, ambient temperature and solar radiation intensity as well as solar power supply. These values are most significant factors for developing the evaporation and condensation of thermal transfer process in solar distillation system. The relationship between water temperature inside solar still and sun radiation intensity is more linear by combining the solar power systems than exposing the solar still to only solar radiation. The production rate using second and third systems was 150% and 480% of the conventional type production respectively. The higher absorptivity of sun radiation can be obtained by using glass instead of transparent plastic as cover of solar still.

Acknowledgment
The author would like to acknowledge the support of Universiti Teknologi Petronas in this work.

References
[1] Velmurugan V, Deenadayalan CK, Vinod H, Sridhar K 2008 Desalination of effluent using fin type solar still Energy 33 1719–1727
[2] World Health Organization 2008 Guidelines for Drinking e Water Quality (Electronic Resource) Incorporating 1st and 2nd Addenda, Recommendations -third ed
[3] Ali A B, Ahmad A. A1-Hallaq, Imam A E S, and Mohammad Z O 2005 A solar still augmented with a flat-plate collector Desalination 172 227-234.
[4] Shiv Kumar, Tiwari G N, Gaur M K 2010 Development of empirical relation to evaluate the heat transfer coefficients and fractional energy in basin type hybrid (PV/T) active solar still Desalination 250 214–221
[5] Zeroual M, Bouguettaia H, Bechki D, Boughali S, Bouchkima B, and Maheen H 2011 Experimental Investigation on a Double Slope Solar Still With Partially Cooled Condenser in the Region of Ouargla (Algeria) Energy Procedia 6 736–742.
[6] Ahmed Z. Al-Garni August 2012 Productivity Enhancement of Solar Still Using Water Heater and Cooling Fan Journal of Solar Energy Engineering 134 / 031006-1
[7] Sampathkumar K, Arjunan T V, Pitchandi P, Senthilkumar P 2010 Active solar distillation—A detailed review Renew. Sustainable Energy Rev 14 1503–1526.