



Renewable Energy

Elixir Renewable Energy 102 (2017) 44193-44196

Elixir
ISSN: 2229-712X

Different Methods to Enhance the Evaporation Rate Using Photo-Catalyst in Solar Still – A Review

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ARTICLE INFO

Article history:

Received: 23 December 2016;

Accepted: 5 January 2017;

Published: 10 January 2017;

Keywords

Photo catalyst,
Solar still,
Evaporation rate,
Distillation.

ABSTRACT

Nowadays water scarcity existing in many countries even though earth is covered by three –fourth of water. Worldwide rapid growth of industries and the immeasurable population are the major reasons for scarcity of water. Solar still is the only effective solution for water problems in dry areas where the scarcity of water and electricity exists. Solar still is a efficient solar device which converts the available brackish water into potable water. An extensive review on different methods to enhance the evaporation rate using photo-catalyst in solar still has been carried out in this paper.

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Introduction

Water plays a vital role for all life forms on earth-human, plants and animals. Water covers three fourths of the earth's surface. About 97% of saltwater in oceans and the remaining 3% as fresh water in the form of ice, ground water, lakes, and rivers present in the earth surface, which fulfill the needs of living things. Only 1% fresh water reaches the humans. Remaining 2% of fresh water is used by the nature for the purpose of hydrological cycle.

Population and growth of industries leads to the imbalance between supply and demand of fresh water. Most desalination plants such as reverse osmosis, membrane distillation, multistage and multiple effect distillation are not possible without use fossil fuel as a source of energy. To supply clean potable water to rural and urban people the above-mentioned treatment processes are available. Although the people living in remote areas had no devices to supply drinking water in an effective manner.

The first conventional solar still was designed by Swedish engineer C.Wilson in the year 1872 for supplying fresh water to mining community in Northern Chile. Evaporation and condensation are the two processes that combine the both operation of solar still and hydrological cycle.

A black painted basin filled by brackish water or waste water. Transparent cover is enclosed in a completely air tight area. Transparent cover passes incident solar irradiance and it is absorbed by the basin plate. Consequently basin water gets heated up and evaporates in the saturated conditions inside the still killing all pathogenic bacteria. Water vapors rises towards the cooler inner surface of the cover, where they condense to pure water, due to gravity and run down along the cover bottom surface, getting collected in a collecting tray. The still is easy to fabricate and does not require maintenance and skilled labors.

The Factors affecting the yield of solar still and the performance of solar still is generally expressed as the quantity of water produced by basin area in a day.

The quantity of water produced by solar still varies with solar radiation available, atmosphere humidity, ambient temperature, sky conditions and wind speed, and cannot be controlled by humans as they are meteorological parameters. The design parameters such orientation of the still, area of absorber plate, inclination of glass cover, slopes of the cover, insulation materials, depth of water, inlet temperature of water and the temperature difference between the glass cover and the basin water affect the production rate.

There are two types of solar stills namely active solar still and passive solar still. The additional collectors or condensers are used to enhance the productivity in active solar still. The simple modifications within basin are used to enhance the productivity in passive solar still. Kalidasa Murugavel et al [1] reviewed in improving the effectiveness of single basin passive solar still Velmuruganetal. [2] Reviewed the performance analysis of solar stills based on various factors affecting the productivity. Kabeel et al. [3] Reviewed there search and developments on solar still. Kaushalet al. [4] Reviewed the different types of solar still. Sampath kumar et al. [5] reviewed the active solar distillation in detailed. Xiao et al. [6] Reviewed the solar stills for brine desalination. However, the still productivity mainly depends one vapourization and condensation rate. Hence, the main objective of this review is on different methods to enhance the evaporation rate using photo-catalyst in solar still.

2. Different methods to increase the evaporation rate using photo catalyst:

A.K. Rajvanshi [7] analysed the study of the effect of adding dyes to a solar distillation unit is reported in this paper. The analytical model was developed and treats the transient heat transfer inside the dye solution as one dimensional. The bulk fluid is discredited into layers with conduction, convection and radiation interactions occurring between them. Black naphthylamine, red carmoisine and dark green are the dyes used at various concentrations.

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Dye solution is able to increase the distilled by output as much as 29 per cent (for black dye with 172.5 ppm concentration) are the results shown. Based on these tests, a method of calculating the percentage increase in evaporation effected by a specific dye over that from the control unit is developed. Among the dyes tested black naphthylamine dye is found to be most suitable from two points of view: increased evaporation and no photochemical degradation. The agreement between the results from analytical model is excellent. The analytical model subsequently used to study the effect of ambient temperature, wind velocity and dye concentration on still productivity.

It predicted an increased in still productivity with increased in wind speed. The analytical model also predicted the increased of distilled with increased in concentration of dye up to 500ppm, which it is independent of the concentration. An analytical method of predicted an optimum concentration of a particular dye is developed. The optimum concentration for a dye is obtained where the function is maximum.

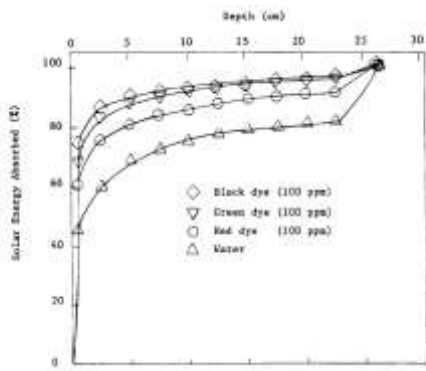


Fig 1. percentage of solar energy absorbed with depth of solution [7].

S.G. Patel et al. [8] enhance the overall efficiency of conventional basin type solar still by different semiconducting oxides like CuO, PbO₂ and MnO₂ as photo catalysts. It is observed that metal oxides not only improve the efficiency of the process but the rate of production of desalinated water was also increased to a remarkable extent. The water quality for its various parameters like pH, TDS, etc. are analyzed (for raw and desalinated water).

It is a well known fact that semiconducting oxides act as photo catalyst. The total amount of water collected is measured. The results are observed that the rates of production of desalinated water increases with sunlight and it reaches an optimum after 2–3 h. The metal oxides used improve the rate of production of desalinated water as compared to desalinated water production without photo catalyst.

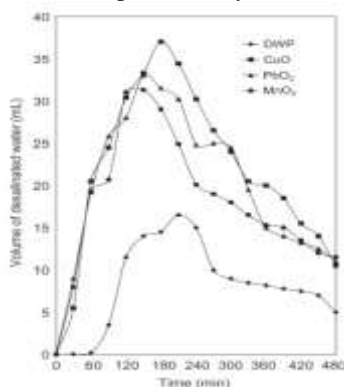


Fig 2. Rate of production of desalinated water in presence of oxides [8].

B.A. Akash et al. [9] analyse the study of the effect of using different absorbing materials in a solar still, and thus enhance the productivity of water. Results shown that the productivity of distilled water was enhanced for some materials. By using an absorbing black rubber mat increased the daily water productivity by 38%. Using black ink increased it by 45%. Black dye was the best absorbing material used in terms of water productivity. It resulted in an enhancement of about 60%. The still used in the study was a single-basin solar still with double slopes and An effective insolation area of 3 m².

It shown that the maximum amount of production rate occurred, for all materials used. The production rate was highest when black dye was used. The lowest production rate occurred when water alone was used and there was not any other absorbing material inside the still. It indicated that black dye can absorb solar radiation at higher rates than other materials considered in this study.

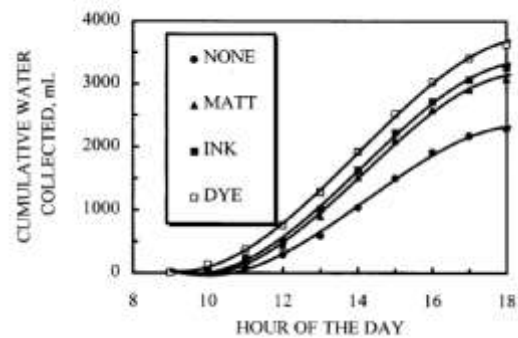


Fig 3. Hourly cumulative water collected [9].

Y.H. Zurigat Et al.[10] analyse the study of a regenerative solar desalination unit and its performance evaluated. The unit consists of two basins (effects), with provision for cooled water to flow in and out of the second effect. An arrangement had the advantages of increasing the temperature difference between water and glass cover in the first effect and utilizes the latent heat of water vapor condensing on the glass of the first effect to produce more fresh water in the second effect. The performance of the regenerative still is evaluated with the performance of the conventional still. The results of the simulations shown that the productivity of the regenerative still is 20% higher compared to the conventional still. The wind speed has a significant effect on the productivity of the stills; it can increase the productivity by more than 50% if the wind speed is increased from 0 to 10 m/s.

It is concluded that the productivity of the regenerative still is more than 20% higher than that for the conventional still. Making the stills perfectly insulated increases their productivity two and one half folds. There is more positive effect due to insulation on the regenerative still compared with the conventional still.

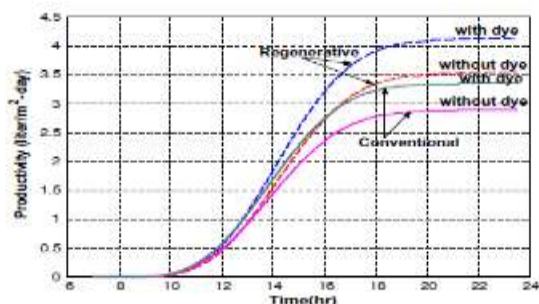


Fig. 4 Productivity of stills with and without dye [10]

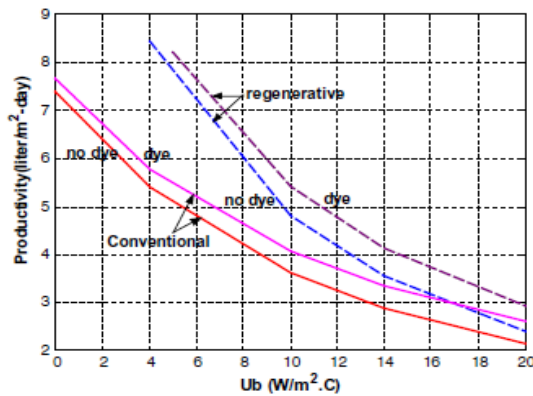


Fig.5 Effect of insulation and dye on productivity of stills [10]

A.Muthumanokar [11] enhance the chemical reaction and the productivity by the use of titanium dioxide as photo-catalyst. Using titanium dioxide, (TiO_2) as photo-catalyst, the process was successfully degraded and reduces the organic pollutant and microorganisms in wastewater. It is non-toxicity, photo-chemically unwavering and highly reactive. Otherwise, the catalyst itself is inexpensive and commercially available in various crystalline forms. The daily productivity of single basin single slope solar still without the use of photo-catalysis was 615 ML/0.25M²/day and with the use of photo-catalysis was 670 ML/0.25M²/day.

It concluded that titanium dioxide (TiO_2) as photo-catalyst reduced the organic pollutant and microorganisms in wastewater. Photo catalytic water splitting was the simplicity of using a powder in water and sunlight to produce H_2 and O_2 from water and it was provided a clean, renewable energy, without producing any greenhouse gases and affecting the atmosphere. The daily productivity of conventional solar still is 615ML/0.25M²/day and the daily productivity of solar still with photo-catalysis reaction is 670ML/0.25M²/day. When titanium dioxide is placed in basin there was 8.2% increased in productivity. In the presence of sunlight, TiO_2 was accelerating the natural decomposition of low-level organic compounds in aqueous solutions.

R.P.N. Ayuthaya et al.[12] experiment on developing a mathematical model for predicting the productivity of an ethanol solar still of basin type. A horizontal evaporating surface and a condensing surface inclined 14° to a horizontal. Various concentrations of ethanol water solution were employed.



Fig. 6. Titanium Oxide in solar still basin [11]

The distillation temperature range included boiling point. The collected data were used to estimated the mass-transfer coefficient and mass transfer conductance of the solar still. Accordingly, a mathematical model was developed based on the Spalding theory of convection and the Fick's law of

diffusion. In order to increase the performance at the outdoor conditions, a basin solar still was integrated with a set of fin-plate fitting in the still basin for distillation of a 10%v/v alcohol solution. It was found that the productivity of the modified solar still was increased by 15.5%, compared to that of a conventional still. Moreover, the predicted still efficiency by the model could increase to 46% when a number of fins that raised an effective absorptance were increased. Condition of high concentration output and high productivity was investigated. Monthly mean productivity and efficiency of the still were found to increase with daily mean insolation.

The developed mathematical model to predict still performance was based on the Reynolds flow model. The Grashof number was positive and air was present in the unit. Moreover, the Fick's law could be applied when the Grashof number was negative and no air as in the cases of boiling or high concentrated solutions. The integration of fin into the basin solar still could increase productivity. Adding fin to the basin could decrease the preheating time required for evaporating in the still basin, because an extended fin surface could increase the effective absorptance of basin plate and the solution temperature. The simulated productivity agreed well with the experimental results for both indoor and outdoor conditions. It was found that the more productivity having high concentration could be obtained at or near a boiling condition.

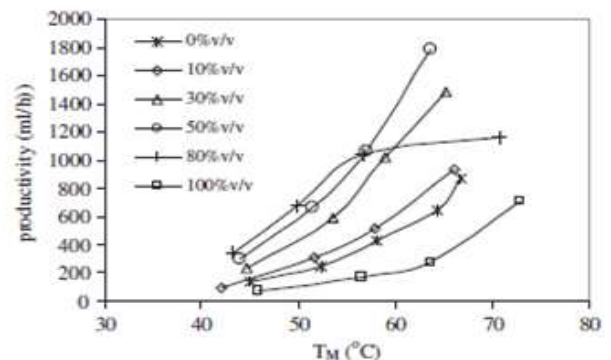


Fig7. Measured productivity as a function of solution temperature and concentration [12].

Future scope

The studies carried out in this paper have contributed significantly to both fundamental understanding and development of different methods to enhance the evaporation rate using photo-catalyst in solar still. Distilled water is very useful for industries and laboratories. It can be used for drinking by adding a certain percentage of normal water. Solar still is very useful in desert or rural areas where no connection of electricity is available to run modern RO (Reverse Osmosis) systems. So Al_2O_3 nano-particles of size 50 nm to 100 nm mixed with black paint is used at absorber surface (basin) for increasing the efficiency of solar still work will be useful for providing this facility in the villages which have not electricity connection. The PPM of raw water is more than the PPM of distilled water given by the solar still is the proof of quality of distilled water. Ordinary people can setup small solar still on the roof of the building and get distilled water continuously. This work will also provide growth of the small scale industries which produce distilled water in India. In the setup small investment is required initially and its maintenance is very little. The technology involved in the fabrication of solar still is very simple and can be maintained at the village level itself.

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