Fabrication and performance of solar water distiller for treatment of groundwater

Kyaw Wunna

Abstract

Recently, shortage of fresh water has been encountered all over the world with respect to over consumption of fresh water. In the way to solve this problem brackish and saline water from sea is desalinated to produce fresh water using ultrafiltration method. However, this method is too expensive to use in developing countries. Evaporation and condensation of water are also used in order to produce fresh water. However, this method also consumes certain amount of fuel. Therefore, solar water distiller will be fabricated to evaporate the water by using the heat from the solar radiation. The construction of solar water distiller is cheaper than other distillers. Due to its ability of removal of hardness of groundwater, it can be used in the region having the high hardness-groundwater. Moreover, it can also be used in central dry zone and coastal regions of Myanmar having less access to fresh water; and in the disaster area as emergency water purifier. In this present work, solar water distiller will be constructed, followed by performance test, comparison of characteristics of groundwater before and after treatment, data collection and data analysis.

Keywords: solar water distiller, groundwater, fresh water, hardness, emergency water purifier

Introduction

Clean water play a vital role for the survival on the Earth. Fast growth of population and the poor water management with more water pollution lead to restriction of the fresh water sources from the nature. The contaminated or polluted water contains harmful bacteria and viruses such as *E. coli*, chemical and physical contaminants dissolved and undisclosed materials such as arsenic, lead, mercury, calcium, magnesium, chloride, sulphite and silt, which may cause bad health. Therefore, it is necessary to find out the alternative method or technique to distil the impure water available from various sources like from rain, underground water, rivers or oceans, etc (Singh et al., 2018).

The direct use of solar energy is a potential alternative for eliminating the major energy cost of distillation plants, especially in arid regions where solar radiation is year-round available or intense. The supply of water in the driest areas is of great importance for small communities. Underground water in most of the cases become scarce, or if it is found in small quantities, is brackish. In dry zone areas, water cannot be found for several kilometers. Rain is another rare phenomenon in these areas, and in a few semi-dry regions the rain collected is not always enough to supply the community year round. Therefore, the problem of providing drinking water in developing dry regions is growing at an uncommon pace. It is important, therefore, to find a way for additional sources of water (Bouchekima et al., 1998). Myanmar has central arid zones including Magway, Mandalay and Lower Sagaing Regions in which their groundwater available is scarce and has low quality especially with highly hardness of water.

Solar evaporation is an old technology that has drawn extreme attention due to the abundant resource of solar energy, widely available water sources, and simplistic provisions in combination with substantial improvements of conversion efficiency enabled by improved photothermal materials, thermal management, and interfacial heating system designs in recent years. Solar evaporation or distillation, which combines above resources, can be considered

Assistant Lecturer, Industrial Chemistry Department, Yadanabon University

as one of the most attractive implementations of solar thermal technology and as cost-effective solution for the environment and has been used to generate potable water since ancient times. Steam and clean water generation, from either wastewater or seawater, is the basic application of the solar evaporation technique, which represents one of the most promising green and sustainable solutions to the pressing global challenge of water shortages. Nowadays, more and more applications are being driven by this fundamental photothermal process, including electricity generation, steam sterilization, and fuel production (Chen et al., 2018).

This work is aimed to study the construction and design single slope solar water distiller to obtain distilled water which will alleviate the need for drinking water in daily life. In this work, the effect of day time temperature on productivity of distillate will be evaluated.

Theoretical Background

Solar distillation of brackish or seawaters is conducted on a large-scale basis in greenhouse type distillers of with certain practical installations which can obtain several thousand square meters. Since installations are low cost per square meter, the surface area is relatively large. In these stills, solar radiation passes through the transparent cover and provides heats the horizontal bottom of the basin containing a pseudo-stationary layer of water (Bouchekima et al., 1998).

The basin water temperature is a function of depth with day variation of solar radiation intensity. Effect of water depth, insulation thickness, solar radiation, inclination angle, cooling the transparent cover on the thermal performance of the basin type solar still was investigated. It was observed that the nocturnal distillation is significant in the case of higher depths of basin water due to the increased amount thermal energy stored within the basin water. The optimum tilt angles for the glass cover should be as small as possible during summer and equal 50° during winter in Tanta (30° 47′N) and the optimum insulation thickness is found to be 0.075m. The still productivity could be enhanced by adding dark soluble dye to the brine by up to 20%. The water temperature, distillate output and efficiency of the system increase with decreasing mass flow rate (Performance analysis, E. El-Bialy, 2014). In addition, increased solar thermal absorption causes higher distillate output (Singh et al., 2018).

Types of solar distiller units

Solar distiller units are very adaptable and sustainable technique for potable eater production by using freely available solar energy and water resources. Solar distiller units are generally categorized as passive solar distillation system which represents still without any kind of external power production or consumption with the help of any external or internal source and active solar distillation system which represents still with some external or internal power producing or consuming devices.

Passive solar distiller unit

It is a very simple unit in which direct solar radiation from sun heats the unit to evaporate the saline water. It is formed as single and double slope type as well as with several integrations but without connection any power source. Fiber reinforced plastic and transparent glass cover are employed to design distillation system. Dark black basin liner is used in order to absorb maximum solar radiation. The incidents of solar rays on the inclined glass cover of still enters the water surface and then to the basin liner. Some solar radiations are reflected and the rest is absorbed by these and the highest solar radiation is obtained in water surface and still basin liner. In this way, maximum energy is absorbed by basin liner which goes to water by convection and results increased water temperature.

Active solar distiller unit

It is the active form of solar distiller unit which receives the external power source to increase the evaporation of water. The forced circulation of water increases the water temperature and consequently evaporation of water increases. Circulation of water can be done by using pump operated with either direct electricity or by photovoltaic module. After receiving the direct sun light, the photovoltaic thermal system generates the electricity which is consumed by water pump and pump causes a forced flow of water. Now the water receives the heat from the collector and the collector receives the energy from the solar radiation which is utilized by PV cells to produce the electricity as well. In this way a forced flow of water can be prepared by utilizing conventional or nonconventional energy resources.

Performance evaluation methods for solar water distiller

Performance of solar distillation systems can be described by some other universal identified evaluation indexes tools such as gained output ratio (GOR), performance ratio (PR), etc. GOR generally describes the net energy needed for the production of unit volume distillate. It is dependent upon the incident solar radiation energy, area of solar collector and evaporation area of still basin. GOR is the ratio of the net energy output i.e. distillate output multiplied by evaporation enthalpy to net energy input of the solar system. GOR represents the performance index for that solar system. Performance ratio (PR) shows the ratio of system yield to reference yield and represents the actual available energy to export to grid (Singh et al., 2018).

Description for Design and Construction of Solar Distiller

The present design is constructed based on the report by El-Bialy (2014). Single slope single basin solar distiller (SBD) (figure 1) is designed, constructed and tested experimentally. The proposed design is shown in figure 1. It consists of a basin made of galvanized iron (1 mm thick). The basin of the distiller is square in shape with 0.6 m height support. The inner surfaces of the basin are painted black to increase absorption of solar radiation intensity. The side of basin is covered with polystyrene insulation to minimize back and side heat losses. An ordinary glass sheet of thickness of 3 mm was used as a cover plate in the top of the basin with a tilt angle of 15° with horizontal to maximize the transmitted solar radiation, and to minimize the top heat losses. A pipe with tap was fixed in the bottom of the basin for discharging the water from the basin during the cleaning period of the still. A tray was fixed at the lower edge of the glass cover to collect the condensate. Rubber gaskets with clamps were used to seal the cover on the basin to vapor leakage.

Data Collection

This section includes water sample collection, test of water quality before and after solar distillation, daily recording of distillate volume, measuring of temperature at time intervals such as hours, days and months.

Sample collection

Underground water sample is collected from tube well in the area near Yadanabon University located in Amarpura Township, which is one of the tube well water used as drinking and cooking purposes. The collected water sample is stored in the plastic containers and kept at room temperature before further use.

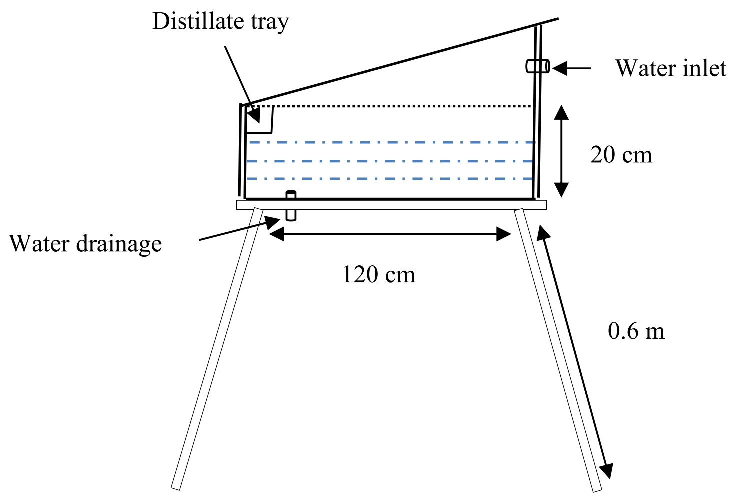

Figure (1). Proposed design of solar water distiller

Test of water quality

After collecting the sample, pH of water sample is measured by pH meter and, acidity, alkalinity, total hardness of water are analyzed by titration method. Trace elements such as arsenic and lead are analyzed in atomic absorption spectroscopy (AAS). According to the previous report (Kyu Kyu Mar,2018), concentrations of trace elements of underground water were within WHO standard. The concentration of arsenic was less than 0.001 mg/L. However, total hardness concentration as carbonate content was 427 mg/L and it was little higher than the standard. After the distillation of collected sample, above mentioned parameters are also measured again and the results of before and after solar distillation are compared.

Effect of temperature

Temperature influences on the productivity of distillate water. In this project, day-time temperature is recorded at time interval such as hours, days, weeks and months. Average day-time temperature in study area is 28°C in winter, 36°C in summer, and 32°C in the rest.

Conclusion

In this work, experimental study of single slope solar distiller is performed. Effect of daily temperature and climatic changes are investigated. In addition, efficiency and productivity are going to be observed at per unit area per day for maximum solar intensity. It is expected that good performance of solar distiller can be achieved by conducting this experiment. This work can conclude that the distillate generation can be augmented when the temperature of water increases. The efficiency of the solar distiller depends on the temperature of the feed water and the intensity of solar radiation. This distiller can provide reduction of polluted water, reduction of environmental impact, and cheap and green technique.

Acknowledgement

The author would like to express the grateful thanks to Dr. Khin Hnin Aye, professor and head of Industrial Chemistry Department, Yadanabon University, for her kind permission to conduct this project.

References

Bouchekima B., Gros B., Ouahes R., Diboun M., 1998. Performance study of the capillary film solar distiller. *Desalination. 116, 185-192*

Chen C., Kuang Y., Hu L., 2018, Challenges and opportunities for solar evaporation. *Joule: Cell Press Review. DOI: 10.1016/j.joule.2018.12.023*

El-Bialy E., 2014. Performance analysis for passive single slope single basin solar distiller with a floating absorber – An experimental study. *Energy. 68, 117-124*

Kyu Kyu Mar, 2018. Evaluation of heavy metal concentration in water and soil and their potential impacts to the environment in Amarapura area, Mandalay Region. *Research and Innovation Conference, Yagon. 2018*

Singh A.K., Singh D.B., Mallick A., Kumar N., 2018. Energy matrices and efficiency analyses of solar distiller units: A review. *Solar Energy. 17, 53-75*