ABSTRACT

More than 90% of salt used in Uganda is imported from neighbouring countries despite the existence of over 22.5 million tonnes of mineral deposit at Lake Katwe. This is due to the current traditional mining techniques employed at the salt deposit that yield low quantity and quality salt. To avert this, a salt extraction process unique to the brine of Lake Katwe is needed to reduce Uganda's dependency on imported salt. This study therefore, aimed at application of process technologies for improved salt production from Lake Katwe, Uganda. This involved, a) determining the phase chemistry of the ternary and quaternary systems of Lake Katwe brine particularly considering the effects of temperature, b) developing an extraction process for the various domestic and commercial salts from Katwe brine and c) modelling and validating the salt pan for increased salt productivity in terms of quantity and quality.

The Pitzer model embedded in PHREEQC software was used to predict the precipitating salts, their respective yield, and the order in which they crystallize from Lake Katwe brine. This was supplemented by computing the phase diagram using the Extended UNIQUAC employed in the MATLAB environment. To validate the thermodynamic calculations, isothermal evaporation experiments were done. The mineralogy and morphology of the precipitates from the isothermal experiments were determined by the XRD and SEM techniques, respectively. Furthermore, by using the Taguchi experimental design method, the parameters affecting the crystallization of halite from brine were investigated. The salt pan, an integral part of the solar salt works was modelled to optimize its dimensions in OpenFOAM. A techno-economic analysis followed in SuperPro Designer where the process flow sheets were modelled.

The precipitation sequence mainly started with sulfate followed by chlorides and lastly carbonates at all temperatures after the precipitation of the carbonates of calcium and magnesium. Halite emerged the most dominant mineral, with thernadite, trona and glaserite following respectively. Thenardite, glaserite, and burkeite precipitation flourished at lower temperatures (30 & 40 ℃) whereas soda ash precipitation flourished at higher temperatures (60 & 70 ℃). Halite equally precipitated at all temperatures thus not showing temperature preference. The results from the signal-to-noise analysis aimed at determining the effects of several parameters on halite crystallization showed that the optimum conditions for maximum crystal yield were achieved when the feed concentration, mixer speed, residence time, and heating load are 0.248 g of NaCl/g of solution, 830 rpm, 50 min, and 1400 W, respectively. Moreover, the ANOVA results indicated that the residence time and heating load are the most significant parameters influencing the salt crystal yield with a contribution of 57.11% and 20.07%, respectively. The mixer speed and feed concentration had the smallest effect on the crystal yield with a contribution of 19.55% and 3.3%, respectively. Efforts were made to enhance the salt pan performance, the model results from OpenFOAM revealed that a depth of 0.1 m produced the highest brine temperature. Thus, the salt pan should be as shallow as practically possible. Results from the techno-economic analysis showed that halite of purity >99% was produced after the flotation of burkeite and trona. Additionally, soda ash and sodium sulfate were produced by a combination of flotation, carbonation and calcination techniques. The unit production cost of halite was 0.2629 and 0.4724 $/kg with a NPV of $ 2,447,853 and -12,085,796 of the solar salt and mechanical evaporation processes respectively. As a result, the solar salt extraction process proved highly feasible from both engineering and economic standpoints and thus can be scaled up to a pilot scale using conventional industrial equipment.

Keywords: Salt Extraction; halite; Lake Katwe; SuperPro Designer; PHREEQC; Extended UNIQUAC; MATLAB; Taguchi analysis; OpenFOAM.