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A Laboratory experimental study on effect of porous medium on salt diffusion of salt gradient solar pond

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Abstract

A salt gradient solar pond with porous medium bed has been paid more and more attention, due to potential positive effect of porous medium on the thermal performance of salt gradient solar pond and also the delay action salt diffusion. Stability of salt gradient solar pond depends on the maintenance of the salt gradient. In this paper the effect of the porosity porous material on the salinity diffusion under the constant Lower Convective Zone (LCZ) temperature is experimentally studied, and the cleaned and screened coal cinder was used as the adding porous material. Under the same salt gradient conditions, the salinity development of LCZ with porous medium layer with porosity of 61%, 65.5%, 67% and 74% is respectively studied, the blank experiment without adding any porous material was used for comparison, and according to the experimental data, the salt diffusion coefficient in each depth was calculated by numerical method. Experimental results show that within the experimental temperature range, the porous medium can delay the salt diffusion upward. Some signs show that the porous material seems to have the absorption effect on salt. The smaller porosity the porous medium is the more slowly salt diffuses.

Keywords: Salt gradient solar pond; Porous medium; Porosity; Laboratory experiment

1. Introduction

Salt Gradient Solar Pond (SGSP) is an artificial salt water pond. Generally, it consists of three zones: the pond surface layer is called Upper Convective Zone (UCZ), which is filled with freshwater; Non-convective Zone (NCZ) with an increasing salinity downward is in the middle; and the lowest layer with high concentration salt is called Lower Convective Zone (LCZ). Due to the ability of collection and storage heat, SGSP has significant potential for solar thermal energy long term storage, and it sustained attention (Cohen et al., 1977; Al-Juwayhel and El-Refaee, 1998; Angeli and Leonardi, 2004; El-Sebaii et al., 2005; Karakilcik et al., 2006a,b; Velmurugan et al., 2009; Hung et al., 2010; Wang et al., 2014; Appadurai and Velmurugan, 2015). Solar ponds can provide reliable thermal energy at temperature ranging from 20 to even 90 °C (Cohen et al., 1977; Busquets et al., 2012). However for the practical salt gradient solar pond, it is difficult to attain a higher temperature more than 70 °C (Kurt et al., 2006; Kurt and Ozkaymak, 2006; Dah et al., 2010; Suárez et al., 2014; Yu et al., 2015). To increase the temperature of the storage zone, various methods have been presented by many researchers (Ibrahim and El-Reidy, 1996; Arulanantham et al., 1997; Aboul-Enein

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et al., 2004; El-Sebaii et al., 2005; Moh'd and Al-Dafaie, 2014; Tundee et al., 2014; Bozkurt and Karakilcik, 2015).

Porous Medium Salt Gradient Solar Pond (PM-SGSP) is formed of four layers. As shown in Fig. 1, porous materials are added on the bottom layer in the traditional salt gradient solar pond. So LCZ consists of two layers, which is the mixture of porous medium and salt water, that we call this layer as PM, and the pure salt water Layer on top of it. The introduction of the porous medium makes the research of salt gradient solar pond enter a new stage (Arulanantham et al., 1997; Al-Juwayhel and El-Refaee, 1998; Chen et al., 2004; Wang et al., 2009, 2014; Karim et al., 2010, 2011; Shi et al., 2011; Hill and Carr, 2013a, b). Due to the thermal performance of the porous material, the research reports have proved that adding porous material, such as rock and slag is benefit to increase temperature of LCZ (Al-Juwayhel and El-Refaee, 1998; Wang et al., 2009, 2014). We have studied the temperature increasing effect of different materials adding to salt gradient solar pond, and the results show that 0.1 m thickness slag layer got 8.5 °C HSZ temperature increasing compared to non-porous material one (Wang et al., 2014). Karim et al. (2010) experimentally studied the stability of solar pond with porous medium at bottom; the result shows that the existence of the porous medium increases the stability of the NCZ and so the stability of the solar pond.

From previous research work and the theory of thermal science, we have fundamentally identified the effect of porous medium on the temperature of SGSP, in which it can increase LCZ temperature within a certain range. However, how it affects on salt diffusion is still unclear, and there are not lots of attentions on this issue. In this paper, the easily available and cheap porous medium material of slag, which is the burning residues of the coal in boiler, was used to add at the bottom of the small scale modeling SGSP. Under constant bottom temperature conditions, porous medium layer's porosity influence on the salt upward diffusion was investigated. And also the salt

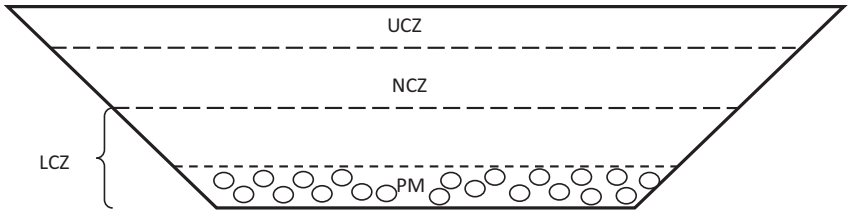

Fig. 1. Diagram of PM-SGSP.

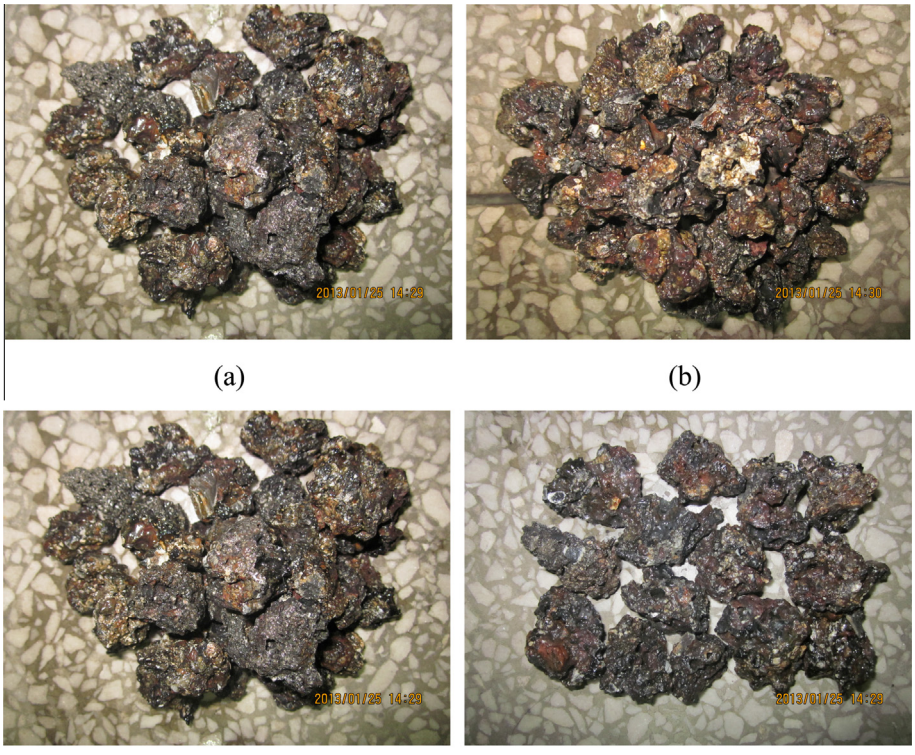

Fig. 2. The slag used in experiments.