Modeling of crystallisation processes in solar evaporation ponds in a quasi-continuously driven small pilot plant

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1. Introduction

A small indoor plant has been built and tested. With it a performance of solar evaporation processes combined with a fractional crystallization is possible. In the given example a Carnallite crystallization process was modeled with a synthetic brine and compared with evaporation process of the natural brine on site. The data thus obtained allow for an evaluation of an industrial solar evaporation-crystallization process of brines.

2. Equipment

The plant consists of four tubs with a volume of 550 liters and a depth of 70 cm. Each of the tubs was isolated with rock wool and fitted with nine 150 W IR-bulbs. For a further increase of the evaporation a heating radiator was mounted side on at each tub. This radiator can be driven with an electrical power supply of 600, 1200 and 1800 Watts. Further each tub was equipped with a fan heater. In order to get an optimum distribution of the hot air current above the liquid surface, slit-nozzles were mounted on the fan heater. For temperature registration three Pt-100 temperature sensors were mounted into each tub. By this the brine temperature in different diving depths, i. e. 1 cm, 20 cm and 30 cm can be recorded. A digital unit records continuously the data of the temperature measurement in each tub and regulates the radiation intensity as well as the working time per day within a weekly cycle, for example a day/night-rhythm. The temperature near the liquid surface is controlled by the switch on and switch off of the IR-bulbs. The heating radiators were driven continuously as basic energy source. The used commercial software allows to turn on and turn off the complete plant respectively different parts of the plant by time and date and the storage of the experimental data in a personal computer.

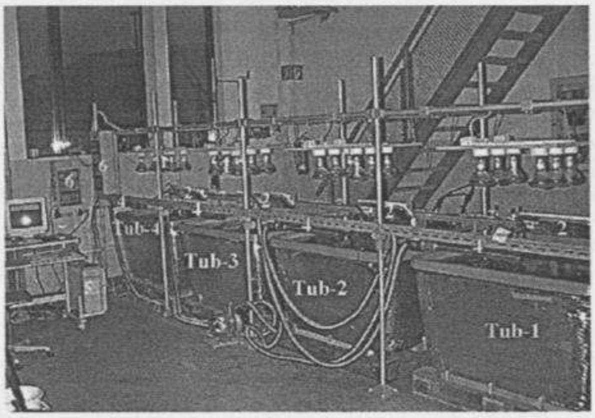

Fig. 1. The small plant for modeling solar evaporation of brines. The components of the plant for each tub are **1** IR-bulb; **2** heating radiator; **3** blower; **4** fan heater and **7** Pt-100 temperature sensors. The registration of the measurement data and the process controlling via personal computer and external interface **5**, as the electrical power supply **6** follows central for all four tubs.

For a registration of the actual, maximum and minimum humidity and temperature directly above the tubs, thermo-/hygrometer are fitted above them during the experimental works.

With the regulation of the energy input the evaporation rate can be adjusted within the range 2,5-12 mm/day for sweet water. If only IR-bulbs are working an evaporation rate of 2,5 mm/day is reached. If in addition to the IR-bulbs the heating radiators are working with 1800 Watts as well as a hot and dry air current the evaporation rate increases to 12 mm/day.

3. Commissioning of a continuously driven fractional crystallization process by modeling solar evaporation

The modeling of a solar evaporation process and a fractional crystallization of halite and carnallite was carried out for a hexary brine system with the components Na, K, Mg, Ca, Cl and NO_3. The four tubs were fed with the brines in a sequence of increasing brine densities (i. e. 1,26 g/cm^3 to 1,45 g/cm^3). In this density sequence each brine represented a particular degree of evaporation of the basic brine. The compositon of the diferent brines is given in table 1.

Tab. 1. The compositon of the basic brine and the brines in the tubs at 25°C

		basic-brine	tub-1	tub-2	tub-3	tub-4
NaCl	g/l	82,1	71,3	33,6	12,0	7,7
KCl	g/l	9,5	10,6	14,9	11,7	4,8
$MgCl_2$	g/l	63	71	107	145	170
$CaCl_2$	g/l	199	220	289	382	456
$Ca(NO_3)_2$	g/l	13	14	23	32	36
water	g/l	890	883	860	815	770
density	g/ml	1,26	1,27	1,33	1,40	1,45

For the modeling of the evaporation process a rhythm of day and night was chosen with a running time of 12 hours and a resting time of 12 hours. The principle course of the temperature at different diving depths during one day is shown in fig. 2.

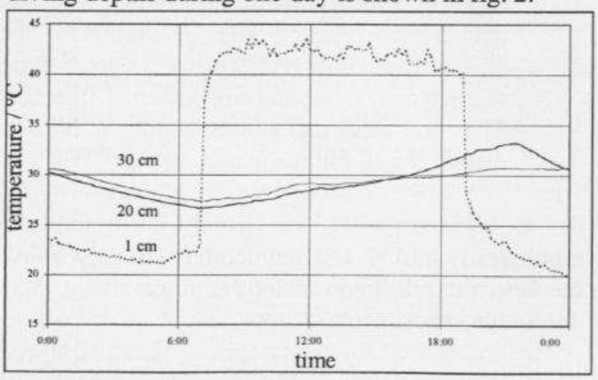

Fig. 2. The typical daily course of the temperatures of the brine in different diving depths during the solar evaporation process

The most experimental effort concerned the regulation of the mass flow caused by evaporative losses. It had to be compensated periodically. For this a special procedure of output and feed of the brines in the different tubs was executed, to get the mass flow shown in fig. 3. The process ran quasi-continuously about 4 weeks. After finishing the process the crystalline crop within the tubs was harvested, weighted. By this the balance of the mass flow was determined as shown in fig.3.

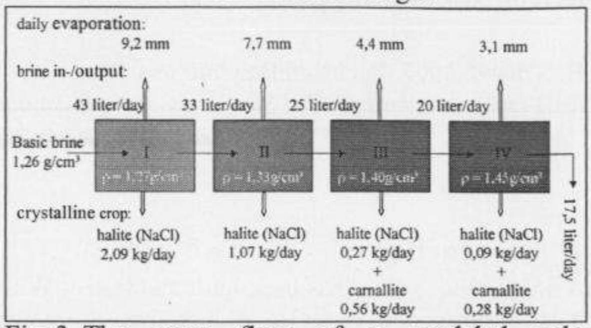

Fig. 3. The mass flow of a modeled solar evaporation process of a hexary brine system with the components Na, K, Mg, Ca, Cl and NO_3

4. Results

Decisive for a commercial use of the described solar evaporation process is the production of potash-fertilizers. During the evaporation process KCl at first becomes enriched to a maximum concentration of 21 g/1000 g H_2O KCl at a brine density 1,38 g/cm^3 and then impoverished to a minimum concentration of 5 g/1000 g H_2O at a brine density 1,45 g/cm^3. Using this procedure78% of the original KCl content crystallize in the tubs-3 and –4 as carnallite together with NaCl, whereas in the tubs-1 and –2 only NaCl crystallizes. There is a pretty well correspondence to the natural evaporation process, as shown in fig. 4. Because of this, these results can be used for a development of a solar evaporation system.

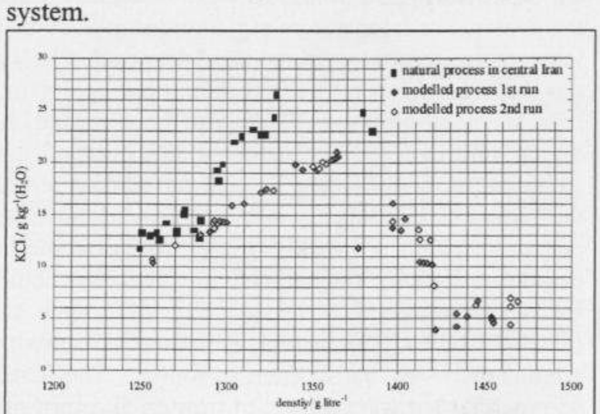

Fig. 4. A comparison of natural and modelled course of KCl during the evaporation process.