Optimization of the Solar Brine Evaporation Process: Introduction of a Solar Air Heater

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Published online 5 October 2018 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ep.13062

The purpose of this study was to investigate the evaporation process of reject brine by using a solar system. The solar system contained a solar still coupled with a solar air heater (SAH). Solar still had a heated base, which was connected to the solar collector with a copper pipe. The influence of the introduction of the SAH to the system and increased levels of air mass flowrates was investigated. Variations in temperature and solar irradiation were monitored as well as brine evaporation. Introducing the SAH and increasing the air mass flowrate resulted in faster brine evaporation, higher utilization rate of solar radiation, higher brine, and base temperature levels within the solar still compared to the system without the SAH. The mean base temperature of the system with the SAH was 43.46 ± 11.3°C, while that of the system without the SAH was 30.62 ± 7.35°C. The use of the SAH and high air mass flowrates influenced the temperature distribution within the solar still, which affected the evaporation of the brine in a positive way. Introduction of the SAH and high air mass flowrate increased the drying efficiency of the solar system at a level of 120%. © 2018 American Institute of Chemical Engineers Environ Prog, 38:e13062, 2019

Keywords: air mass flowrate, drying efficiency, solar air heater, solar still, temperature distribution

INTRODUCTION

Desalination of seawater has recently emerged as a technology for addressing the problem of fresh water scarcity. The growth of desalination capacity worldwide is clear. Lattemann and Hopner [1] estimated that worldwide water production with seawater desalination accounts for 24.5 million m^3/day whereas Ghaffour, Missimer and Amy [2] reported this capacity to be ~66.4 million m^3/d in 2013, with the growth rate at 55% per year by using estimates by GWI [3]. As the capacity of desalination plants increases, the amount of hypersaline reject brine, which is generated by the desalination plants and discharged into the marine environment, also increases.

The primary environmental considerations associated with the discharge of reject brine include increases in the salinity and toxicity of the receiving water bodies resulting from the discharge of both salt and chemicals within the brine, which may affect coastal water and sediment quality, along with marine benthic communities [1,4–7]. The temperature increase induced by the reject brine from thermal desalination plants may be another environmental concern [1,6].

To date, most of the research has focused on production of freshwater to meet growing demand; limited research has been devoted to the environmental aspects of reject brine discharge and its management [5,8]. One method of brine management is to dilute it with other wastewaters such as power plant cooling waters, seawater, and municipal wastewaters [5,9–11]. Research is also being conducted to develop new diffuser systems [4].

Thermal-based, pressure-driven and other technologies are being applied worldwide to manage brine, with the main goal of minimizing its volume. Morillo *et al*. [12] grouped the technologies for brine management as solar evaporation using shallow evaporation ponds, phyto-desalination with plants evolved for high salt tolerance, thermal evaporation and crystallization systems demanding energy input, membrane distillation, reverse and forward osmosis, closed circuit desalination, and electrodialysis. Each of these technologies has its own pros and cons. The solar stills have economic advantage over other distillation processes, with reduced operating and maintenance costs [13]. Ongoing research tries to enhance the performance of the solar stills with various techniques such as using energy storage materials [13], coupling the solar still with solar still-flat plate collector system [14].

A limited number of publications focus on reject brine evaporation using solar drying [15,16]. In a previous study by our group [17], which reports on the factors influencing solar drying of reject brine, existence of a heated basin and a mirror were found to be the most influential factors. Additionally, the air extractor, which removes the vapor produced in the process, was found to adversely affect the evaporation performance of the solar still, due to the cooling effect of air from the outside, which is then sucked by the extractor [17]. The purpose of this study was to improve the evaporation performance of a solar still designed for brine management with the introduction of a solar air heater (SAH). The solar system used in this study is a modification of the solar still studied in our previous publication [17].

SAH are devices used to enhance the performance of drying process [18–20]. SAHs preheat the air for various applications, such as space heating, building heating, crop drying, solar water desalination, and various industrial heating processes [19,21]. SAHs are typically absorber plates that receive solar irradiation and create passages for the flowing air; thus naturally increasing the temperature of the air. They are easy and cheap to fabricate, involving a glass cover as a roof along with insulation at the bottom and sides to avoid heat losses [21]. Varun *et al*. [22] used solar dryer integrated with SAH to