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# Experimental Study of Evaporation Process; Salt Crystals

**Siamak Daneshyar[1, 2], Farshad Farahbod[3, *]**

[1]Department of Chemical Engineering, Sirjan Science and Research Branch, Islamic Azad University, Sirjan, Iran
[2]Department of Chemical Engineering, Sirjan Branch, Islamic Azad University, Sirjan, Iran
[3]Department of Chemical Engineering, Firoozabad Branch, Islamic Azad University, Firoozabad, Iran

## Abstract

Zero discharge desalination (ZDD) processes are the most promising technologies to prevent salinity and thermal shocks by effluent streams of desalination unit drained into sea ecosystems. Pretreatment, solar pond and forced circulation crystallizer are one option to provide the purposes of zero discharge desalination process. The effluent stream from solar pond is conveyed to one forced circulation evaporator in order to producing of salt and distilled water.

## Keywords

Forced Circulation Evaporator, Zero Discharge Desalination, Salt Crystals

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## 1. Introduction

Published researches about the crystallization of exit concentrated brine wastewater from solar pond are rare. These two serial units are one proposed method to reach zero discharge desalination purpose (Ericsson and Hallmans, 1996; Macedonio et al., 2011). Crystallization is a thermal separation, and therefore a purification process that produce a solid product from a solution, from a melt, or from a vapor. As for all thermal separations, non-equilibrium conditions are essential as a driving force for the process. Although evaporation of solvent or temperature reduction (cooling) is the most frequent means employed to establish the required non-equilibrium conditions. Pressure can, in principle, also be used to enforce the non-equilibrium state essential for a phase change. However, in industrial applications this parameter is most frequently kept constant. The process of crystallization is used basically to separate minerals from their water solution, as the solution reaches saturation state (Omar et al., 2010; Kim, 2011). Crystallization is one of the pristine unit processes (Galán et al., 2010; Macedonio et al., 2011; Koay et al., 2011). It may be assumed that our ancestors used sodium chloride found in crevices of the surface rocks after drying caused by the sun; this process is still in use in modern solar ponds. For crystallization to occur from a solution it must be supersaturated. This can be achieved by various methods, with (1) solution cooling, (2) addition of a second solvent to reduce the solubility of the solute, (3) chemical reaction and (4) change in pH being the most common methods used in industrial practice. Other methods, such as solvent evaporation, can also be used. This process is used to concentrate dilute liquor by evaporating its solvent (usually water). Most industrial crystallizers are of the evaporative type, such as the very large sodium chloride whose production accounts for more than 50% of the total world production of crystals. The most common type is the forced circulation (FC) model. Nowadays many searches are held to study the operating parameters of the FC crystallizers (Baranov, 1983; Plewik, 2011, Ryhl Kearn et al., 2013; Zhu at al., 2013; Rahman et al., 2013). Factors such as temperature of heat exchanger, flow rate of cooling water, vessel design,

* Corresponding author
E-mail address: mf_fche@iauf.ac.ir (F. Farahbod)

vaporization rate and residence time can have a major impact on the size distribution and amount of crystals produced.

This work focuses on major principles in performance of one forced circulating evaporator supposed for salt recovery and also distilled water production. Feed supply of this process is the effluent stream of one solar pond. This crystallizer is one step of the zero discharge desalination processes.

## 2. Experimental Set up

Slurry is pumped from the bottom cone of the crystallizer through the tubes of the vertical heat exchanger, where heat is added, and back into the main body of crystallizer where evaporation occurs. The liquor in a forced-circulation evaporator is pumped through the tubes to decrease tube scaling or salting when precipitates are formed during evaporation.

## 3. Results and Discussion

In this experimental work, three major factors are investigated and the effect of these parameters is shown in following graphs.

### 3.1. The Relation Between Cooling Water Flow Rate and Produced Salt Crystals

In this part, the effect of variation of cooling water flow rate which used in condenser on top of the crystallizer. Amount, color and size distribution of produced salt crystals and pH are investigated. Also energy consumption of experimental set up versus different mass flow rate of cooling water is investigated.

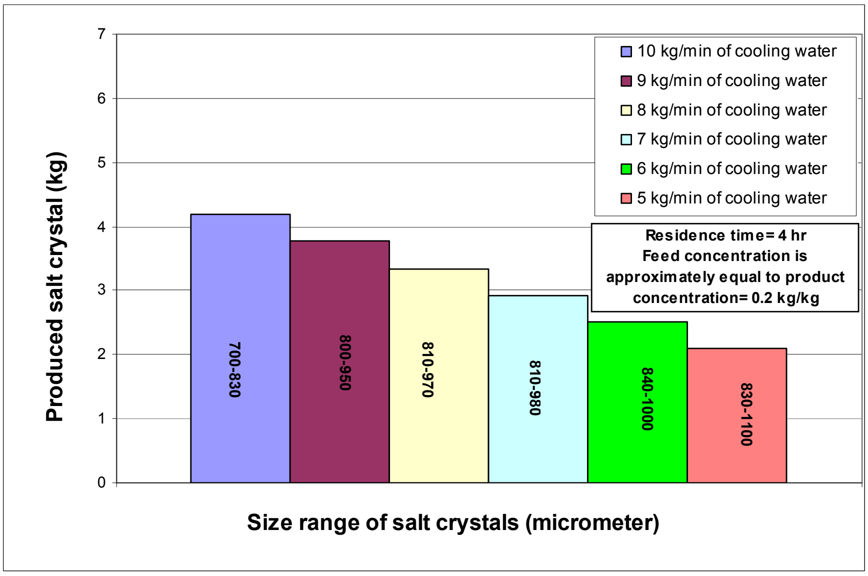


**Figure 1.** Amount of produced salt crystals versus size range.

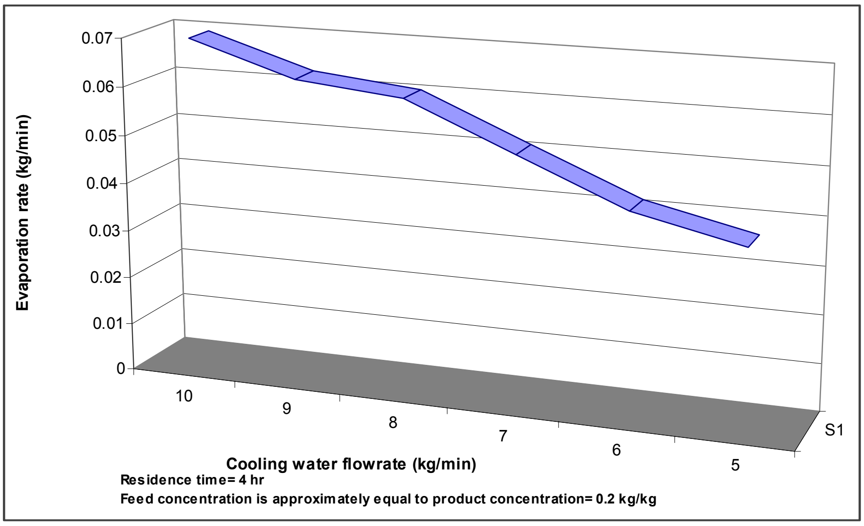


**Figure 2.** Variation of evaporation rate versus cooling water flow rate.

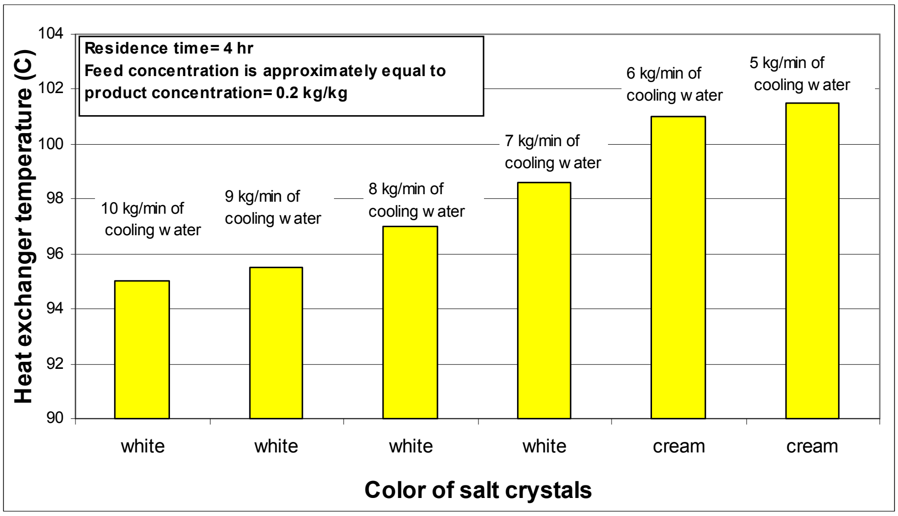


**Figure 3.** Temperature of heat exchanger versus color of produced salt crystals in different flow rates of cooling water.

Figure 1 shows the amounts of produced salt crystals versus size range of salt crystals. According to the Figure 1 coarse salt crystals will be produced with decreasing of cooling water flow rate and therefore temperature of heat exchanger increases but this isn't sufficient to produce considerable amount of salt crystals. So the highest amount of salt production is obtained with 10 kg/min of cooling water flow rate during 4 hours comparing with other cooling water flow rates.

### 3.2. The Relation Between Cooling Water Flow Rate and Evaporation Rate

Also, as shown in Figure 2 the relation between evaporation rate and cooling water flow rate is direct and evaporation rate increases according to increasing of cooling water flow rate.

### 3.3. The Relation Between Cooling Water Flow Rate and Heat Exchanger Temperature

Figure 3 indicates that heat exchanger temperature increases with decreasing of cooling water flow rate and also illustrated the color of salt crystals.

## 4. Conclusion

Zero discharge desalination is the main promising solution for environmental problems which are resulted from concentrated brine wastewater of desalination units. According to this subject, different serial units can be used such as pretreatment unit, solar pond and crystallizer. The authors focus on the crystallizing section. Since forced circulation evaporators are optimally suited as crystallizing evaporators for saline solutions so this type is considered.

Main applications for this crystallizer are in the concentration of soluble materials, crystallizing duties, and in the concentration of thermally degradable materials which result in the deposition of solids. In the FC model, the liquid is circulated through the calandria by means of a circulation pump, where it is superheated at an elevated pressure, higher than its normal boiling pressure. The appearance and size range of a crystalline product is very important in crystallization. If further processing of the crystals is desired, large crystals with uniform shape and size are desirable for washing, filtering, transportation, and storage. Results show that residence time of 4 hr is the best duration for this experiment because the crystal growth is in the suitable range and also according to results the best residence time is 4 hr.

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