BIOLOGICAL MANAGEMENT OF KRYSTALLINE SALT WORKS, MALINDI DISTRICT, KENYA

R.Venkat, Krystalline Salt, Gongoni,Malindi District , Kenya
Email: rvkrish1@yahoo.com
A.Abdul Rahaman, SRM University,Kattankulathur-603203,Tamil Nadu , India
Email: aarahaman@gmail.com
Deepak K.Patel, Krystalline Salt, Kenya
Kanjibhai K.Patel, Krystalline Salt, Kenya

Abstract
Krystalline salt limited comprises of salt works located at Marareni, Gongoni and kurawa in Malindi district, Kenya has been taken for study. The Marareni found to be much better in quality of salt and quantity of production. However the system of ponds at Gongoni and Kurawa receives nutrient rich intake water from tidal mangrove flat and hence there is an excessive biological productivity in the low salinity ponds of the system.This is evident from the results of the water and soil samples collected from these areas and indicated that the bottom of the pond is greenish black with organic material bacteria which is accumulating and decreasing the pond depths .In the case of Marareni local species of Artemia are abundant, therefore the development of red halophylic bacteria in sufficient quantities destroy significant quantities of organic matter in the crystallisers to carbon di oxide and water and therefore the results show that there is quality in salt and results in quantity of salt production. However, this is to be developed in Gongoni and Kurawa salt works. Further the gypsum precipitation and contamination of insolubles and Ca, Mg in these salt works is reasoned. The role of halophylic bacteria in salt crystallization leading to quality and quantity of salt production is discussed. The role of bacteria in gypsum crystallization, like sodium chloride crystallization needs to be explored.

Introduction
The solar evaporation of sea water to produce brine is not only considered to be a physical phenomena but there is also an organic contribution from biological communities within pond from reservoirs to crystallisers . The hyper saline salt water previously thought to be lifeless is now considered to be a dynamic eco system.(Borowitzke 1981) .This organic contribution to evaporation process influences production of salt. (Rahaman et al 1991 and 1993). Thus, the quality and quantity of salt production is strongly influenced by biological factors in salt operations.(Davis, 1980). The biological communities in salt works are beneficial as well as harmful to salt production. The organic impurities as algae agglomeration, may contaminate salt as black due to oxidation and reduce size of crystals and salt quality. (Sorgeloos 1983. Haxby and Takert 1987) The present study was undertaken in Krystalline salt works,Kenya. .

Mombasa is the second largest city in Kenya that sustains tourism, Port related activities etc. It significantly contributes to the national economy on economic activities, one such is solar salt production, . Most of the inhabitants approximately 750,000 use and require iodised salt for their consumption, in addition, iodised salt from Mombasa is also consumed by neighboring countries like Uganda, Tanzania, Rwanda etc. Since iodised salt is considered to be an important

commodity to the health which prevents goiter and also acts as minerals in our diet.

Fundisha salt works was set up in 1930 and later it was sold in 1992 and purchased and now functions as Krystaline salt limited since 2007 which comprises of three salt works located at Marareni, Gongoni and Kurawa .

The biological management of salt works is taken for the present study with the objective to improve the quality and quantity of salt production through biological management . Such management has been receiving much attention in various parts of the world, however in Krystaline salt works a similar biological management of solar salt works has been undertaken. Details pertaining to the hydrobiological factors and maintaining the entire salt works with reference to water quality , pond depth, construction of finger dykes etc were recorded. Care has been taken in the improved management of flow of brine to prevent mixing of brine at different densities due to contour of land site .

Materials and Methods

Krystalline salt limited, is the largest salt works in Kenya catering to the population of 60 percent of population of Kenya and other countries. It is situated at Gongoni, Malindi District, Kenya in the latitude 4° 03' S, Longitude 39° 38' E, in the Indian coast. The meteorological conditions of all salt works were recorded as per conventional methods . The phyto and zoo plankton, macro and micro algae from such ponds were collected and identified. The local Artemia species present at Marareni salt works is improved its population and the cysts were collected and hatched further population keep increased. However, such Artemia species absent at Gongoni and Kurawa salt works. The water samples passing through mangroves were collected and the pyhsico-chemical analysis was done according to standard methods. The in take of water for salt production is always from sea through mangroves and creek and high tides. The water is pumped to reservoir and used for salt production. However, the tidal water flow at Marareni covers mostly barren land and have least contact with mangroves. When compared to the above aspects, Gongoni and Kurawa salt works receives rich amount of organic matter through mangrove forests and water quality is considered rich in nutrients and thereby more algae are grown . However at Marareni salt works the local population of Artemia helps biologically purifies the brine. Therefore, in order to confirm the finding of biological management of salt works, salt samples were collected from these three salt works and were analysed for its chemical composition.

The methods used for present works based on methods described by KEBS, 2002. and also the plankton samples were collected using 40, 100 micron mesh and were identified with help of monographs and publications. The result of the present study is reported.

Results

All salt works have maximum production in the months of January February and March. The production tends to minimum during the last week of April with approach of seasonal rains in the first week of May which will extend up to middle of July.

Table 1.Showing the meteorological conditions of all 3 salt works.

Parameters (Annual Average)	Marereni	Gongoni	Kurawa
Evaporation Rate in mm	8.5	8.0	9.2
Relative Humidity percentage	76	78	72-74
Rainfall (mm)	800	900	740
Wind-speed km/hr	6.4	7.0	5.2
Sunshine – Hr/Day	11.0	11.0	11.0

The water colour is light green in the pump intake but in the reservoir it becomes clear. As the water enters at the end of finger dykes gets disturbed and turbidity slowly increases and the colour of the water becomes yellow, green making slightly turbid and turbidity completely disappears in the crystallizer which turns into light green and olive

green.The temperature of water ranges between 26 to 28° C and salinity of water at pump intake is 3.5° Be and increase in the reservoir to 6.5 ° Be and when it becomes turbid when salinity increases from 7.8 to 8.2° Be .When turbidity increases, salinity also increases to 10.5 to 11.5° Be. At 11.5° Be it turns to olive green. However, in condensers it becomes clear reaching to 12° Be. In the condenser salinity ranges from 14.8 to 25.4° Be and in crystallizers it reaches to 26.5 to 27.5° Be. Bittern is drained at 27.5° Be. However, at pre-crystallizers salinity is maintained besides clarity of brine, however one could observe brine depth, using secchi disc. It is recorded that in the pump house the depth is 14.5" and water is light green in colour whereas in reservoir some depth is maintained until it reaches to the ponds especially in the condensers 11.5" depth is maintained. However, in parallel circuits maximum depth of 16" was recorded. In crystallizers 4 to 6" was maintained and in some ponds brine depth ranges from 3 to 5" at a salinity of 26° Be. With respect to substances present in the pond, floor, filamentous algae such as Rizoclonium found to be dominant and population of snails such as Cerethidium species were recorded. Similarly, in pond with clear water heavy growth of filamentous algae are present, numerous snails are also recorded, however when the brine gets turbid no green filament are found and sometimes calcium carbonate precipitates when excess dissolved organics of substances were noticed. In the condenser pond Artemia were recorded and top layer about 0.1mm and black layer of 5" thickness were also recorded in condensers. In case of crystallizers heavy Dunaliella salina population accumulation in the brine was recorded In Gongoni Salt works on windward corner of pond hopper crystals from 1 to 3 mm conglomerates, which are clear and clean in crystallizer at a depth of 4 inches.

With reference to plankton dinoflagellates, diatoms, numerous bacteria were recorded in low salinities. In higher salinity, blue green algae, few diatoms were recorded. At salinity of 12 ° Be numerious Artemia, almost no particulates, were seen even penetrates into condensers. This is particularly observed in Marereni salt works when Artemia population is found to be highest and uneven in distribution population from low to higher salinity. However, in Marereni condenser ponds Aphanothece halophytica and red halophilic bacteria were recorded abundantly.The faecal pellets of Artemia in condenser ponds 18°Be were observed.. In the case of crystallizer ponds, no such organisms were recorded in any of the pond except in the case of Marereni where red halophilic bacteria were apparent because of water colour.

Table 2. Showing the values of Salt Analysis from three salt works.Each value is an average of twenty samples.

Constituents (on dry basis) Percent by Mass	Marereni	Gongoni	Kurawa
Sodium, Chloride as Nacl-Drybasis	98.8-99	97.8-98.2	98-98.4
Calcium as Ca2+	0.10	0.20	0.18
Magnesium as Mg2+	0.25	0.45	0.38
Sulphate as SO4	0.48	0.64	0.56
Water insolubles	0.08	0.18	0.14
Moisture	5.0	5.6	5.4

Discussion and recommendations

Generally salinas at Krystalline salt at Gongoni and Kurawa receives always nutrient rich water from tidal mangrove forests both by pumping and tidal inflows. However in Marareni water flow is clear from sea due to less mangroove vegetation. In Gongoni and Kurawa the green water carries microscopic and macroscopic organism which contributes to the high concentration of NH4+, NO3, PO4 etc. In low salinity ponds mangrove flats contribute rich nutrients for microorganism to reproduce in high concentrations and thereby reduce excessive quantity of organic substances.

In salt works of Gongoni and Kurawa the biological productivity is high. There are filamentous green algae such as Boodleopsis and Rhizoclonium on pond floor. When

such algae reach at intermediate salinity they die and release combined nitrogen , phosphate and organic substances. These released organic substances act as fertilizer for growth and production of recruitment of new set of algae and plankton.. Because of this excessive concentration of particulate and dissolved substances going to bottom and water becomes greenish with black organic materials settling at bottom with bacteria that accumulates and decreases pond depth. In Marareni such organic contribution is mostly absent because of the even distribution of Artemia population in intermediate ponds.

Red halophilic bacteria which is present in Marareni however do not develop in other two salt fields due to insufficient quantities to destroy organic matter in crystallisers to CO2 and H2O. This results organic matter flows to crystallisers causing small layer hopper crystals which retains water inside the nucleus and Ca, Mg etc and results in increase of impurities of mushy salt. Further, organic content also interferes with growth of gypsum. The musilage produced by Aphanothece halophytica results insoluble complexes of calcium carbonate and sulfates which turns brine to milky color etc. therefore in crystallisers large amount of particulate and dissolved matter enters which results in development of Dunaliella salina making brine pink color. This interferes in the crystal formation and increases contaminants in the produce.

This is clearly seen in the result of salt analysis in Kurawa and Gongoni. However, because of Artemia population and halophilic bacteria present in intermediate ponds and crystallizers, salt quality is better in Marereni, where the viscosity of water gets oxidized making improved quality of salt (Sorgeloos, 1983, Haxby and Takert 1987). It was stated that low viscosity level promote formation of larger crystals and thereby improves the quality of salt. The experimental study of isolation of halophilic bacteria and subjecting the brine with halophilic bacteria have produced white and large crystals and increased salt production (Rahaman, and Jeyalakshmi Personal communication, 2009).

With reference to quality of salt, it is considered that Marereni salt produced is a good quality compared to Gongoni and Kurawa. The sodium chloride content on dry basis ranges between 98.6 % to 99 % in Marereni compared to Kurawa and Gongoni where it is 97.8 % and 97.6 % respectively. With reference to calcium and magnesium it is less in Marereni compared to Kurawa and Gongoni similarly results show that moisture is low in Marereni salt compared to other salt work taken for study.. At Gongoni rate of crystallization is far less, crystal growth is sluggish and mostly needle shape. The same phenomena was observed in Kurawa also. When salt was analyzed, the insoluble content in salt is not only sand but also gypsum. This is confirmed while analyzing the salt, white insoluble mass along with sand particles were observed. Gypsum layer in Gongoni is increasing year by year and not removed. Further bittern drainage is not appreciable from crystallizers which needs improvement where as in Marereni, natural drainage of bittern is available thereby magnesium content is low in harvested salt compared to Gongoni and Kurawa. In Marereni, gypsum is removed and gypsum formation obviously increased in pre-crystallization area because of presence of Artemia. The calcium along with micro algae settles in bottom of ponds as gypsum which also probably provides the substrate for bacterial growh and releases mucilage for hardening the bottom.. It is presumed sodium chloride crystals are formed along with halophilic bacteria which is found at the new place for evaporation of brine quickly leads to oxidation of organic materials thus lowering the viscosity for large size crystal formation which is favoured well in Marereni. However, this concept holds good in case of gypsum as gypsum settles along with fecal matter of Artemia which will favour for production of bacterial growth need to be explored..

REFERENCES

1. Borowitzka, L.J.1981, The microflorn, Hydrobiologia 81:33-46
2. Davis , J.S. 1980 . Experience with Artemia in solar salt works , In: G. Persoone , P. Sorgeloos, D.A. Reels and E.Jaspers (editors) . The brine shrimp Artemia Vol-3, ecology , culturing and use in aquaculture, Universa press, wetteren, 456pp.

3. Haxby R.E. and Tackaert .W, 1987 , workshop report : Role of Artemia in solar salt operations. 291-293

In:Artemia research and its applications .vol 3. sorgeloos, P.: Bengston, D.A.: Decleir W.: Jaspers , E(Eds) , Univer Press , wetteren, Belgium , 556pp

4 . Kenya Bureau of Standards- 2002.

5. Rahaman , A.A. Sosamma-Esso and Ambikadevi M.1991.Hydrobiology of Artemia in solar salt works of Vedaranyam, India In:Lanna Cheng (editor), Proceedings of the international symposium of Biotechnology of salt ponds. The salt research institute, Tianjin, China 283pp.

6. Rahaman, et Al: 1993: Biological management of Indian solar salt works .In: Proc.seventh international symposium on salt , vol 1.Elsevier science publishers , B.V. Amsterdam :633-643

7. Rahaman, Abdul.A, and Jeyalakshmi .R : The role of Halophylic bacteria in salt crystallization – World Salt 2009., China. (Paper submitted).

8. Sorgeloos,P.1983. Brine shrimp Artemia in solar salt works , In :Expensive source of food for variety integrated aquaculture . Washington aquaculture 83.Washington.

9. Sundaresan et al: Biological management of Sambhar lake saltworks (Rajasthan,India), 2006 International Sympsium on Ecology and Salt Works Santorina, Greece.