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A Review on Different Design of Solar Stills

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ABSTRACT

Safe and fresh water is one of the major requirements all over the world and solar energy is liberally and radically accessible in the earth. Among different types of desalination process, solar distillation is one of the most useful methods. Solar still is eco-friendly and economical device. Fresh water is very desirable for the rural inhabitants. Researchers have worked on various aspects of solar still for its efficient and economical use e.g. various types of absorbing materials were used to observe their produce on the yield of the solar distillation. In the present article, a review has been presented on various recent researches carried out in the field of solar desalination.

Keywords: Solar still, energy absorbing material, water productivity, freshwater, saline water

I. INTRODUCTION

Water is one of the most important aspects for human life and fresh water availability is highly desirable all over the world. Increasing population and industrialization leads to decreasing world's water resources. Industries and agricultural sector depend on natural resources like rivers, sea, lakes etc. All ecosystems depend on fresh water for daily purposes [1]. Solar still is one of the most important techniques to produce distilled water, and it is suitable for small scale water production where solar energy is easily available. In a solar still, impure water is contained in the basin, where it is evaporated by solar radiation reaches through transparent cover glass. The distilled water vapour condenses on the transparent glass cover surface and drops down and it is collected. Distillation replicates the way nature makes rain. This process eliminated impurities such as heavy metals, microbiological organisms and salts. Solar still can be easily designed and fabricated that could provide daily amount of potable water. Many researchers have worked on technical aspects of solar stills to produce potable water, efficiently and economically, using solar energy. The oldest design of solar still is basin type and many improvements in design have been made in the past to increase its efficiency [2]. Single slope solar stills are the one of the most important devices which can be used for production of distilled water. There is a wide scope to improve the effectiveness of various type solar stills, like the use of different absorbing material improves the efficiency [3]. A basin type solar still is the simplest type of solar still which consists of a basin and glass cover. Inclined cover basin type solar still are most attractive type. Many researchers like El-Sebaii and El-Bialy [4] presented a review on different designs of solar stills like the double, triple and multi-effect solar stills, vertical stills, tubular type solar stills, finned and corrugated stills, and stepped type solar stills. A detailed cost analysis for different configurations was also presented and various parameters affecting the performance were outlined. Further, researchers like Murugavel et al. [5] presented progresses in the works done on single basin passive types still to improve its productivity. They reviewed about the optimization of orientations and inclinations to receive maximum radiation and lower the condensation loss. Different materials can be used in the basin along with water to improve the heat capacity, radiation absorption capacity to improve the evapouration rate. Rubber was found to be the best basin material to improve absorption, storage and evaporation effects. The effect of depth of the basin water was also studied. Some of the innovations and researches done in the past decade are discussed below.

Vertical multiple-effect diffusion solar still coupled with a flat plate reflector

Tanaka [6] constructed and examined a vertical multiple-effect diffusion solar still, consisting of a glass cover and a series of closely spaced vertical and parallel partitions in contact with saline-soaked wicks, coupled

with a flat plate reflector in outdoor experiments at Fukuoka, Japan. The overall daily productivity of the proposed still with 6-effect and 5 mm diffusion gaps was about 13.3 kg/m^2 day at maximum when the global solar radiation on a horizontal surface was 13.4 to 15.7 MJ/m^2 day and radiation on the glass cover was 20.2 to 22.9 MJ/m^2 day. The productivity of the still was higher than or approximately equivalent to other types of multiple-effect diffusion still.

Study of cascade type solar still

Ziabari et al. [7]. studied a cascade solar still in arid and semi arid areas of Iran where there is very low rainfall. This experiment was experimented for 1 month, operational and technical problems were analysed in this site. The average water production was found to be 6.7 lit/day m^2 from the modified solar still.

Modelling and Analysis of Single Slope Solar Still at Different Water Depth

Somanchi et al. [8] studied the performance of solar water distillation using Phase Change Materials viz. Magnesium Sulfate Heptahydrate ($MgSO_4$ $7H_2O$) and Sodium Sulphate (Na_2S $7H_2O$). Further, Titanium oxide was as nano-material used for energy storage material. Among these energy storage materials Magnesium Sulfate Heptahydrate improved the efficiency of solar water distillation.

Performance Evaluation of a Single Basin Solar Still Using Different Energy Absorbing Materials

Gugulothu et al. [9] presented experimental results of a single basin solar still in the presence of different phase change materials viz. Potasium dichromate (K2Cr2O7), Magnesium Sulfate Heptahydrate (MgSO4 7H2O) and sodium Acetate (CH3COONa). It was found that Magnesium Sulfate Heptahydrate (MgSO4 7H2O) gives a better productivity of potable water.

Experimental study on evaporation, condensation and production of a Tubular Solar Still

Ahsan et al. [10] studied the comparative performance of two different models. The first model i.e. Tubular Solar Still (TSS) was designed using a vinyl chloride sheet as a transparent tubular cover. The second model is improved in assembly, economy and maintenance over the first model with a polythene film as the cover. As a result, the cover weight and cost of the second model were noticeably reduced and the durability was distinctly increased. A set of laboratory experiments were carried out using a special technique to investigate the evapouration, condensation and distilled water production performance independently and simultaneously on the second model. It was observed that the hourly evapouration, condensation and production fluxes were proportional to the humid air temperature and relative humidity fraction. An empirical equation was proposed based on this relation to predict the hourly distillate. The applicability of this equation was examined by comparing with the field experiments in Fukui, Japan and in Ras Al Khaimah, UAE. It was found that the calculated results had a good agreement with the field data.

Experimental study on a hemispherical solar still

Arunkumar et al. [11] designed a new solar still with a hemispherical top cover with and without flowing water over the cover. The study was carried out at Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore. The daily distillate output of the system is improved by lowering the temperature of the cover by water flowing over it. The efficiency was 34%, and increased to 42% with the top cover cooling effect. Diurnal variations of a some of the important parameters like water temperature, cover temperature, air temperature, ambient temperature and distillate output were observed during field experiments.

Study on a hybrid (PV-T) active solar still

Dev et al. [12]. presented a hybrid active solar still (PV-T) with combination of flat plate collector and solar still included with glass photovoltaic module. Two methods were employed to find the quality equation of hybrid (PV-T) active solar still. In this process, linear or non-linear curves were plotted for instant increases the efficiency (ηi) with respect to x = (Tw−Ta)/I (t) which represents factors of operational and climatic parameter. Both methods are used for conventional direct loss efficiency (ηiL). Experimentally show that the performance of non-linear equation is better than linear equation.

Performance evaluation of solar still using vibratory harmonic effect

Eldalil [13] presented a new concept of active vibratory solar still. A flexible packed stretched media is installed at the bottom of the basin to increase the efficiency of the still. The flexible packed media is formed from stretched helical coiled copper wires. A vibrator is

installed in the middle of the system structure for generating forced vibration to excite the flexible packed media which breaks the boundary layer and surface tension of the saline water and, thus, improves the convective heat transfer. Further, vibrator excites the condensed polycarbonate glass cover to assist the condensed droplets to slide down before it becomes bigger and possibly falls down in the basin, thus increasing the water vapourization and condensation. The productivity due to added backed helical wires is found to be 3.4 l/m^2 day, with an efficiency of about 35%, and the productivity with vibration is increased to be 5.8 l/m^2 day and the average daily efficiency is about 60%. The nocturnal production ranges from 38% to 57%.

Experimental study on utilization of thermoelectric cooling in a portable active solar still

Esfahani et al. [14] used a solar collector, a wall covered with black wool and a water sprinkling system to enhance the evaporation rate. Also, a thermoelectric cooling device was used to increase water condensation. To make the solar still durable, the walls were made from Plexiglas. The experiments were conducted under the climate condition of Semnan, Iran for nine winter days. It was reported that ambient temperature and solar radiation had direct effect on still performance, but with the increase of wind speed, water productivity drops. The effectiveness of the solar still was found to be better in summer as compared to winter. The results also reveal that the cost price of water obtained from the still was comparable with other types of solar stills.

Theoretical and experimental parametric study of modified stepped solar still

Kabeel et al. [15] developed a stepped basin solar still and evaluated its performance. An hypothetical as well as experimental investigation was carried out. Two solar stills were used: a single slope solar still and a modified stepped solar still. The effect of depth and width of trays on the performance of the stepped solar still was studied. The temperature of feed water of this modified still is varied with the help a vacuum tube solar collector. The improving the distillate a wick on the vertical sides is attached to the stepped still. A good agreement between the experimental and theoretical results was found. It was found that the yield of the modified solar still remarkably depends on the tray depth and width. The maximum productivity of still is attained at a tray depth 5 mm and tray width 120 mm and was 57.3% higher than that of the conventional still. The daily efficiency and cost of 1 l of distillate were approximately 53%–0.039$ and 33.5%–0.049 $ for stepped and conventional solar stills, respectively.

Performance evaluation of a solar still with enhanced condensation

Kumar and Bai [16] designed, fabricated and investigated a basin type solar still (0.5 m^2) with a novel condensation technique. The condensation occurs on the glass surface as well as on the four sidewalls which was cooled by water circulating through tubes attached on the wall surface. The maximum daily productivity was about 1.4 L/m^2 with an efficiency of about 30%. The condensate water quality was found to be akin with rainwater and mineral water. Some design features that could improve the thermal performance of the still were identified and discussed.

Design, construction and experimental study of a wick-type solar still system

Mahdi et al. [17] designed and fabricated a tilted wick-type solar still with a charcoal cloth as an absorber/evaporator and for saline water transport. The distillation system consists of: the still, main reservoir, constant head device, distillate bottle and brine reservoir. Experiments were performed in indoor as well as outdoor experimental conditions to investigate the effect of input water flow rate and salinity on the still productivity, along with the variation of the solar still efficiency with absorber temperature. For the still, the daily efficiency of about 53% was observed on clear days in summer. It was inferred that the charcoal cloth is a good option to be used as an absorber/evaporator and also as a water transport medium. With the increase of input water flow a reduction in the efficiency was observed. The still efficiency decreased linearly with increase of salinity of the input water.

Portable single-basin solar still with an external reflecting booster and an outside condenser

Monowe et al. [18] designed a portable thermal–electrical solar still with external reflecting booster with an outside condenser. This still reduces the loss of latent heat of condensation to the environment. The latent heat is stored in the condenser and is used to preheat the saline water for domestic purposes or during night times. The efficiency of still was about 77% when the preheated saline water is used for domestic purposes, and about 85% if preheated saline water is used during

night times and to recharge the still by the next lot of preheated water.

Enhancing the stepped solar still performance using internal reflectors

Omara et al. [19] presented a stepped solar still with internal reflectors. An experimental as well as theoretical investigation was carried out to compare the performance of modified stepped solar still with trays and conventional solar still. It was concluded that the yield of the modified stepped solar still with and without internal reflectors was higher than that for conventional still approximately by 75% and 57%, respectively. The daily efficiency for modified stepped still with and without internal reflectors and conventional solar still was approximately 56%, 53% and 34%, respectively.

Experimental study of vertical multiple-effect diffusion solar still coupled with a flat plate reflector

Tanaka [20] constructed and examined a vertical multiple-effect diffusion solar still consisting of a series of closely spaced vertical and parallel partitions in contact with saline-soaked wicks, coupled with a flat plate reflector in outdoor experiments at Fukuoka, Japan. The vertical partitions reduce the diffusion gaps between partitions and increase the fresh water yield. The maximum overall daily productivity of this new still with 6-effect and 5mm diffusion gaps was about 13.3kg/m^2day when the global solar radiation on a horizontal surface was 13.4 to 15.7MJ/m^2day and radiation on the glass cover was 20.2 to 22.9MJ/m^2day. The productivity of the still was greater than or almost equivalent to other types of multiple-effect diffusion still.

Monthly optimum inclination of glass cover and external reflector of a basin type solar still with internal and external reflector

Tanaka [21] presented a theoretical analysis of a basin type solar still with internal and external reflectors. The external reflector can be inclined forwards or backwards according to different months. The daily fresh water yield, throughout the year, varies according to the inclination angle of both the glass cover and the external reflector, at 30°N latitude. The increase in the average fresh water yield throughout the year of a still with inclined external reflector with optimum inclination in addition to an internal reflector, compared to a conventional basin type still was found to be 29%, 43% or 67% with the glass cover inclination of 10°, 30° or 50° and the length of external reflector is half the still's length.

Comparative study of double basin and single basin solar stills

Rajaseenivasan et al. [22] introduced an additional basin in the double slope solar still to to improve the freshwater yield of a solar still. Two solar stills: single basin double slope and double basin double slope with the same basin area were fabricated and tested at Kovilpatti, Tamil Nadu, India. It was found that for both stills, water yield decreases with increase in water depth. With the use mild steel pieces as storing material in the basin, the productivity improves in both the stills. Though the cost of double basin still was a little higher, its production was 85% more than single basin still. Providing the wick, also, increases the productivity. The maximum water yield for double basin still was 3.58 l/day (5.68 l/m2.day).

II. Conclusion

From the above literature survey it has been concluded that freshwater demand is rising day to day. In present day's rapid development in industrial and population, the solar desalination is found to be cheap process of distilling the saline water. Various solar still have been developed and studied which included the effect of design parameter and operating parameters on distillate productivity. The daily amount of productivity can be increased by using the external or internal reflector, optimizing the inclination angle of reflectors, glass cover and water depths, using wicks, storage systems.

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