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Review Article

A REVIEW ON DIFFERENT DESIGNS OF SOLAR STILLS

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Abstract: The radiation continuously emitted by the sun is the inexhaustible source of energy which is the root of almost all forms of energy renewable as well as non- renewable; the only exceptions being geothermal energy and nuclear energy. The use of solar energy for desalinating seawater and brackish well water has been demonstrated in several moderate-sized pilot plants worldwide. Most important features of solar still which affect the performance of solar still are basin area, slope of glass cover and depth of water. Many researchers and developers introduced internal reflectors, stepped solar still, varying the shape of glass cover, increasing the slope of glass cover, internal and external reflectors to increase the productivity of solar still. In this review, an attempt has been made to study the present status of different designs used to improve the productivity of conventional solar stills.

Keywords: Stepped solar still, inclined type solar still, flat basin with reflectors, desalination

Introduction: Drinking water is one of the basic elements required for human beings. Water is necessary for the survival of humans. Nowadays, supplying fresh water for people with a basic required amount of drinking water in some parts of earth has become a great challenge. The percentage distribution of the water on the earth is 2.53% and 96.54% of freshwater and seawater, respectively [1]. Fresh water is necessary for all life forms on earth like plants, animals and human being, etc. From centuries humans depend on rivers, ponds, lakes and underground water reservoirs for fresh water requirements [2]. As a result of the continuous increase in population and the rapid development of industry, supply of fresh water has become a problem facing many different areas on earth [3].

Fortunately, ample amount of sun light is available in those parts of earth where these problems of scarcity of fresh water exist. These methods include electro dialysis, reverse osmosis activated carbon filtration and vapor

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compression to convert the saline water into drinking water. But these technologies are costly and cannot be adapted by all peoples especially for remote areas. One of the options used to obtain fresh water from seawater is to use solar desalination system since solar energy is an available at free of cost and is also reliable source of energy, it can be utilized for domestic usage. Solar stills are reasonable in price, having low maintenance and they are perfect devices to meet such conditions in many countries [4].

Enhancing the stepped solar still performance using internal reflector: Omara introduced internal reflectors as a modification of stepped solar still. A comparison was made between and conventional solar still and modified stepped solar still with trays (5 mm depth×120 mm width) was carried out to at the same climate conditions to evaluate the performance of developed desalination system. Reflecting mirrors were installed on the vertical sides of the steps and distillate productivity was investigated. Both theoretical and experimental investigation was carried out. It was found that the productivity of the modified stepped solar still with and without internal reflectors was greater than that for conventional still which was approximately by 75% and 57%, respectively. The daily efficiency was also calculated with conventional solar still was approximately 56%, 53% and 34%, respectively [5].

Study of modified basin solar still with air-cooled condenser: Ibrahim constructed a modified basin type solar still incorporated with an air-cooled condenser was constructed and tested. It was operated at reduced pressure in batch-wise mode. The performance of the modified still was compared with that of the conventional solar still. The system was solved numerically and simulated using a mathematical model using a computer program written in MATLAB code. The developed model was validated against experimental measurements. The parametric study was done on validated model was carried out to evaluate the improvement potentials of the constructed system [6].

Modified stepped solar still: Kabeel made a stepped basin to improve the performance of solar still. The investigation was carried out through both theoretical & experimental. The investigation include two solar stills a conventional single sloped solar still and a modified stepped solar still are used simultaneously and both use saline water. The parameters selected for investigation are depth and width of trays. A vacuum tube solar collector was used to vary the feed water temperature. A wick on the vertical sides was also added to the stepped still. The experiment results show that the productivity of the stepped solar still mostly depends on the tray width and tray depth. The maximum productivity of stepped still was available at a tray depth 5 mm and tray width 120 mm, which was about 57.3% greater than that of the conventional still [7].

Solar still with an integrated flat plate collector: Rajaseenivasan promotes the performance of the single basin solar still by introducing an integrated flat plate collector arrangement which was used to preheating the saline water using. A single slope flat plate collector basin still (FPCB still) and conventional single slope single basin still were fabricated having same basin area of 1 m^2. The FPCB still was identical to a conventional still, with the basin was modified into six small compartments and a horizontal flat plate collector. The flat plate collector was used to preheat the saline water before it enters the basin and the projected space between the consecutive basins acts as an extended surface which increases the temperature of the basin. This increases the evaporation rate for the same depth of water in the basin, the mass of water reduces due to separate compartments (absorber plate) in the basin. Both stills were employed with energy storing materials in basins and experiments were carried out by varying the water depth in the basin. The result shows that

FPCB still gives about 60% greater distillate than the conventional still for the same basin condition [8].

Study on a hemispherical solar still: Arunkumar made an improvement in the design of solar still with a hemispherical top cover for water desalination and water could be floe over the cover. By lowering the temperature of the cover by water flowing over it the daily distillate output of the system was increased. The fresh water production performance of this new still was observed in Sri Ramakrishna Mission Vidyalaya College of Arts and Science, Coimbatore (11° North, 77° East), India. The efficiency of conventional still was 34%, and increased to 42% with the cooling effect of top cover. Diurnal variations of a few important parameters were observed during field experiments such as distillate output, atmospheric temperature , cover temperature , water temperature, air temperature and Solar radiation incident on a solar still was also discussed here [9].

Hybrid solar still using waste heat: Park introduced dual heat sources of solar thermal energy and waste heat and designed multiple-effect diffusion (MED) hybrid solar still with simpler seawater feeding device. The three operational parameters used for performance test include the seawater flow rate to the wick, the amount of heat input into the hybrid still and the seawater level in the basin. The productivity of the hybrid still was a function of heat input, recording 18.02 kg/m^2 at 22.37 MJ/d. The maximum productivity was obtained at the lowest seawater level even in the case of the experiment with waste heat source. The results indicate that the MED section of the hybrid solar still plays a more important role than the basin section in the entire performance of the hybrid still [10].

Single and double basin double slope glass solar still: Elango implemented a new material for basin i.e., glass to enhance the productivity of the solar still. Single and double basin double slope solar stills were fabricated of same basin area using glass. The experiments were carried out under both insulated and un-insulated conditions by varying the water depths from 1 to 5 cm. The production of distillate in single basin was more during the heating period than the double basin and the production of distillate in double basin was more during the cooling period than the single basin. The productivity of the stills was more at the lowest water depth of 1 cm. At 1 cm water depth, double basin insulated and un-insulated stills gave 17.38% and 8.12% higher production than the single basin still [11].

Solar still in domestic and industrial wastewater treatment: Asadi made a stepped solar still and conducted an experiment in which he treated the sanitary and industrial wastewater in Malaysia by UKM (University Kebangsaan, Malaysia) University during November and December 2011 and January 2012. This experiment was conducted by feeding three types of wastewater into a solar still. The effective area of this stepped solar still was 0.8 m^2. The bacteria contains in the raw sea water was removed by this method [12].

Solar still with internal and external reflector: A theoretical analysis was made on conventional solar still with internal and external reflectors. The external reflector can be inclined as per the requirement. The theoretical analysis was done throughout the year and predicted the daily amount of distillate produced by the still which varies according to the inclination angle of both the glass cover and the external reflector, at 30°N latitude. The optimum external reflector inclination found for each month with a glass cover inclination of 10–50°. The daily amount of distillate produced by the still was compared to a conventional basin [13].

Simple solar with different inclination of the external reflector: N. Khalifa presents an experimental investigation on the productivity of a solar still with modifications include internal and external reflectors tilted at angles of 0° (vertical) 10°, 20° and 30° for still cover

angles of 20°, 30° and 40°. A simple still equipped with internal and external reflectors was investigated in winter at latitude angle of 33.3° N. It was found that the daily productivity was a function of larger cover angle at any reflector angle. The most productive solar still in winter was has a cover angle of 20° and an internal and external
Reflector inclined at 20°; the productivity increases to2.45 times than he conventional still [14].

Solar Still with Double Slope: Aburideh studied the internal parameters on a double slope plane solar still. Different conditions were selected for experiment. The result shows that the production of distillate was increases when the difference between the temperature of water and glass decreases. The presence of wind and the climatic changes also influence the distillate [15].

Tilted wick solar still with flat plate bottom reflector: Tanaka introduce a tilted wick solar still with a flat plate bottom reflector to enhance the productivity of solar still in such a way that it extending from the lower edge of the still on four days (the spring and autumn equinox and summer and winter solstices) at 30°N latitude when the still's inclination was fixed at 30° and the reflector's length was the same as the still's length. A geometrical model was calculated the solar radiation reflected from the bottom reflector and absorb by the evaporating wick. A numerical analysis of heat and mass transfer was also done on the still. The result shows that the average distillate value for four days was highest when the reflector's inclination was about 35° and would be about 13% more than that of a conventional tilted wick still [16].

Modified basin type solar still working on sub-atmospheric pressure: Ibrahim investigated a solar desalination system which was working on sub-atmospheric pressure. The decrease of the saline water evaporation pressure makes the still to work on less energy. The solar still basin was connected with evaporator and it used vacuum pump to create a vacuum. The experiments were conducted in various seasons. The maximum efficiency of desalination system obtained was 40%. The productivity and thermal efficiency of solar still was enhanced by 16.2% and 29.7%, respectively when compared with conventional solar still. To evaluate the constructed desalination system economic or not a cost analysis was also carried out [17].

Solar still with heat pipe, evacuated tube and parabolic trough collector: Mosleh investigation shows that the use of linear parabolic trough collector improves the efficiency of desalination system. The solar still was employed with a twin-glass evacuated tube collector was utilized with a parabolic trough collector and a combination of a heat pipe. When aluminum conducting foils were used in the space between the heat pipe and the twin-glass evacuated tube collector to transfer heat from the tube collector to the heat pipe the rate of production and efficiency can increases to 0.27 kg/(m^2 h) and 22.1% . When oil was filled between heat pipe and twin-glass evacuated tube collector for the transfer of heat the production and efficiency can increase to 0.933 kg/ (m^2 h) and 65.2% [18].

Thermal analysis of a conical solar still performance: Gad made an attempt to estimate the heat transfer coefficients of a conical solar still. The productivity of solar still was increased by decreasing the shadow effect and maximizing utilization of solar radiation. He designed and constructed a conical solar still at faculty of engineering Sheben El-Kom – Egypt (latitude 30.56 N and longitude 31.01 E). The still base area was 0.8 m^2, and the acrylic cover of still inclined at 31° which equal to the city latitude. The experimental results of conical solar still were compared with a conventional solar still of sane area. The daily productivity for conical and conventional solar
Stills were 3.38 and 1.93 L/m^2 day, respectively [19].

Modeling and analysis of single slope solar still at different water depth: Somanchi Naga

introduced Phase Change Materials to increase the performance of solar still.

In the experiment Sodium Sulphate (Na2S 7H2O), Magnesium Sulfate Heptahydrate (MgSO4 7H2O) were used as phase change material and for energy storage Titanium oxide a nano-material was used. The efficiency of solar still was improved by using energy storage materials Magnesium Sulfate Heptahydrate (MgSO4 7H2O) [20].

Conclusion: From the above literature review, it can be concluded that the most important features of solar still which affect the performance of solar still are basin area, slope of glass cover and depth of water. Various researchers and developers introduced internal reflectors, stepped solar still, varying the shape of glass cover, increasing the slope of glass cover, internal and external reflectors to increase the productivity of solar still.

In enhancing the stepped solar still performance using internal reflector we find that the daily efficiency was also calculated with conventional solar still was approximately 56%, 53% and 34%, respectively. In Hybrid solar still using waste heat the results indicate that the MED section of the hybrid solar still plays a more important role than the basin section in the entire performance of the hybrid still. In tilted wick solar still with flat plate bottom reflector the result shows that the average distillate value for four days was highest when the reflector's inclination was about 35° and would be about 13% more than that of a conventional tilted wick still. In a solar still with heat pipe, evacuated tube and parabolic trough collector, we find that the rate of production and efficiency can increases to 0.27 kg/ (m^2 h) and 22.1%.

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