

Mineralogical composition and microalgae communities of solar salt tumuli from Tuticorin, Southeast coast of India

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The present work deals with the microbial population and mineralogical composition of solar salt pan tumuli (gypsum crust). Tumuli containing multicolor layered microbial communities develop in the crystallizer ponds of commercial salterns. The upper crust is densely populated by orange unicellular cyanobacteria. Below is a layer of green- colored filamentous cyanobacteria. *Bacillariophyta* and *Chlorophyta* groups are also identified microscopically. X-ray powder diffractometer (XRD) patterns and the intensity peaks observed in tumuli indicated the predominance of gypsum, calcite and halite along with other associated minor minerals viz; quartz, chlorite, kaolinite, ilmenite and illite are confirmed by Fourier transform infrared spectroscopy (FTIR). The scanning electron microscopic (SEM) analysis of tumuli was also carried. Associated occurrence of mineralogical composition and microbial communities are highlighted and investigated.

[Keywords: PCR; aromatic hydrocarbons; *Chlorella vulgaris*; Toxicity]

Introduction

A salt pan deposit consists of layered macrocrystalline gypsum deposits showing an equant mosaic fabric of prismatic gypsum. These deposits are formed by subaqueous growth from evaporating brines¹. The gypsum acquires interesting bed form that is curly and layered in crystallizer ponds called tumuli. Primarily gypsum crystallizes as mats along with microbial layers and manifest in the form of tumuli, acquired by gypsum growing laterally into ridged up structures. These crests are frequently broken and are called as teepees². Tumuli composed principally gypsum, calcite, halite and also quartz, chlorite, kaolinite, ilmenite and illite as dominants³ (gypsum crust), are the byproducts of salt pan in large quantities during salt (Halite) production. In the study, mineralogical investigation of tumuli was conducted using X-ray powder diffractometer (XRD) and confirmed by FTIR. XRD results showed that samples

mainly included gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$), calcite (CaCO_3) and halite (NaCl) as predominant compounds. FTIR studies of the salts helped identification of minerals present in the tumuli. The coupled vibrations are appreciable due to availability of various constituents in the sample. The peak obtained due to the vibration of water molecules (H-O-H) and (C=O) in the structure of tumuli⁴.

The microalgae are found in sediments of floors of saltpan filled with NaCl-saturated brine⁵. The upper orange-brown layered crust is densely occupied by unicellular cyanobacteria, and the bottom by green-colored layer composed of filamentous cyanobacteria. In microbial communities, the cyanobacteria are the major organism of solar saltpans, salt flats and hypersaline environment^{6, 7}. Many of these cyanobacteria can also grow at higher salinities of 200g l⁻¹ and higher^{8,9}.

Microscopical examination indicated the predominance of cyanophyta group from solar saltern tumuli followed by *Bacillariophyta* and *Chlorophyta*. These microorganisms are playing an important role in the saturation of salt. Some of these mats lead to the formation of microbialites, which are microbes induced mineral precipitations such as gypsum, calcite and halite^{10, 11, 12, 13, 14}. In this study, we investigated the microbial communities and mineralogical composition of solar salt tumuli in Tuticorin salt pans, for microscopical examination, differently colored layered tumuli were collected and analyzed. The mineralogical compositions were analyzed by XRD, FTIR and SEM.

Material and Methods

Samples of tumuli (gypsum crust) were collected from a solar saltern, located at Tuticorin (Lat. 8°45' N and Long. 78°13' E), Tamil Nadu, Southeast coast of India (Figure 1). Tuticorin is the second largest solar salt producing area in India. It is also known for its fishing and harbor activities. This area is mainly used for sea-salt production. The salt is produced throughout the year except winter season. The salinity gradient is 0–11°Be (Degree of Baume unit) in the rainy season and gradually increases in the salt-producing season up to 30°Be.

The wet tumuli were collected from shallow water of crystallizer ponds of saltpan. Half of the

collected sample was preserved in 5% formaldehyde for microbial examination and the remaining was stored in dry polyethylene bag for mineralogical investigation. The microbial populations were observed under optical microscope (Olympus BX51) with various magnifications (5, 10, 40 and 100x). The morphological identification of microbial communities was carried out^{15, 16, 17, 18, 19, 20}.

Five gm of dried and powdered sample was used for the mineralogical determination by using FTIR, XRD and SEM. The Perkin Elmer FTIR spectrometer was used for mineralogical identification of tumuli²¹ based on standard KBr pressed-disc technique. The XRD pattern tumuli were obtained from powder X-ray diffractometer to analyze the minerals; scanning electron microscopic (SEM) images of tumuli were used for learning the mineralogical phases and their morphology.

Result and Discussion

In order to investigate the influence of gypsum crust and mineralogy on the genesis of tumuli, data derived from SEM microphotographs, X-ray diffraction and FTIR were employed. Figure 2 shows the SEM micrographs of natural tumuli showed well-defined crystalline structure of needle shaped crystals. XRD is used to determine the qualitative and quantitative mineralogical composition of multiphase tumuli mixtures.

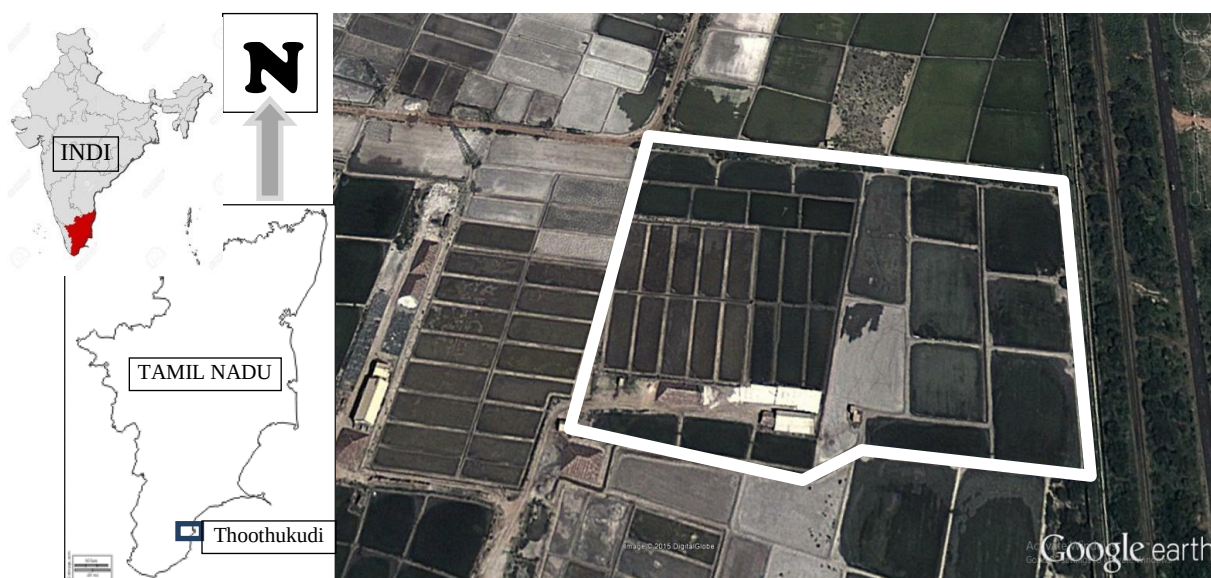


Figure 1. Location of tumuli sampled from a solar evaporated salt pan, Tuticorin, Tamil Nadu.

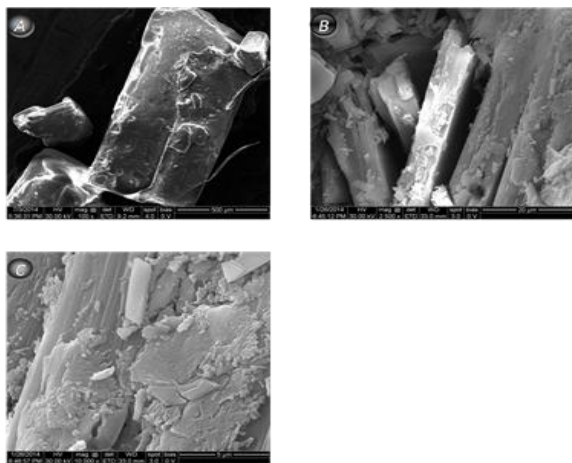


Figure 2. SEM microphotographs of Tumuli crust
A. A single needle structure of salt tumuli
B. Gypsum crust of tumulus
C. Mass of gypsum and halite microcrystals in tumulus layer

XRD patterns and the intensity peaks observed in tumuli indicated the predominance of gypsum, calcite and halite along with other associated minor minerals viz, quartz, chlorite, kaolinite, illite, ilmenite, aragonite and sylvite²². The XRD pattern shows (Figure 3) that the dominant minerals of tumuli are gypsum with 2 θ peaks at 20.90, 28.19 and 47.93; halite is at 27.33, 45.49, 56.53; calcite is inferred at 12.08. The FTIR spectrum of tumuli is shown in figure 4. The FTIR were recorded in the transmittance mode. It was observed that the frequencies at 1631 cm⁻¹, 1685 cm⁻¹ and 3854 cm⁻¹ are assigned to H–O–H stretching vibration^{20, 21}. The peak observed at 2360 cm⁻¹ and 752 cm⁻¹ are assigned to C–O stretching vibration of tumuli.

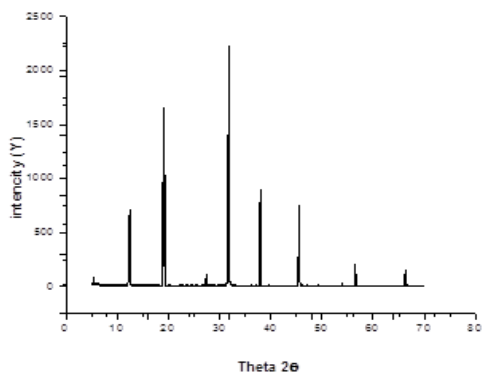


Figure 3 Shows the XRD pattern of tumuli

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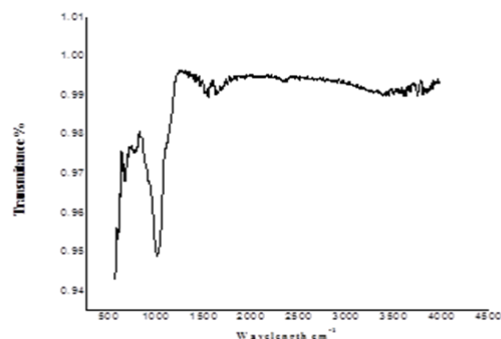


Figure 4 Shows the FTIR pattern of tumuli

Gypsum crusts called tumuli containing multicolored, microbial communities develop in the evaporation and crystallizer ponds. The benthic microbial mats play a significant role in salt production. Increased solar absorption initiated by the pigmentation of microalgal communities raise temperatures and in turn improves evaporation.

In addition, the microbial mats sequester minerals and accumulate organic matters from the overlying brine to control/ prevent the brine leakage^{4, 23, 24}.

Excessive development of cyanobacterial communities interferes with the production of good quality salt in the crystallizer ponds. Cyanobacteria communities form the greatest part of the biovolume of brown and green layer of tumuli. The layers sustain the life of different types of microalgae like²⁵, Cyanophyta, Bacillariophyta and Chlorophyta. The tumuli mat appearing in green, red and yellow color, are reflections of different kinds of microbial communities. The yellow colored layer is of unicellular cyanobacteria; red color is by filamentous cyanobacteria (Phormidium) and green is by photosynthetic sulphur bacteria³⁸. The surface of the mat contains unicellular colonies of Lyngbya sp. In the photosynthetic tumuli crust, the cyanobacterial communities are the dominant group of microalgae. Concentration of dissolved oxygen in solar salt pan which increases the bloom of cyanobacteria help deposits the salt precipitation on the floor of pan. Many of the cyanobacterial species grown in higher salinities also adapted to hyper saline environments (>200 g/L) overlying NaCl saturated brine sediment mats²⁷. Cyanophyta is the major group of gypsum crust with the brown and green layers dominated by filamentous cyanobacteria and unicellular cyanobacteria. While the green layer is dominated most of these belong to the Phormidium and

Spirulina species. Other groups of organisms found in tumuli are Bacillariophyta and Chlorophyta. Nitzschia sp., Diatoma sp. are dominant species of Bacillariophyta. Chlorella sp is of chlorophyta. In overall, microalgae community of solar salt tumuli are Oscillatoria sp, Spirulina sp, Lyngbya sp, Phormidium sp., Aphanoceps sp., Synechococcus sp., Chroococcus sp., Synechocystis sp. and Anabaena sp. (Cyanophyta) followed by Nitzschia sp., Navicula sp., Amphora sp., Diatoma sp., Pleurosigma sp., (Bacillariophyta) and Chlorella sp., Chlorococcum sp., Dunaliella sp., (Chlorophyta). In this observation, it is found that Cyanophyta was the dominant group over Bacillariophyta and Chlorophyta (Figure 5). Tumuli are about 2 cm thick salt pan byproduct layers consisting of microorganism laden salt pan minerals. Microorganisms render color to tumuli and are visible in yellow, green and red layers and are due to unicellular and filamentous Cyanobacteria, Bacillariophyta and Chlorophyta respectively.

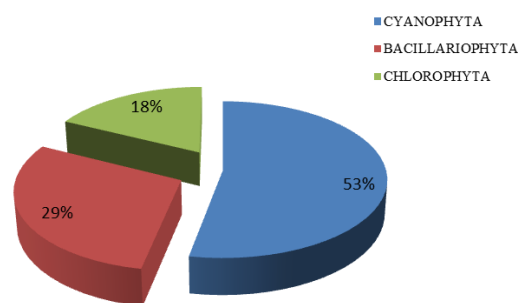


Figure 5. Microalgae diversity of tumuli

Conclusion

XRD, FTIR and SEM studies indicate the presence of mineralogical sequence of tumuli in the order of gypsum, calcite and halite along with other associated minor minerals viz., quartz, chlorite, kaolinite, illite, ilmenite, aragonite and sylvite. Furthermore, there is a difference between the mineral precipitations in the bottom of brine from crystallizer ponds of solar salt pans. Microbial organisms are also involved in the precipitation and formation of tumuli. Cyanobacteria are the predominant group of salt pans and it is deposited layer by layer along with tumuli. There is difference between the kinds of organisms in in-situ and greenhouse-maintained pan mats. Microalgae communities are widely distributed in the mat floor of salt pan in different time and depth condition.

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