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Theoretical Evaluation of Energy Efficiency of Solar Basin by Experimental Data

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Abstract

This work represents a novel method for producing sweet water from effluent wastewater and generating electricity using renewable energy sources, solar energy specifically. Performance of a closed solar basin, which is jointed to photovoltaic cell and is equipped by nano plate for producing sweet water from effluent saline water of the Mobin petrochemical complex, is studied in this paper. The effect of nano plate on wastewater temperature, energy consumption and the amount of fresh water is considered, experimentally. Also, capability of photovoltaic cells to generate electricity is reported due to insolation rate during a year. Highest and lowest amounts of fresh water are reported to present design parameters of solar basin capacity. The received energy, efficiency factor and error function are formulated in this paper. The regression for error function formula is 0.772.

Keywords

Solar Basin, Nano Plate, Photovoltaic Cell, Wastewater

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1. Introduction

Obviously, lack of potable water is one of the most crucial hassles, which is directly effective in human life [1]. It has been estimated that 97% of total water around the world is saline. So, much of the remaining freshwater is also unavailable as it is locked away in the ice caps and glaciers [2]. Non-saline water that can be readily abstracted for domestic and industrial use is only available from lakes, rivers and from aquifers. This finite volume of water is increasingly contaminated by human activities [3]. Moreover several regions of the world including Iran are already encountering the problem of freshwater shortage [4 and 5]. Therefore, the transformation of seawater, saline ground water, polluted, and wastewater to fresh water has become indispensable [6]. These days, many new technologies such as desalination and water-treatment, which mostly based on fossil fuel consumption, are popular in the market [7 and 8]. However the problem of lack of fresh water can be solved by using these technologies especially desalination, but it face both unlimited amount of nonrenewable energy sources and the global warming of climate change [9, 10, 11 and 12]. In addition electrical energy sources using coal, wood, gas and oil generate large amounts of pollution or carbon dioxide emissions, thereby posing health risks. Under these circumstances, alternate method for producing sweet water from effluent saline water and generating electricity from renewable energy sources for both using and saving must be explored. The desalination technique which is joined with Photovoltaic cells and Nano plate is the most promising technology which is introduced due to the growing global demand of potable water; on the other hand, environmental pollution from fossil fuels, lack of nonrenewable resources, wastewater, and electricity neediness that is every day becoming more expensive and economical benefits from utilizing renewable energy resources such as solar energy. Investigation and improvement in these issues will be useful

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and constructive to meet the continuously increasing appeal of freshwater in a cost-effectively sustainable way. It also can be helpful in mitigating global climate change (i.e. reduce carbon dioxide emission). Solar energy is one of the renewable energy sources, which is the most important supplier of energy for the earth and at the same time it is the most environmentally friendly, pollution-free, self-contained, reliable, quiet, long-term, maintenance-free, year-round continuous and unlimited operation at moderate costs form of all energies can be used for desalination. It is really amazing to produce drinking water from effluent saline water and generating electricity from photovoltaic cells without burning any fossil fuels or producing fresh water from effluent wastewater instead of discharging wastewater into the sea, or desert, which is really harmful to the ecosystem, moreover polluting the atmosphere will be prevented seriously.

2. Materials and Methods

2.1. Solar Desalination Basins

Solar basins represent one of the simplest methods for directly collecting solar irradiation and converting it to thermal energy. Moreover, it is a solar power collector and a thermal storage unit at the same time. All natural pools and lakes convert solar radiation into heat, although most of that energy is misplaced to the atmosphere mainly as a consequence of convection and evaporation. The principle of the salinity gradient solar basin, on the other hand, is to prevent vertical convection and/or evaporation (according to the type of solar basin). Based on the convection behavior of the saline solution in solar basins, they may be classified into two main categories: non-convecting and convecting solar basins. Salinity-gradient solar basin is a vertical saltwater gradient, so that the denser saltier water stays at the bottom of the basin and does not mix with the upper layer of fresher water. Consequently, the lower salty layer gets very hot and this heat can be used to make electricity.

Solar desalination systems have been classified in many ways, i.e., direct and indirect systems or in other definition the solar distillation systems are also classified as passive and active solar stills.

Direct systems use solar energy to produce distillate directly in the solar still or collector, whereas in indirect systems, two sub-systems are employed: one for solar energy collection and one for desalination.

The solar basin integrated with a heater or solar concentrator panel is generally referred to as an active solar basin while others are referred to as passive basins. Water reservoir commonly called solar basin is one passive type, which can be used to convert saline, brackish water into drinking water. In this case, some techniques like applying single slope in cold climate versus double slope in hot climate, cover cooling, using an additional condenser and injecting black dye in the wastewater can have operating performance augmented.

Totally, solar basins are becoming more popular each day due to many significant reasons such as; combined collection and storage of solar energy, ease of construction and on-demand extraction of heat. Salinity-gradient solar basins can directly collect and convert solar energy to thermal power, on the other hand, this technique is really helpful to prevent environmental and ecosystem to become more polluted. Scholars mostly, have fulfilled their investigation of the technical feasibility of solar basins during 1986 to 1995. After that till to 2000, the focus has gone on the development of solar basin. Since 2000, economics and thermodynamic efficiency factors have been investigated in order to make it more economically and competitive with other desalination techniques such as RO, multistage flash (MSF), multi effect distillation (MED), ED, etc., which some of them (i.e. MED and MSF) employ with direct use of fuel energies.

In this experimental work a solar basin is introduced. The mentioned solar basin, which owns two individual pieces including photovoltaic cells for generating electricity directly and Nano plate, which is set up on the bottom of the solar basin for increasing evaporation rates and preventing heat losses from the bottom and corners of solar basin, is proposed after a pretreatment unit.

In this experimental work, several effective parameters of closed solar basin, which is applied to desalination unit, are surveyed. Evaluation of insolation rate in during the day (hourly), annual ambient temperature, and daily insolation rate are studied.

In addition, temperature gradient, evaporation rate, amounts of highest and lowest production, electricity generation and density are investigated in this closed solar basin during a year. Additionally, the effect of Nano plate, which is directly influenced on efficiency, is surveyed.

2.1.1. Photovoltaic Cell

The sun is almost an inexhaustible source of energy capable of supplying large amounts of energy. The total amount of solar energy absorbed by the desert area in six hours is comparable to the total global energy consumption in an entire year. Photovoltaic (PV) technology converts this energy into electrical energy. The basic element of PV technology is the solar cell. A solar cell consists of a p-n junction fabricated in a thin wafer of layers of semiconductor similar to a diode. When exposed to light, photons with

energy greater than the band-gap energy of the semiconductor create an electron-hole-pair. These carriers are swept apart under the influence of the internal electric fields of the p-n junction and create a current proportional to the incident radiation. In order to obtain adequate output voltage, PV cells are connected in series to form a PV module. These PV modules may be connected and/or combined to form PV arrays, which yield a desired output power. In this experimental work, PV cells are used for generating electricity for both saving and providing solar powered-basin electricity's neediness (i.e. vacuum pump).

2.1.2. Glass Roof and Walls

The glass passes the 96% of inlet radiation rays, approximately. So, this material can be as best choice for structure of solar basin.

2.2. Methods

This solar basin operates on the same principle as rainwater: evaporation rate and condensation. The water from the oceans evaporates, only to cool, condense, and return to earth as rain. When the water evaporates, it removes only pure water and leaves all contaminants behind. This solar basin mimics this natural process. The used solar basin is jointed to the photovoltaic cell. This has a top cover and walls made of glass. The glass cover allows the solar radiation (short-wave) to pass into the basin, which is mostly absorbed by the blackened base. The evaporation process started when the solar rays are trapped in the basin. The distilled water is produced due to the temperature difference. The used solar basin is closed and so, the quality of distilled water is very high.

3. Results and Discussion

Experiments are held to find the effect of nano plate in solar energy adsorption, rate of water production and amount of energy saving in the proposed solar desalination basin. The vacuum pump pulls out the water vapor slightly from the solar box and improves the vaporization. So, the effect of weather moisture and wind velocity on the vaporization may be minor comparing with the effect of insolation rate. In this work, insolation rate is considered as the most important independent variable, which affects the solar performance and is reported in illustrations. Three zones of wastewater can be considered as basic zones in heat transfer. The lower zone, middle zone and upper zone have basic role in conduction and convection heat transfer and received energy and efficiency, finally. Equations 1, 2 and 3 state the amount of efficiency percentage, energy consumption percentage and received energy percentage, respectively. The accuracy of the introduced equations is reliable. The regression for the equation 1, 2 and 3 is 0.983, 0.791 and 0.9673, respectively.

$$Efficiency\% = \sum_{i-1}^{12}(-0.369M^2 + 4.8723M + 0.4939)\times\frac{100}{12}$$
$$R^2 = 0.983 \quad (1)$$

Also, the energy consumption factor can be calculated by the equation 2.

$$EnergyConsumption\% = \sum_{i=1}^{12}(-0.0004M^2 + 0.0048M + 0.0692)\times\frac{100}{12}$$
$$R^2 = 0.719 \quad (2)$$

In addition the solar energy in the different months can be as the equation 3.

$$ReceivedEnergy\% = \sum_{i=1}^{12}(-0.636.18M^2 + 7971M + 3972.5)\times\frac{100}{12}$$
$$R^2 = 0.9673 \quad (3)$$

Experimental data show the highest and lowest amount of insolation rate is obtained on June and December, respectively. The difference between highest and lowest insolation rate is at least 20000 $kJ / m^2.day$. The increasing of waste water average temperature with the increasing of insolation rate is predictable. However, with the same amount of insolation rate on November and March, higher average temperature value is obtained on March and this may related to regular windy days on last month of fall. Finally, the equation 4 states the error function for the production rate in different months. The regression for this equation is 0.772.

$$ErrorFunction\% = \sum_{i=1}^{12}(-0.0001M^2 + 1.231M + 0.0428)\times\frac{100}{12}$$
$$R^2 = 0.772 \quad (4)$$

4. Conclusion

The effect of using ZnO nano plate in performance of one solar desalination basin is investigated experimentally in this research. Application of nano science and solar energy in fresh water production and also electricity generation from wastewater of desalination unit in one petrochemical industry is considered during a year. Insolation rate, ambient temperature, average temperature of wastewater, density of wastewater in basin, amount of produced water, electrical energy are presented. Experiments show the highest amount of produced water is 18 lit/m2. day on July which represents 7.78 $kW.h$ as energy saving. The accuracy of the introduced equations is reliable. The regression for the equation 1, 2 and 3 is 0.983, 0.791 and 0.9673, respectively. Also, the predicted model for calculation of error function is reliable and its regression is 0.772.

References

[1] Farshad Farahbod, Dariush Mowla, M. R. Jafari Nasr, Mohammad Soltanieh, 2013, Experimental study of a solar desalination basin as second stage in proposed zero discharge desalination process, Sol. Energy, 97, 138–146.

[2] Farahbod, F., Mowla, D., Jafari Nasr, M. R., Soltanieh, M., 2012. Experimental study of forced circulation evaporator in zero discharge desalination process. Desalination. 285, 352-358.

[3] Mittelman, G., Kribus, A., Mouchtar, O., Dayan, A., 2009. Water desalination with concentrating photovoltaic/thermal (CPVT) systems. Sol. Energy. 83, 1322-1334.

[4] Farahbod, F., Mowla, D., Jafari Nasr, M.R., Soltanieh, M., 2012. Investigation of Solar Desalination Basin Performance Experimentally and Mathematically, J. Energy Resour. Technol., 134, 041201.

[5] Karakilcik, M., Kıyma, K., Dincer, I., 2006. Experimental and theoretical temperature distributions in a solar basin. Int. J. Heat Mass Transfer. 49, 825–835.

[6] Roca, L., Berenguel, M., Yebra L., Alarcón-Padilla, D.C., 2008. Solar field control for desalination plants. Sol. Energy. 82, 727-786.

[7] Farahbod Farshad, Bagheri Narges, Madadpour Fereshteh, 2013. Effect of Solution Content ZnO Nanoparticles on Thermal Stability of Poly Vinyl Chloride, Journal of Nanotechnology in Engineerin and Medicine, DOI: 10.1115/1.4025209, 4 / 021002-1.

[8] Farshad Farahbod, Sara Farahmand, Mohammad Jafar Soltanian Fard, Mohammad Nikkhahi, 2013. Finding of Optimum Effective Parameters on Sweetening of Methane Gas by Zinc Oxide Nanoparticles, DOI: 10.1115/1.4025467, 4 / 021003-1.

[9] Leblanc, J., Akbarzadeh, A., Andrews, J., Lu, H., Golding, P., 2011. Heat extraction methods from salinity-gradient solar basins and introduction of a novel system of heat extraction for improved efficiency. Sol. Energy. 85, 3103-3142.

[10] Mahdi, J. T., Smith, B. E., Sharif, A.O., 2011. An experimental wick-type solar still system: Design and construction. Desalination. 267, 233–238.

[11] Ortiz, J.M., Expósito, E., Gallud F., García-García V., Montiel V., Aldhaz A. 2008. Desalination of underground brackish water using an electrodialysis system powerd directly by photovoltaic energy. Sol. Energy. 92, 1677-1688.

[12] Farshad Farahbod, Sara Farahmand, 2014, Experimental study of solar-powered desalination basin as second stage in proposed zero discharge desalination process, J. Energy Resour. Technol., DOI: 10.1115/1.4026915, 136(3), 031202.