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Review on the Research of the Porous Media Effect on the Thermal Performance and Stability of Salt Gradient Solar Ponds

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ABSTRACT

Porous media has the function of strengthening heat transfer, and the addition of porous media layer to the reservoir of salt gradient solar pond has an effect on the diffusion of heat and salt in solar pond. The research on the effect of adding porous media to the salt gradient solar pond on the performance of the solar pond has recently been paid attention to, and is one of the hot spots in the application technology of the solar pond at present. This paper summarizes the research progress of porous media technology applied to salt gradient solar ponds, and provides reference for researchers in this field.

INTRODUCTION

The salt gradient solar pond is a salt water pond with the ability of absorption and storage solar energy. Solar ponds provoid heat for seawater desalination, mariculture, drying and other low-temperature heating. As shown in Figure 1, the solar pond consists of three layers, the upper layer is a freshwater layer, called the Upper Convective Zone (UCZ), which is the thinnest and the temperature is close to the ambient temperature. The density gradient of salt water inhibits the temperature gradient upward, so it is also called Non-Convective Zone (NCZ). The sun shines on the surface of the pond, passes through the UCZ and the intermediate gradient layer NCZ, reaches the Lower Convective Zone (NCZ, and also known as the heat storage layer), is absorbed by the concentrated salt water in the UCZ, and the sun radiation energy is converted into heat energy and stored. As a result, the heat stored in the heat storage layer can only be transferred to the upper low temperature environment by means of heat conduction. Because of the salt gradient in the gradient layer, and NCZ likes a thick insulated layer, the heat stored in the heat storage layer can not be lost by convection heat transfer through the gradient layer.

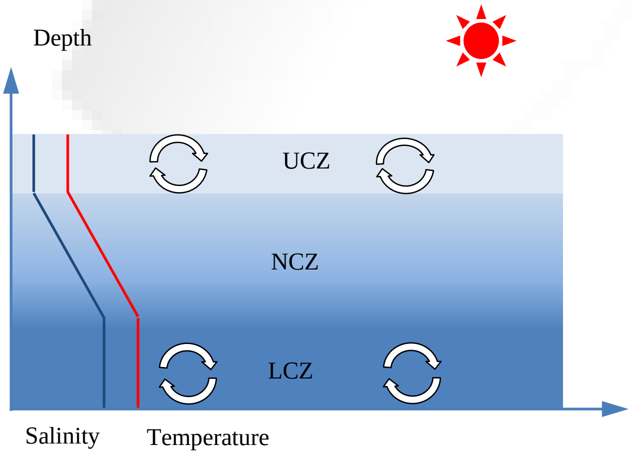

Figure 1. Schematic diagram of solar pond

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DEVOLOPEMENT OF SOLAR POND

The solar pond was first discovered in 1902, when Hungarian Kalecsinsky(Kalecsinsky, V. 1902) observed salt deposits at the bottom of a natural saline lake Madoc in Transylvanian, where the surface of the lake often flows into new fresh water, with a vertical gradient of salt concentration inside the lake. It was observed that the temperature below a few feet was significantly higher than that of the water surface. The temperature in summer was even 70℃ at 1.32 m deep and the least temperature is 26 °C in early spring. Later he found that this temperature varies with the depth of the lake water, which is precisely due to the saltwater concentration gradient in the water along the depth direction. after this study, he proposed the idea of using artificially manufactured salt-gradient solar pond to collect solar energy. In 1958, two experimental solar ponds had been constructed by Tabor(Kaushika, N. D. 1984: 24), and later in 1979, a application solar pond with area of 7500 m^2 was constructed by them. This solar pond was located Ein Boqeq near the Dead Sea, in that time ,this solar pond suplied 35 kW continuous heat in summer and 15kW in winter. But the total efficiency of the solar pond is only 1%. In 1989, according to the experimental study of Hull (1989:112; 1989) found that solar radiation incident inside the solar pond will be stored in the bottom area, as the density gradient caused by the concentration difference will suppress the natural convection caused by the temperature difference in the pond. Australia's Melbourne Institute of Technology Akbarzadeh (Akbarzadeh, A. 1992; 1989;1984) has made important contributions to experimental and theoretical research in the solar pond. They set up a solar pond of about 3000 m^2 in the PyramidHill, with a maximum temperature of 80°C in the LCZ. In addition to the solar pond experiments established, research experts and scholars have done other experimental and theoretical studies. Researchers (Zhang, G. 2016; Ranjian, K. R. 2014; Akbarzadeh, A. 2019; Ding, L.C. 2016a, 2016b, 2016c; Elsarrag, E. 2016) have combined solar pond technology with residential heating, seawater desalination, wastewater treatment, industrial process thermal production and power generation.

EFFECT OF POROUS MEDIA ON THERMAL PROPERTIES AND STABILITY OF SOLAR POND

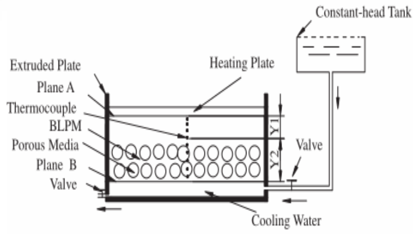
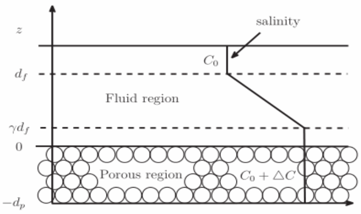
Considering that the temperature of the solar pond LCZ is rather low, which often limits the thermal application, and the research aimed at increasing the temperature of the solar pond. Here it does not refer to the passive way of reducing heat loss by using conventional methods such as high quality heat insulation, but to the technical and theoretical research of adopting certain technical means to improve the temperature of heat storage layer in solar pond. This research direction is roughly as follows: one is to use transparent insulation materials to replace the heat storage layer or to reduce the evaporation loss of the surface; the other is to add mirrors to the surface of the pond to increase the effective solar radiation area.

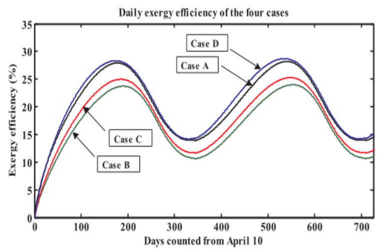
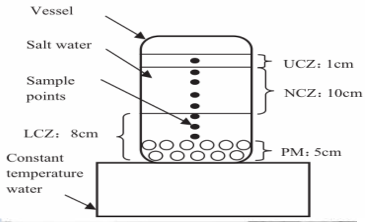
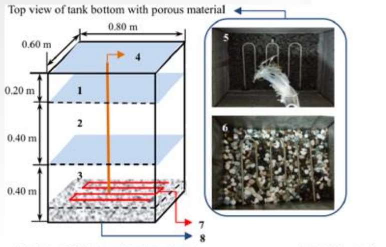
The first method is mainly aimed at the non-salt solar pond. According to the location of the transparent material, it can be divided into two kinds. One is to place the transparent material inside the solar pond, the other is to float the transparent (or opaque) material on the surface of the solar pond. For the first method, reference (Rabl, A. 1975; Hull, J.R. 1980; Alfonso Pinto, C. 1981; Zavargo, Z. 1982; Hadim, A. 1992) proposed the use of plastic sheeting or appropriate tubes to replace gradient layers; for the second method, Ortabasi et al .(Ortabasi, U. 1983; Kaushika, N.D. 1985, 1983;Schaefer, R. 1992; Cole, M.A. 1992; Arulanantham, M. 1997) used transparent materials floating on the water to fill paraffin oil to reduce heat loss from the surface. Wilkins and Lee et al. (1987,1991) use different water-insoluble liquids or solids to cover the surface of the solar pond, Zeddam(1993) use the cylindrical vacuum glass to float on the surface of the solar pond. As Spyridonos (2003) pointed out, although the first method can replace the effect of salt gradient layer to some extent, it is difficult to generalize to the need of large solar ponds, while the method of floating liquid on the surface of water, because the influence of wind, rain and so on in large solar ponds is more obvious and difficult to control, so it makes difficult to maintain the floating liquid on the surface. Velmurugan et al (2006,2007) added a mirror to the small solar pond to increase the amount of solar radiation received by the solar pond. This method, although simple and effective, has the same disadvantages as the above ways, which is difficult to apply to large solar ponds.

AL-Juwayhel (1998) numerically studied the effect of adding stone bed to the salt water layer at the bottom of the solar pond, that is, the materials such as marble, clay and other materials with less thermal diffusivity are laid on the bottom of the solar pond to form a mixed layer of concentrated salt water. The authors compared the development of LCZ temperature in solar ponds with different materials as added stone bed and different thickness of stone bed. The results showed that the heat storage layer temperature increased significantly when materials with low thermal diffusion coefficient were used. At the same time, the heat storage layer temperature decreased significantly when stone with high thermal diffusion coefficient was used. The thickness of the added stone bed also has a significant effect on the temperature of the solar pond, and the thick stone bed is more increase of heat storage layer temperature. Obviously, Al-Juwayhel et al .(1998) put forward this idea, which can be easily applied to large solar ponds from both technical and economic perspectives.

Later, researchers have gradually developed the study of porous medium salt gradient solar pond. As shown in Table 1, Sun Wence and others of Dalian University of Technology (Shi, Y. 2011) used coal cinder to lay to the bottom of the solar pond. The effect of coal cinder layer on heat transfer and salt diffusion in the solar pond was studied experimentally. Hill and Carr (2013a,2013b) have experimentally and theoretically studied the effect of porous media layer on the linear stability of salt gradient layer. the results show that the stability of the solar pond with porous media layer is related to the heat extraction amount. When the heat extraction ratio is less than 0.6, the porous media layer is favorable to stability and vice versa. Wang hua et al [2014; 2018a; 2015; 2018b] used coal cinder, cobblestone and vermiculite as porous media materials, respectively, and added them to the bottom of the heat storage layer of the solar pond. the effects of the physical parameters, such as the type of porous media, temperature development, porosity of porous media, on the thermal properties, tarsal properties and salt diffusion of the solar pond were investigated experimentally and theoretically. The results show that the increase of porosity and thickness of porous media is beneficial to increase the temperature of heat storage layer and delay salt diffusion, and the porous media with low volume heat capacity and low thermal diffusivity is beneficial to the solar pond to reach higher temperature. Wu Dan et al .(2013) that porous media can save heat and reduce turbidity of solar pond. The combination of heat storage layer and solar collector in solar pond can obviously increase the temperature of convection zone, but it has little effect on non-concurrent zone and upper convection zone. Wasaburo Unno and Masao Taga (1993) studied the physical stability characteristics of the solar pond. As a result, Rough and transparent artificial lawn or chord can prevent convection and maintain the stability of solar pond, and the heat conduction and viscous force scale in the porous solar pond are significantly reduced, and the Rayleigh number can be reduced below the critical value of convection.

Table 1. Typical studies on the salt gradient solar pond with porous medium in LCZ

Authors	Brief review	Highlights	Schematic diagram
Yu Feng Shi et al.[36]	PCMs influnce on the heat and salt diffusion of solar pond.	The addition of PCMs is benefits for keeping the salt gradient of solar pond and reaching higher temperature. Brine layer with porous media plays more positive role in heat insulation effect when thermal conductivity of the ground is big.	
Hua Wang et al.[37]	the influnce of adding PCMs to the LCZ on the thermal performance of solar pond.	The effect on temperature is related to the type of porous medium, coal cinder shows better performance than other involved bottom treatments. Addition porous medium layer usually increases the temperature of solar pond.	
A A Hill and Magda Carr[38]	Effect of porous media layer on the linear stability of solar pond	About 60% of porous medium in the LCZ appears to optimise the maximum temperature that can be stored in the LCZ. When the heating ratio is less than 0.6, the porous medium layer is favorable to stability, otherwise it is unfavorable.	
A A Hill, Magda Carr [39]	The linear instability of the gradient zone with porous and fluid interface.	Solutes with low Rayleigh number of in the gradient zone can maintain the same stability to the same low convection region temperature.	

Hua Wang et al.[40]	Transient thermal properties of salt gradient solar ponds with four different porous media have be studied	The high temperature, high volume heat capacity and low thermal diffusivity of the porous media favorable to the energy and the storage of the solar pond.	
Hua Wang et al.[41]	The effect of porosity of cinder as porous medium on salinity diffusion was studied.	The porous medium can delay the upward diffusion of salt. In a certain range, the smaller the porosity, the more favorable it is to inhibit the diffusion.	
Dan Wu[42]	Effect of solar collector combined with solar pond on the thermal performance of solar pond.	The porous media can save heat and reduce the turbidity of solar pond. The introduction of solar collector obviously increases the temperature of LCZ, but has little effect on NCZ and LCZ.	
Wasaburo Unno and Masao Taga[43]	the Physics characteristics of the stability of solar pond	Rough and transparent artificial lawns or chords prevent convection, and the Rayleigh number can be reduced below the critical value at initial convection.	
Hua Wang et al [44]	Experimental and theoretical studies on the exergy perfomance of solar pond	The results show case C gains the highest LCZ temperature and exergy efficiency and case A has the lowest temperature and efficiency The addition of porous medium, that is, cinder or mixture of cinder and cobblestone, improves the heat storage temperature and stability of solar pond.	 1.UCZ 2.NCZ 3.LCZ 4. Temperature sensors 5. With cinder 6.With multi-layer of cinder and cobblestones 7. Electric heater 8. Porous medium zone with depth of 0.10 m

CONCLUSIONS

The porous medium has a large specific surface area and strong heat transfer and uniform temperature ability. In terms of heat transfer, the heat transfer and uniform temperature of the heat storage layer are significantly enhanced. On the other hand, because of its low specific heat capacity, it also has a significant effect on increasing the temperature of the heat storage layer. The influence of porous media layer on the diffusion of heat and salt in solar pond is also closely related to the porosity of porous media layer, the characteristics of porous media material, the thickness of porous media layer, and the amount of heat raised In recent years, scholars have carried out more full research in this field, and obtained valuable research results, which provides a scientific theoretical basis for the application of porous media in solar ponds.

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REFERENCES

V. Kalecsinsky A. Ueber die ungarischen warmen und heissen Kochsalzseen als natürliche Wärmeaccumulatoren, sowie über die Herstellung von warmen Salzseen und Wärmeaccumulatoren. Annalen Der Physik, 1902, 312(2): 408–416.

Kaushika, N. D. (1984). “ Solar ponds: A review ”. Energy Conversion & Management, 24(4): 353-376.

Hull, J. R. (1989a). “Maintenance of Brine Transparency in Salinity Gradient Solar Ponds ”. Journal of Solar Energy Engineering, 112(2): 65-69.

Hull, J. R. (1989b). Salinity-gradient solar ponds. CRC Press, Inc..

Akbarzadeh, A., Golding, P. (1992). “The importance of wall angle for stability in solar ponds”. Solar Energy, 49(2): 123-126.

Akbarzadeh, A. (1989). “Convective layers generated by side walls in solar ponds: observations”. Solar Energy, 41(1): 17-23.

Akbarzadeh, A., Parker, G., Wong, C.(1984) “Development of a simple instrument for determination of salt concentration profile in the operation of solar ponds”. Solar Energy, 33(3): 283-287.

Akbarzadeh, A., Macdonald, R W G. (1982). “Introduction of a passive method for salt replenishment in the operation of solar ponds”. Solar Energy, 29(1): 71-76.

Zhang, G., Wu, Z., Cheng, F., et al. (2016). “Thermophilic digestion of waste-activated sludge coupled with solar pond”. Renewable Energy, 98:142-147.

Ranjan, K. R., Kaushik, S. C.(2014). “Thermodynamic and economic feasibility of solar ponds for various thermal applications: A comprehensive review”. Renewable & Sustainable Energy Reviews, 32(5): 123-139.

Akbarzadeh, A., Johnson, P., Singh, R. (2009). “Examining potential benefits of combining a chimney with a salinity gradient solar pond for production of power in salt affected areas”. Solar Energy, 83(8): 1345-1359.

Ding, L. C., Akbarzadeh, A., Date, A., et al. (2016a). “Transient model to predict the performance of thermoelectric generators coupled with solar pond”. Energy, 103: 271-289.

Elsarrag, E., Igobo, O. N., Alhorr, Y., et al. (2016). “Solar pond powered liquid desiccant evaporative cooling”. Renewable & Sustainable Energy Reviews, 58: 124-140.

Ding, L. C., Akbarzadeh, A., Singh, B., et al. (2017). “Feasibility of electrical power generation using thermoelectric modules via solar pond heat extraction”. Energy Conversion & Management, 135: 74-83.

Ding, L. C., Akbarzadeh, A., Date, A. (2016b). “Electric power generation via plate type power generation unit from solar pond using thermoelectric cells”. Applied Energy, 183:61-76.

Ding, L. C., Akbarzadeh, A., Date, A, et al. (2016c). “Passive small scale electric power generation using thermoelectric cells in solar pond”. Energy, 117:149-165.

Rabl, A., Nielsen, C.E.(1975). “Solar ponds for space heating.” Solar Energy, 17:1-12.

Hull, J.R. (1980). “Computer simulation of solar pond thermal efficiency with diffusively reflecting bottom.” Solar energy, 25:33-40.

Alfonso Pinto, C.,Reis,A.(1981) .”On the application of immiscible liquids to the insulation zone of a solar pond”. Proceedings of Solar World Form, Brighton, England, 667-676.

Zavargo, Z., Novacovic ,M.M.(1982). “Solareni bazen sa transparenton matricom.” Proceedings of the Symposium on Solar Energy, Opatija, Yugoslacia.

Hadim,A., Burmeister, L.C. (1992) “Conceptual design of a downward-convecting solar pond filled with water-satuRated porous medium”. Journal of Solar Energy Engineering, 114:240-245.

Ortabasi, U., Dykstechuis, F.H., Kaushika, N.D. (1983). “Honeycomb stabilized saltless solar pond.” Solar Energy, 31:229-231.

Kaushika, N.D., Baneriee, M.B. (1985). “Thermal analysis of honeycomb solar pond.” Energy Conversion and Management, 25: 3-7.

Kaushika, N.D., Baneriee,M.B.(1983). “Honeycomb solar pond collector and stoRage system.” Energy, 8: 883-890.

Schaefer, R., Lowrey, P.(1992). “The optimum design of honeycomb solar ponds and a comparison with salt gRadient ponds.” Solar Energy, 48:62-78.

Cole,M.A., Lowrey, P.(1992). "Improving the performance of floating solar pond covers." Journal of Solar Energy Engineering, 114:227-233.

Arulanantham, M., Acanti,P., Kaushika, N.D.(1997). "Solar Pond with honeycomb surface insulation system." Renewable Energy, 12:435-443.

Wilkins,E., Lee,T.K.(1987). "Development of the solar gel pond technology." Solar Energy, 39: 33-51.

Wilkins, E.(1991). "Operation of a commercial solar gel pond." Solar Energy, 46:383-388.

Kamiuto,K., Miyamoto,T., Saitoh S.(1999). "Thermal characteristics of a solar tank with aerogel surface insulation." Applied Energy, 62:113-123.

Zeddam, D.(1993). "Etude du compotement thermique d'un floteur transparent et isolant por un lac solaire a eaudouce." These 3eme Cycle, Ecole Nationale Superieure de Mechaniqueet d'Aerotechnique, Laboratoire d'Etudes Thermiques, Poitiers, France.

Spyridonos, A.V., Argiriou, A.A., Nickoletatos, J.K.(2003). "Thermal storage efficientcies of two solar saltless water ponds." Solar Energy, 75:207-216.

Velmurugan, V., Mugundhan, K., Srithar, K. (2006). Experimental studies on solar stills integRated with a mini solar pond: Proceedings of the third BSME-ASME international conference on thermal engineering, Dhaka, Bangladesh.

Velmurugan, V., Mugundhan, K.(2007). "Solar stills integRated with a mini solar pond-analytical simulation and experimental validation." Desalination, 216:232-241.

Al-Juwayhel, F., El-Refaee, M.M.(1998). "Thermal performance of a combined packed bed-solar pond system-a Numerical study." Applied Thermal Engineering, 18: 1207-1223.

Shi,Y., Yin F., Shi,L., Sun, W., Li,N., et al.(2011). "Effects of porous media on thermal and salt diffusion of solar pond." Applied Energy, 88(7):2445-2453.

Wang, H., Zou, J., Cortina, J.L., Kizito,J.P.(2014). "Experimental and theoretical study on temperature distribution of adding coal cinder to bottom of salt gradient solar pond." Solar Energy, 110: 756-767.

Hill, A.A., Carr,M.(2013). "Stabilising solar ponds by utilising porous materials." Advances in Water Resources 60: 1-6.

Hill,A.A., Carr,M. (2013). "The influence of a fluid-porous interface on solar pond stability." Advances in Water Resources, 52: 1-6.

Wang, H., Wu, Q., Mei,Y., Zhang, L., Pang, Sh. (2018). "A study on exergetic performance of using porous media in the salt gradient solar pond." Applied Thermal Engineering, 136: 301-308.

Wang, H., Yu, X., Shen, F., Zhang, L. (2015). "A Laboratory experimental study on effect of porous medium on salt diffusion of salt gradient solar pond." Solar Energy, 122: 630-639.

Wu D. (2013). "Experimental study of thermal characteristics for enhanced solar pond. " Journal of Dalian University of Technology, 53(5): 647-652.

Unno, W., Taga, M.(1993). "Physics of a Porous Solar Pond." Japanese Journal of Applied Physics 32(3): 1329-1333.

Wang, H., Zhang, L.G., Mei, Y. Y.(2018). "Investigation on the exergy performance of salt gradient solar ponds with porous media." International Journal of Exergy, 25(1): 34-53.