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SOLAR DESALINATION: THE FUTURE OF WATER PURIFICATION

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Abstract:- *Demand of energy is increasing in day today life; we require energy for doing many works like industrial, agricultural, domestic and laboratories. We are continuously using conventional sources of energy which will be exhausted in few decades. Hence, the use of non-conventional sources ought to be our priority. Nowadays, the majority of the consumed energy all around the world comes from conventional fossil fuels like coal, natural gas, crude oil, etc. Due to the limited reserves of fossil fuels, their rising prices, polluting of nature and the increasing concern over global warming, the interest in renewable energy sources has significantly increased. Solar energy is the type of non-conventional energy which is available over worldwide at free of cost. Solar energy can be used for various purposes like electricity generation, heating, cooling and desalination etc. Solar desalination is very useful technique for converting brackish water into fresh water. A lot of research work has been done on stepped and inclined solar still incorporated with the absorber to enhance the productivity of the solar stills. Some of them have been reviewed and studies in this paper, and also the better ones are compared.*

Keywords: *solar still, clean water, renewable energy, solar energy*

Contents

1. Introduction

Nowadays, the availability of clean water resource is a major issue for mankind. About 71% of the earth surface is covered with the water, but only 1% clean drinkable water is available. Various techniques have been employed to convert brackish water to potable water [1]. Solar still is basically the alternate renewable energy technology to supply water to remote areas at a very low cost [2]. Fabrication of solar still is easy on small scale and requires very less maintenance [3]. A solar desalination system collects the solar energy to produce pure water by the process of evaporation and condensation in the basin, leaving behind all the organic and inorganic impurities [4].. In this article, various designs of solar stills used at domestic level have been reviewed. The article also provides complete analytical methodology for performance evaluation of solar still in terms of heat transfer analysis, energy analysis, exergy analysis, thermal performance and economic analysis. Many studies have been carried out to enhance the thermal efficiency and productivity of the still by various researchers [5-7]. Since solar radiation is free, abundant and available and this device has many advantages such as uncomplicated fabrication from readily available materials and maintenance free operation minimal with labour required.

2. Classification of solar still

Solar still can be classified into various types, some of them are explained below:

2.1 Cascade solar still

Ziabari et al. [8] reported 1 month daily-based experimental data from a solar still site. Various technical and operational problems of this site were described and a prototype was constructed in order to solve the site's problems. Average distillate of modified cascade solar still was around 6.7 lit/day, which is 26% increase as compare with the initial site's units. A mathematical model is also proposed to simulate the modified still. Various results and experimental data show a significant increase in the fresh water production as compare with the initial site's stills.

Tabrizi et al. [9] used solar still for water desalination in arid lands with lack of water in the fair climatic conditions. In this paper, two cascade solar stills were constructed one is with latent heat thermal energy storage system and other is without latent heat thermal energy storage system. For the phase change material Paraffin wax was used as it acts as a latent heat thermal energy storage system. Various thermal performances of the stills were compared on typical sunny and partially cloudy days. Results show that in a typical sunny day, the total productivity was nearly the same for both stills but for a partially cloudy day, the still with latent heat thermal energy storage system has a significantly higher productivity. So, the still without latent heat was preferred for sunny areas because of its simplicity and low construction costs, while the still with latent heat was proposed for partially cloudy areas due to the higher productivity.

2.2 Single basin with slope type solar still

Alaudeen et al. [10] have done a Study on stepped type basin in a solar still.
In this work a stepped solar still was used to enhance the productivity of the solar still. In this research work the concept of integrating the stepped solar still along with inclined flat plate collector was introduced.
Murugavel et al. [11] made a single basin double slope solar sill. They have done a lot of experiments on this still with a layer of water and different sensible heat storage materials like quartzite rock, red brick pieces, cement concrete pieces, washed stones and iron scraps. Basically they focused on the study to find the best heat storage material for increasing yield still. In this experiment outer basin was lined with concrete, to reduce the heat loss through the bottom. They focused on the study to find the best heat storage material for increasing yield and found that ¾ inch sized quartz rock is the effective basin material.
Shadi et al. [12] studied of a developed inclined stepped solar still system and find out the productivity. In this experiment they basically uses cascaded forward neural network model. They found that the productivity of developed stepped solar still is much higher than the inclined solar still.

Yousef et al. [13] have done a study on the comprehensive energetics performance of a single slope a passive solar still system. Energy and exergy methodologies have been applied for all components of the solar still comprising glass cover, brackish water, and basin-liner. They used various equations of energy and exergy to find out the efficiency of passive solar still.
Zeroul et al.[14] used two identical solar still prototypes, one was used as a reference unit and other was investigated. The reference solar still unit was basically a standard unit and the investigated still is having an aluminium tray to enhance the heat transfer inside basin. In this model they found that there is leakage so he used Silicon sealant to prevent the heat leakage. Results shows that the average daily was improved by about 11.82% when cooling its north glass cover by flowing water over glass cover

2.3 Stepped solar still

Velmurugan et al. [15] connected a mini solar pond, stepped solar still and a single basin solar still in series, to increase the production rate of solar still. Here they replaced the single basin solar still by a wick type solar still. They studied the day and night productivity of the solar stills. Along with daily efficiency and percentage increase in productivity for these modifications for the purpose of feed Industrial effluent water is used. Theoretical analysis gives very good agreement with experimental results.

Samadony and Kabeel [16] made a stepped solar still using water film cooling over the glass cover. They studied the effect of film cooling thickness, flow rate, inlet temperature, and air wind speed on the stepped solar still daily productivity. To increase the performance of the stepped solar still outlet water film cooling is recycled as makeup water. According to them the film cooling thickness, volumetric flow rate, and water film inlet temperature have a significant effect on the daily distillate productivity. Due to the presence of the glass cover, daily productivity of stepped still may increase by about 8.2%

2.4 Hybrid solar still

Kumar and Tiwari [17] made an attempt to estimate the internal heat transfer coefficients of a deep basin hybrid active solar still. The estimation was based on outdoor experimental observation of hybrid solar still for composite climate of New Delhi (latitude28°350N and longitude 77°120E).The internal heat transfer coefficients were evaluated by using thermal models proposed by various researchers. The comparison of hourly yield predicted using various thermal models to the experimental has also been carried out by evaluating the correlation coefficient and percentage deviation It was observed that, Kumar and Tiwari model better validate the results than the others model.

Omara et al. [18] represents a new hybrid desalination approach comprising of evacuated solar water heater, jut geotextile and solar still. An evacuated solar water heater was integrated with the desalination stills to evaluate the continuity production of distillate. Theoretical analysis is verified through experiments. Water productivity was increased very much as compare with conventional still for double layer square wick (DLSW) solar still at 30° base slope angle.

The daily average efficiency of DLSW was 71.5%. In the experiment, they found that the distillate water productivity increased by 215% when hot brackish water was fed during night time.

Singh et al. [19] designed and fabricated a modified photovoltaic thermal double slope active solar still. The system is having three components; double slope solar still, PV integrated FPCs and DC water pump. A glass to glass photovoltaic module of 36 cells has been integrated at the bottom of one of the collector. The DC water pump of size 40W was used to circulate the water in forced mode of operation.

2.5 Pyramidal solar still

Taamneh et al. [20] made pyramidal solar still with a basin area of 0.95 sq. m and a glass cover in the form of a pyramid has been designed and constructed The results shows that the use of fan work with photovoltaic solar panels was cost-effective and viable in enhancing the evaporation rate and hence freshwater production The distillate production for natural and force convection was found to be 2.485 and 2.99 l/day, respectively.

Kabeel[21] developed a pyramidal solar still. Concave wick surface was used for evaporation; whereas four sides of a pyramid shaped still were used for condensation A concave shaped wick surface increases the evaporation area due to the capillary effect. The daily Productivity in day time was 4.1l/m^2 maximum instantaneous system efficiency of 45% and average daily efficiency of 30% were obtained.

2.6 Hemispherical solar still

Ismail [22] developed domestic type transportable hemispherical solar still. In the experiment he used a circular basin and absorber plate carrying the saline water, the hemispherical cover, the conical-shaped distillate collector the distillate output plastic container, and the mobile support structure. The basin contains the absorber aluminium plate which has a surface area of 0.5 sq. m and athicknessof4mm, a hole with diameter of approximately 25.4 mm was drilled into the tray to provide accessibility of saline water into the basin.

Ahsan et al. [23] developed simple triangular solar still. This still was made of waste material as Polythene for cover PVC pipe for frame, Perspex for trough, Nylon rope, and transparent scotch tape to seal the solar still. The daily water production of 1.6 and 1.55 kg/m^2 for 1.5 and 2.5 cm of water depth respectively were obtained.

3. Performance parameters of solar still

There are different performance parameters for various designs of solar still However for providing basic idea of performance evaluation; energy analysis, exergy analysis for a generalized system are discussed in the following section These parameters can be used to predict the performance and productivity of single slope solar still using different operational parameters. The energy and exergy analysis are complementary thermodynamic tools. Energy analysis alone is not sufficient to understand all the aspects of energy utilization in the processes or components of the system.. These equations are programmed by the authors using computer for the estimation of unknown operating variables, comprehensive calculations and graphical presentation of the results.

3.1 Energy analysis

Theoretical and system efficiency of solar still can be evaluated by performing simple energy analysis. By writing energy balance for different parts of the system (such as water, glass cover, absorber plate, etc.), a set of temperature-dependent equations are obtained. The following assumptions were applied in the development of the energy balance equations.

- ❖the device is thoroughly insulated against heat loss and there are no leaks.
- ❖Water and glass temperatures are considered uniform along their path.
- ❖Heat loss from joint parts has been considered negligible.
- ❖the thickness of water flow is regarded to be constant during each experiment and different mass flow rates have been applied in different experiments

3.2 Exergy analysis

Exergy analysis can be performed by using the first and second thermodynamic laws and it is defined as the maximum amount of work that can be produced by a system or a flow of mass or energy as it comes to equilibrium with a reference environment. Energy analysis has systematic flaws in comparison to the exergy analysis

- Process direction is not considered in energy analysis.
- The energy quality does not take into account in energy analysis.
- Energy analysis is failed to interpret some thermodynamic phenomena. For instance, enthalpy change is zero in an isothermal air compression while the exergy is greater than zero.
- Energy analysis does not show the internal irreversibility.

The energy and exergy efficiencies of a system have different behaviours depending on climate and operating conditions. Basically, exergy analysis in comparison to energy analysis gives us a better insight into how a physical process works. Irreversibility escalation causes the entropy to increase while the system's exergy decreases. Therefore, it is necessary to determine and reduce irreversibility for all parts of the apparatus.Exergy is consumed or destroyed because of irreversibility in the process or components. The exergy balance for any system or its components can be obtained by combining the conservation of law of energy and non-conservation of exergy as:

Exergy consumption or destruction =Exergy input – exergy output (useful and/or losses)
- exergy accumulation

4. Conclusion

Various designs of solar still from conventional to hybrid concepts were reviewed in this work the review will help to understand the previously developed domestic designs of solar still. This will pave a way to the researchers to fabricate a new optimum design with better performance. This section summarizes the key aspects of solar still designs:

1. The output distillate and ambient temperature increases linearly with the solar radiation.
2. The distilled water output of the solar still integrated with greenhouse type was higher than that of ordinary single basin solar still type.
3. The efficiency of the solar still depended on parameters like location, solar radiation intensity, atmospheric temperature, basin water depth, glass cover material, thickness and its inclination, wind velocity and the heat capacity of the still. When compared with other parameters, the basin water depth is the main parameter that affects the performance of the still.
4. The solar still should be placed in the East-West direction if the still is installed at a high latitude station. At low latitude stations the orientation has no effect on solar radiation.
5. The productivity of the still decreases with an increase in depth of water during daylight
6. Rubber is the best basin material to improve absorption, storage and evaporation effects.
7. The distilled water output of the solar still integrated with green house type was higher than that of ordinary single basin solar still type
8. The use of external reflector can increase the productivity of the solar still. Inclined reflector gives more distillate than vertical reflector.

5. Scope for further research

Various designs of solar stills have been reviewed in this paper used at the domestic level. These designs needs further improvement as there are still some problems and challenges on the design of solar still. The condensation at the glass cover surface should be increased for which, glass cover temperature inside the basin should be as low as possible compared to basin water temperature. Energy analysis and Instantaneous thermal efficiency are being considered as performance parameters for evaluation of solar still. The inlet water may be preheated to increase the productivity of the solar stills. The evaporation and condensation rate for preheated water is more compared to the ordinary water. The water may be preheated by integrating the still with a flat plate collector, solar pond and heat pipe However, Heat transfer losses and exergy analysis can be used in future for testing performances of different solar still. Design of solar still must be done very systematically to optimize the performance and to improve the productivity

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