Towards The Improvement of Salt Extraction At Lake Katwe

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Abstract:- The occurrence of Lake Katwe salt deposit in Western Uganda is well-known through the East African region. Production of salt from this saline lake has been practiced for decades following traditional methods; however the quality and yield of the products are poor. There are also risks of burns, as the workers get into direct contact with the brine. Detail assessment and evaluation of the mine has been done through field studies, raw sample materials analysis. Results indicate that the raw brine from the lake is rich in sodium, chloride, potassium, carbonates, sulphate ions with traces of calcium, magnesium, and bicarbonate ions. This motivates the aspiration to properly extract salts from such a rich source. The lake brines contain impurities such as organic matter and suspended solids. With increasing demand for usage of sustainable technologies for salt extraction, the present study calls for the improvement of salt extraction at Lake Katwe through optimizing the use of the current solar evaporation technique while integrating it with a mechanized chemical separation process. This would ensure better recovery and process efficiencies, low costs and simple brine pre-treatment procedures.

Keywords:- Lake Katwe, Brine, salt extraction, Evaporate, Uganda, solar ponds, rock salt.

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1 Introduction

Lake Katwe is well-known throughout Uganda and the East African region for its substantial source of salt and has been producing moderate quality salt for several decades. It is the largest of the eight saline crater lakes within the Katwe-Kikorongo volcanic field in Western Uganda, see Figure 1. Preliminary investigative fieldwork studies indicate that the lake contains the best salt reserves evident in its brines and evaporate deposits. There are 22.5 million tonnes of crystalline salts in Lake Katwe which can sustain a plant for over 30 years at 40,000 tonnes/annum NaCl production [1]. Salt mining and processing have for a long time been based on traditional methods, hence small and impure yields. Apart from Lake Katwe, it is reported that limited quantities of salt for human and animal consumption have been extracted from the hot spring waters at Lake Kibiro located in the Albertine region and at Lake Kasenyi on the shores of Lake George. At Kibiro, salt is produced from the waters of the spring and the saline muds around the lake. The Mineral A report on resources of Uganda stated that salt production (almost exclusively from Lake Katwe) in the period 1925 – 1949 averaged 3,000 tons/year which increased to between 7,000 and 9,500 tons/year during the 1950's [2], [3], [4]. The 1992-93 level was approximately 8,500 tons/year. Currently, some producers at the lake put the annual production at closer to 15,000 tons/year, although there is no comprehensive record keeping at the site Furthermore, investigative fieldwork studies by Morton [5], [6] indicated that the lake contains the best salt reserves in Uganda. However, an attempt to mechanize the production of domestic and commercial grade salt from the lake was conceived in 1975, a plant was commissioned, worked for a short time and later collapsed. Several initiatives to revamp salt production at the plant failed.

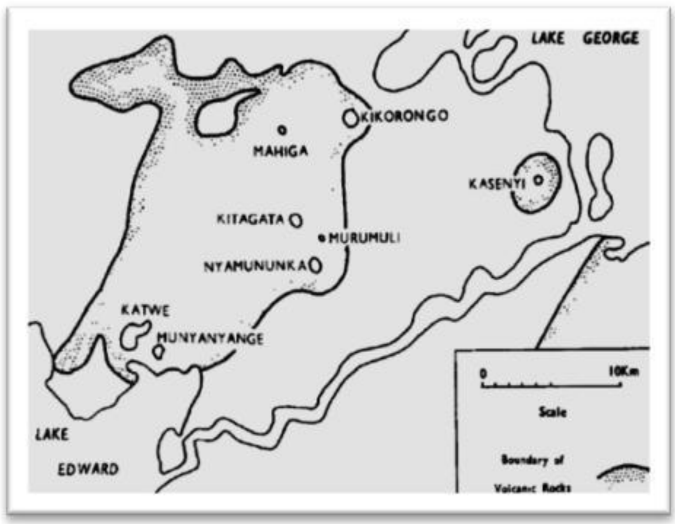

Figure 1: Saline crater lakes of the Katwe volcanic field, after Arad and Morton, 1969

Purification of salts is primarily directed to the removal of impurities which is accomplished by a number of different leaching processes in which the ore is contacted with a leaching solution which becomes enriched with the product being recovered and then subjected to further processing such as crystallization. Other attempts to purify salt have considered selective precipitation wherein a chemical is added to a salt solution or brine to precipitate only the particular material of interest. In these processes, both soluble and insoluble impurities present in the pregnant solution are incorporated, encapsulated or occluded within the resultant salt crystals. In addition to mining the salts, solar evaporation of brine from the lakes as well as the evaporation of brines by open pan or vacuum pan processes are utilized to prepare crystallized salts [7], [8], [9]. The soluble calcium, magnesium and sulphate impurities are present in the source material and normally appear in unacceptably high quantities in the crystallized product thereby requiring further processing to produce a sufficiently pure salt for many industrial purposes. The brine, usually high in organics and carrying bacteria unwanted in food, is often entrapped in solar salt crystals. This exploratory

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study therefore was aimed at developing techniques and concepts of improving the salt mining and extraction process with a view of producing quality salt for domestic and other uses.

2 Materials and Methods

2.1 Field studies and sampling

Field studies were aimed at collecting information to characterize the deposit, understanding the current mining and processing practices and determine the weather conditions of the area. Ambient temperature, wind speeds, humidity, solar insulation, evaporation rate and precipitation were measured using a Davis Pro 2 weather station and a standard class A evaporation pan during the dry season (January – March) and averages were computed. A representative sample of salt water (brine) was taken from the lake. Samples were picked by traversing different points of the lake with a canoe and mixed together in a jerry can to make a representative sample which was stored at room temperature prior to laboratory analyses. Samples of rock salt and processed salt were also collected from the lake and solar pan yields respectively. Physico-chemical characteristics of the brine were recorded in situ using portable equipment. Brine pH, total dissolved and suspended solids, temperature were recorded using a PHH224 meter. The density of the raw brine was measured by a portable DA-130N density meter.

2.2 Laboratory Study

2.2.1 Determinations of major ions

The samples were analyzed for the major inorganic cations and anions namely Na+, K+, Mg2+, Ca2+, CO32-, HCO3-, SO42- and subsequent combinations like NaCl, KCl, MgSO4, CaSO4, Na2CO3 and NaHCO3 in order to ascertain the impurities that exist in Lake Katwe water. All the reagents used were of analytical grade. Table 1 gives a summary of the analytical methods employed.

TABLE 1
ANALYTICAL METHODS USED TO DETERMINE THE COMPOSITION OF CATIONS AND ANIONS

Cation/Anion	Method
CO32-, HCO3-	Auto potentiometric titre pH 4.5, pH 8.3
Ca2+ ,Mg2+,K+,Na+	Spectrophotometry (AAS), Titrimetry, Ion chromatography
Cl-	Mohr method, gravimetry, Auto (ferric thiocyanate)
SO42-	Gravimetry

2.2.2 Salt Extraction

The collected brine was processed to separate the impurities from common salt, sodium chloride. In the laboratory, an alum and Aluminium Sulphate solution was introduced into properly selected pH range (8.5 to 10.5 using lime and subsequently brought back to pH 7.5 using 10% alum) in order to get rid of impurities by coagulation followed by filtration. The subsequent product was then filtered using filter paper, dried and the salt composition was computed.

3 Results and Discussion

3.1 Geological setting

Geographically, Lake Katwe is found within an explosion crater in the formerly active volcanic area north-east of Lake Edward and south-east of Lake George. It is located on the floor of the Western rift valley and south-east of the Ruwenzori Mountain. The lake is found in the small town of Katwe on the outskirts of the Queen Elizabeth National Park in the Kasese District and covers an area of approximately 2.5 km2. The salt lake lies on the floor of an explosion crater formed in tuffs with about 230 meters of rock separating Lake Edward from the crater at the closest point. The explosion crater ejected pyroclastics, tuffs with abundant granite and gneissic rocks from the basement which dominate the area. The volcanic rocks are mainly composed of pyroclastics and ultramafic xenoliths which are deposited on the extensive Pleistocene lacustrine and fluvial Kaiso beds and in some places directly on Precambrian rocks. The salinity of Lake Katwe and the other closed saline lakes is derived mainly by evaporative concentration of mineral spring waters [11]. The saline spring waters filled the crater during Pleistocene vulcanism. Suggestions indicated that salt has also been leached out of the surrounding tuffs by water percolating from Lake Edward into Katwe crater which lies about 30 m below the fresh lake level [4]. In addition, the saline crater lakes in the Katwe volcanic field, Figure 1, are all closed lakes in which the inflow from rainfall and springs is balanced by evaporation. Their depth is <1 – 6 m and the seasonal variation in rainfall and evaporation cause changes in depth of up to 0.5 m and a considerable variation in salinity.

3.2 Weather Conditions of Lake Katwe Area

Lake Katwe is located in a semi-arid with area very little precipitation, high evaporation rates and high ambient temperatures of up to 34°C. There intermittent wind regimes with speeds reaching up to 15 m/s. Humidity levels of up to 85 mmHg and solar insolation of 965 W/m2. The annual water evaporation in Kasese district is about 216 cm per year (i.e. about 5.5 mm/day).

3.3 Current Salt production practices at Lake Katwe

The salt in Lake Katwe and other lakes is believed to come from a salty volcanic rock and it is brought into the closed crater by saline springs around the edge of the lake which discharge water adding about 2,000 tons of salts to the lake each year10. Salt production is done using traditional techniques currently being used based on solar evaporation of brines. Brine is diverted from the lake into the pans (area/volume) also called “Amaziba” in the local dialect. Over 10,000 salt pans are used as this is the major economic activity in this area and it employs over 15,000 people of whom over 75% of the labor force is provided by women (Figure 2). Rock salt is also extracted from the lake bed using bars for breaking it from the lake bed and subsequently loaded on wooden rafters which bring the yield to the shore. Three grades of salt are currently produced at the lake which includes:

a) **Grade I** – mainly for domestic consumption, is formed in mud-lined salt pans through solar evaporation during the long dry season and the labor force here is majorly from women. Floating crystals, which form at night when the lake is cooling, are forced to sink when they drift up against artificial barriers of grass woven between wooden stakes. The accumulated crystals are scooped up from the bottom of the lake. Production is intermittent and dependents on prevailing weather conditions and labor is over 75% women, see Figure 2. Traditional extraction of salt using solar pans is one of the oldest but proves to be both economical and ecofriendly technique particularly in rural areas [8], [9], [10], [12], [14]. However, it must be noted that this is a physical process which in most cases will not handle the removal of the most unwanted impurities which are chemically combined with the NaCl.

b) Grade II – extracted from the remnants of the pond products at the end of the long dry season. This is mainly for animals.
c) Grade III – Rock salt from the Lakebed extracted by mainly men. Slabs of layered crystallized material with a variable composition that includes halite (sometimes constituting less than 50% of the total), burkeite, sodium carbonate, and organic matter (there is a very strong smell of hydrogen sulphide) is prized from the bottom of the lake, placed on a floating wooden rafts and manually pulled to the shore. This is unloaded, stacked, and then sold as grade III salt, see Figure 3. The job of extracting the rock salt from the lakebed is mainly done by men, see Figure 4.

Figure 2 – Women working in a Salt Pan at Lake Katwe

A closer look at the rock salt shows that it is stratified, and the layers are formed by different constituents due to their sequential crystallization as can be seen in Figure 5

Figure 3 – the three grades of salt obtained from Lake Katwe: a) Grade I; b) Grade II and c) Grade III also known as Rock Salt

Figure 4 – A man standing in the saline lake, breaking rock salt from the lakebed with a bar as he loads his harvest on the raft

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3.4 Physico-chemical properties and Contents of Lake Katwe

Lake Katwe contains salt, suspended matter like clay, chalk, and a strong obnoxious ammoniacal odor emanating from degraded bacteria and plant protein is also associated with Lake Katwe water. It is the presence of traces of ammonia; hydrogen sulphate that causes odor problems for the raw salt. Lake Katwe water is also contaminated with soluble proteins, dirt, clay, silica and other suspended impurities. The density of the raw brine is 1.288 kg/l.

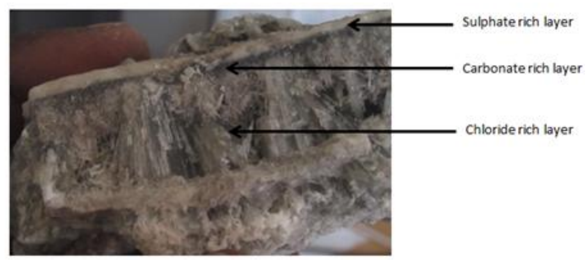

Figure 5 - Rock salt crust mined from the lake bed

Table 2 indicates a high concentration of total suspended solids (500 – 4,000 mg/l), which has a gross impact on the evaporation rate when the current solar evaporation method is used in separation of salt. High concentration of suspended solids and other impurities reduce the evaporation rate. If the Lake water is just discharged to the Solar Evaporation Pans without treatment, as it is done currently, the salt obtained is impure and is not fit for human consumption.

3.5 Chemical Constituent of Katwe Salt

The graph in Figure 6 shows a very high concentration of Sodium ions and Chloride ions. Sodium 33%, the second to Potassium, metal in the electrochemical series combines vigorously with chloride ions about 20% to form salt, Sodium Chloride, the common salt. The sample from Lake Katwe exhibited traces of Calcium, Magnesium, carbonate and bicarbonate as shown by the low weight percentage. The sample from Lake Katwe exhibited traces of Calcium, Magnesium, carbonate and bicarbonate as shown by the low weight percentage.

TABLE 2
CONCENTRATION OF SOLIDS IN LAKE WATER

	Lake water (mg/l)	Pan (mg/l)	Agitated (mg/l)
Total Solids TS	27,500	15,500	33,000
Total dissolved solids	25,000	15,000	3,000
Suspended solids	2,500	500	3,000
Chlorides as Cl-	88,602	88,602	88,602
Sulphates as SO42-	69,000	69,000	69,000

These are impurities that must be removed to make the edible salt. These traces are responsible for the unpleasant characteristics of salt in its raw form; they combine with existing anions to produce the obnoxious smell. The elements above form the following combinations in order to remain stable: Sodium Chloride, Sodium Sulphate, Sodium Carbonate, Sodium bicarbonate, and Potassium Chloride. Raw brine from Lake Katwe contents analysis reveals up to 13% by weight, which motivates the aspiration to extract salt from such a rich source. However, Lake Katwe saline water exhibits greater percentages of impurities that are fundamentally not desirable in common salt such as calcium, magnesium compounds present in significant quantities. This presents a challenge during the current mining and processing of the ore as these impurities need to be removed. Some of these impurities are clay, organic matter, calcium and magnesium compounds, sulphates, carbonates and bicarbonates. Other impurities include the physical characteristics of smell, appearance and haziness. Lake Katwe salt water has an obnoxious smell. At some concentration, it shows a red color due to presence of algae in a saline environment and extremely hazy. But these characteristics are present because of the existing impurity elements in Lake Katwe salt water. The removal of these impurities from the saline water at Lake Katwe automatically eliminates the unpleasant characteristics such as the smell; it becomes clear saline water etc. Lake Katwe therefore has the potential to produce other useful compounds like soda ash, sodium sulphate and potassium sulphate which are removed as impurities in the process of refining the saline water to produce common salt. Markets for these products in Uganda may need to be searched. The additional products from Lake Katwe can be used for making glass, ceramics, water treatment, detergents, fertilizers, pulp and paper manufacture. Table 3 illustrates the composition of Lake Katwe salt during its processing stages. Table 4 shows the performance analysis of the lake brines during their treatment.

TABLE 3
CHARACTERISTICS OF LAKE KATWE SALT

Element/Compound	Lake Katwe water	Solar evaporation	Chemical treatment	Physico Chemical (Chemical + Filtration)
Potassium, (as K), % by weight	8.3000	6.6400	4.9800	0.6225
Calcium, (as Ca), % by weight	0.0089	0.0071	0.0058	0.0047
Magnesium, (as Mg), % by weight	0.0077	0.0062	0.0046	0.0016
Hydrogen sulphide, (as H2S), % by weight	0.2000	0.1200	0.0010	0.0000
Alkalinity (as Carbonate, CO32-), % by weight	16.9400	13.5520	9.6940	1.2705
Alkalinity (as Bicarbonate, HCO3-)	1.7300	1.3840	1.0034	0.1298
Sulphate, SO42-	17.1700	13.7360	9.7020	1.2878
Insolubles	2.7046	2.5005	0.0010	0.0000
NaCl (% by weight)	13.70%	75%	95%	97%

4 Conclusion

Lake Katwe salt deposit has been studied, and the different constituents from this source characterized. Salt production is a major economic activity in this area and a good number of the local population especially the womenfolk earn their living here as key-players in salt production. The salt lake contains substantial amounts of salt which can be commercialized for optimum production. Characterization results suggest favorable constituents in the Lake Katwe water for the mining and processing of edible salt. Outcomes indicate the strong presence of the main component of common salt sodium chloride, high in concentration but also co-existing with impurities. Raw brine from Lake Katwe contents analysis reveals up to 13% NaCl by weight, which motivates the aspiration to extract salt from such a rich source. However the Lake Katwe saline water exhibits great percentages of impurities that are fundamentally not desirable in common salt such as calcium, magnesium compounds present in significant quantities. This presents a challenge during the current mining and processing of the ore as these impurities such as clay, organic matter, calcium and magnesium compounds need to be removed.

TABLE 4
COMPARATIVE PERFORMANCE ANALYSIS OF THE LAKE WATER BEFORE AND AFTER TREATMENT

Scheme/ Units	Purity of salt recovered	Suitability for use
Direct evaporation in Solar Evaporation Pan	75 %	Odor problem due to the degradation of organic matter. Low evaporation rate due to suspended and colloidal impurities. Salt is removed from the solar evaporation pan only after complete drying. Recovered salt is impure and is not suitable for human consumption.
Physico chemical treatment followed by Solar Evaporation Pan	>95 %	Rate of evaporation is improved by (15-30%) due to the removal of suspended and colloidal impurities. The crystallized salt from the solar pans are removed periodically and the salt is relatively pure.
Physico chemical treatment+ + filtration with filter paper followed by Solar Evaporation Pan	>97.5 %	High purity salt/saline water can be recovered and is almost free from organic and inorganic impurities.

Nonetheless, Lake Katwe has the potential to produce other useful compounds like soda ash, sodium sulphate and potassium sulphate which are removed as impurities in the process of refining the saline water to produce common salt. Concentrated brine or salt can be obtained cheaply using solar pans, making this location an ideal and potential area for the construction of solar ponds since there is abundant solar energy favored by the weather conditions of this area. However, the product of solar evaporation is still contaminated and not fit for human consumption, hence the need for chemical separation to accomplish the separation process. Furthermore the solar ponds rely on the weather such that in the rainy season no harvest can be achieved.

5 RECOMMENDATIONS FOR FURTHER RESEARCH

To fully utilize the potential of Lake Katwe salt industry, it is recommended that further research work be done to optimize the current use of solar energy for salt extraction at the lake salt ponds. It is also important that a detailed chemical analysis with Induced Coupled Plasma be done to identify the constituent elements with a higher precision. In addition to the use of solar energy, salt harvesting should be mechanized to improve the purity and recovery hence value addition. This will entail the usage of a suitable chemical separation process. Furthermore, the solar pan (traditional) technology should be maintained considering the socio-economic framework and especially for the womenfolk who earn their livelihood here. Nonetheless, emphasis should be put on ridding the pan products of the contaminant impurities and a safer way of processing to minimize brine-body contact.

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