Geology, Microecological Environment and Conservation of Lonar Lake, Maharashtra, India

Dr. Shaikh Md. Babar
Department of Geology, Dnyanopasak College, Parbhani-431401 (M.S.) India

1. Introduction

The Lonar Crater is almost circular depression in the ~65 Ma old basalt flows of the Deccan Traps. Lonar lake (19°58' N; 76°31' E) in Buldhana district, Maharashtra, India is a circular lake (Fig. 1) occupied by saline water. The crater is 150 meters in depth and is absolutely confined from all sides by the walls of the crater and there is not a single channel of water draining away from it, thereby leaving the lake waters stagnant for thousands of years, a large portion of the lake is rather shallow, preserving about 2 meters of water during the monsoon months. Lonar is the third largest natural salt-water lake in the world, with a diameter of 1800 meter. Fredrickson, et al (1973) found that, about 50000 year back a massive meteor entered into the Earth's gravitational forces ranging 60 meter long and weighing 2 million ton. It was racing at a speed of 25 kms per second towards the planet earth. When it struck the earth the energy released was equivalent to that released by six-megaton atom bombs. The impact was so severe that rocks from all sides came on the surface and reached the height of 20 meters.

2. Origin of Lonar lake

The Lonar crater has attracted the attention of world geologists for investigation of its origin and the source of salinity of lake water. Blandford (1868) and Medlicott & Blandford (1879) have suggested the views about the origin of the Lonar, according to them the crater is formed by some phase of volcanic activity. But the work of Beals et al (1960), Arogyaswamy (1962), the evidence of glassy objects near the Lonar crater (Nayak 1972), impact affected minerals maskelynite (diaplectic plagioclase glass) by Venkatesh (1967), Fredrickson et al (1973), Fudalay et al (1980), Nayak (1993), Poornachandra Rao and Bhalla (1999) and Haggerty and Newsom (2001) suggested that the Lonar crater was formed by the impact of a meteorite.

The formation of impact craters is a complex process and depending on the material properties of the target and projectile, parameters of impact, atmospheric effects and on gravity (dePater & Lissauer, 2001; Holsapple, 1993; Melosh, 1989 and Norton, 2002). Simplistically, crater depth and diameter are functions of the energy of impact and the strength of the target material (O'keefe & Ahrens, 1994, Chai, and Eckstrand 1994 and Walsh et al, 2003). For the same energy of impact, the greater the height of the ejecta, smaller is the

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depth of the crater since a significant fraction of the impact energy goes into the generation of the ejecta (Walsh et al, 2003). The time of excavation of material from the crater may last for several minutes following the impact, while the amount of impact melt produced is dependent on the abundance of water in the target rocks (Melosh, 1989). Target material below the excavation depth is pushed downwards, whereas the strata above this depth may be pushed upwards (dePater & Lissauer, 2001) as seen in the Lonar crater.

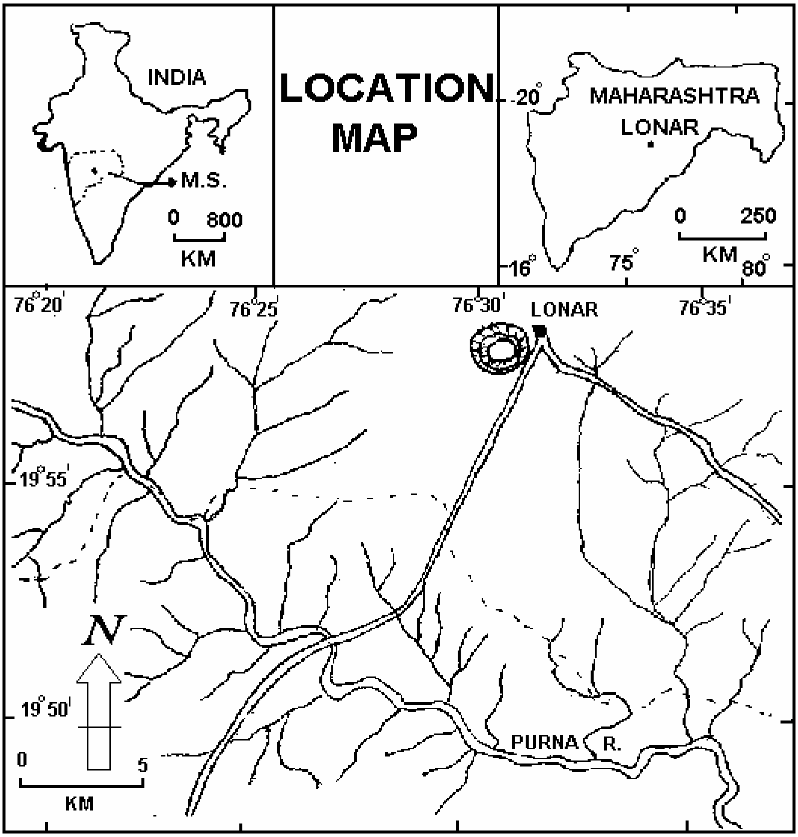

Fig. 1. Location map of Lonar lake.

3. Geology

Geologically, the area belongs to Deccan Basalts of late Cretaceous to early Eocene period (Fig.2). The rocks observed in the lake are compact, vesicular and amygdaloidal basalt. At places the red bole beds separated the two lava flows. The basalt flows dip away from the depression. No appreciable fracturing or shattering is noticeable in the rocks. Compact basalt rocks are highly jointed and weathered around the joints (Fig. 3). The compact basalt also shows the spheroidal weathering in the area.

The Lonar crater has attracted the attention of world geologists and environmentalist for investigation of its origin, biodiversity and the source of salinity of lake water. Regarding the

origin of the Lonar crater, some believed that, it might have been formed by some phase of volcanic activity, but the the evidence of glassy objects near the Lonar crater suggested that the Lonar crater was formed by the impact of a meteorite. The impact origin of the Lonar Crater has been well established based on the evidence of shock-metamorphosed material. Coarse breccias with shatter cones and maskelynite-bearing microbreccia have been reported in drill core samples from the crater floor indicating the impact origin of the crater (Fredrickson et al, 1973). Glassy objects of varying sizes, up to 50 mm in diameter and resembling impact melts, have been recovered from the surrounding ejecta blanket (Nayak 1972).
Thermoluminescence dating of selected impact spherule/melt samples suggests that this crater was possibly formed ~52± 6 kyr ago (Sengupta et al, 1997). The crater is 1830 m in diameter and a shallow saline lake, ~7 m deep (Nandi & Deo, 1961), occupies the crater floor. A 20 m high raised rim around the lake (Fredrickson et al, 1973 and Nayak 1972) formed by both the uplift of the target layers as well as deposition of impact breccias. Coarse as well as microbreccia have been recovered in drill cores from depths of ~350 m beneath the floor of the lake (Fredrickson et al, 1973). A smaller circular depression called Little Lonar, 300 m in diameter and located about 700 m north of the main crater, has been suggested to be a second impact crater. The Little Lonar is thought to have formed either by impact of the throw out from the main crater or by direct impact of a smaller fragment of the main bolides (Fredrickson et al, 1973 and Master et al 1999).

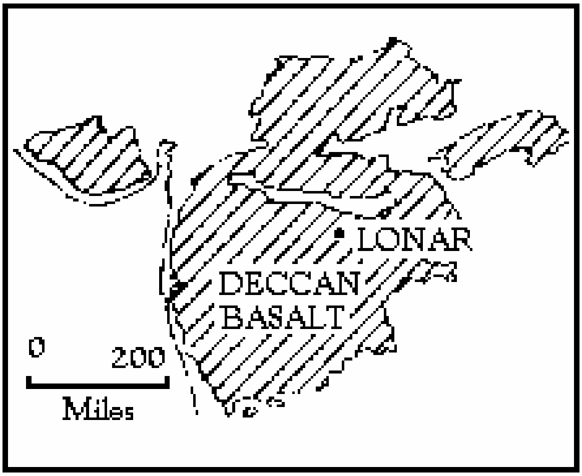

Fig. 2. Geological Map of Deccan volcanic Province

The maximum thickness of the Deccan traps in the Lonar crater region is estimated to be between 400 and 700 m (Subbarao, 1999 and Subbarao et al, 1994). In this region, there are six lava flows, ~8-40 m thick, exposed in and around the Lonar crater, of which the lower four flows are exposed along the crater wall (Ghosh & Bhaduri, 2003). The flows are separated from each other by marker horizons such as thin paleosols, chilled margins, and vugs with secondary mineralization (Ghosh & Bhaduri, 2003). Individual flows are often difficult to characterize because of vegetation and surface weathering features. The lava flows in the Lonar crater margin are upturned and dip away from the crater edge at inclinations of 14° to 27° (Fredrickson et al, 1973 and Fond & Dietz, 1964). Fresh, dense basalts are exposed only in the upper 50 m of the crater wall below which the flows are weathered and friable (Fudali et al, 1980). The impact melts occur within the ejecta blanket (Fig. 4) found around the Lonar crater, which are seen to extend up to 1600 m from the crater rim (Ghosh & Bhaduri, 2003). The ejecta consist of two contrasting types of debris. The bulk of the ejecta is crudely stratified and shows no evidence of shock. The other types of debris in which clasts from different bedrocks are mixed show the evidence of varying degrees of shock (Fredrickson et al, 1973). These two units of the ejecta are similar to the so-called 'throughout' and 'fallout' units as identified in other simple craters (Shoemaker, 1963).

Fig. 3. Jointed compact basalt exposed in the rim of the Lonar crater at the spring.

The gravity and magnetic anomalies of Lonar lake suggests that the impact has modified the magnetization vector and density of the country rock (Deccan trap) up to about 500–600 m below the surface with a brecciated part of about 135 m of bulk density of 2.60 g/cm3 and fragmented layer of about 150 m of bulk density 2.7 g/cm3 with induced magnetization. This is explained through the 3D view of affected part of Deccan trap due to impact computed from gravity anomaly of the Lonar lake (Fig. 5). The google image of the lake is given Fig. 6.

4. Materials and methods

For the present paper water samples were collected from five different sampling stations in airtight and opaque polythene container. From these five samples four samples (A to D) are located in the reservoir and one sample station (E) is the fresh water from influent spring called Dhara (Fig. 7). Water samples were analysed for physico-chemical parameters such as dissolved oxygen (DO), turbidity, pH, Chlorides (Cl), total hardness (TH), total dissolved Solids (TDS), Ca, Mg, Na, K, CO_3, HCO_3, SO_4, BOD and COD (Table 1). DO and pH were measured in the field with necessary precautions. Remaining parameters were analysed by following the methods given by APHA (1989). Microbial examinations were carried out using the standard procedures given by (APHA 1989 and Trivedy & Goel 1986) and the results were compared with maximum permissible limits of BIS (1991).

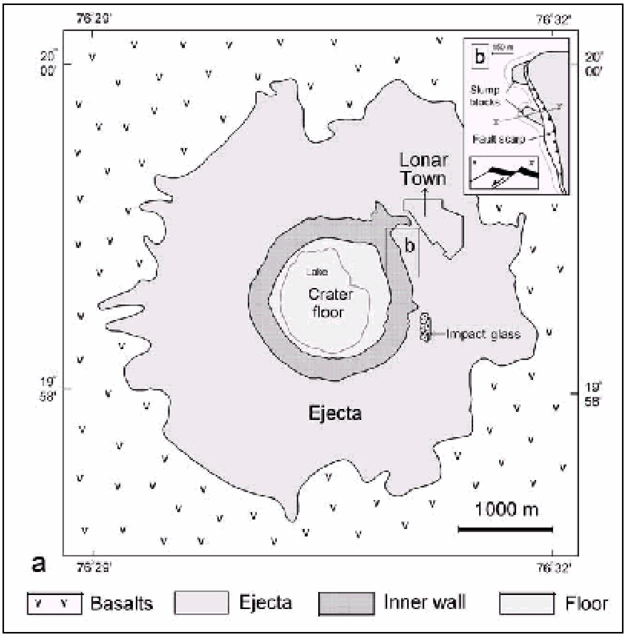

Fig. 4. (a) Geological sketch map of ejecta at Lonar crater (After Ghosh & Bhaduri, 2003 and Senthil Kumar, 2005). A massive basalt flow is well exposed on the upper crater wall, and the underlying flows are covered by basalt debris, soil, and vegetation. Impact melt fragments and spherules are found in the clayey alteration products of the ejecta materials, and one such occurrence is shown in the map. (b) A sketch map of normal faulting in the north-eastern part of the inner wall.

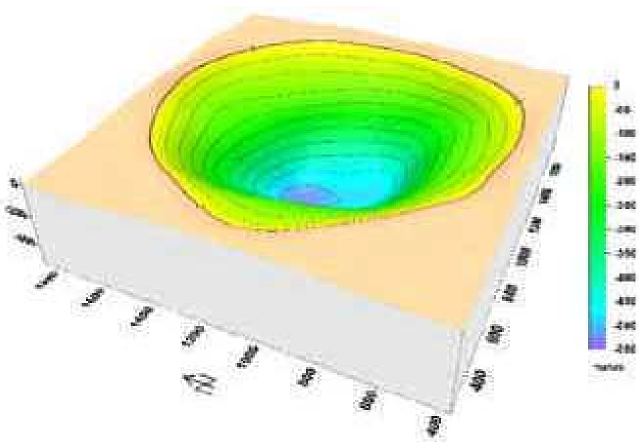

Fig. 5. A 3D view of affected part of Deccan trap due to impact computed from gravity anomaly. It suggests a maximum depth of 500 m of affected part due to impact (After Rajasekhar & Mishra, 2005).

Methods of sampling of microorganisms

1. **Sample Collection**

Algal blooms and water samples were collected in and around four different spot in the Lonar Lake.

2. **Culture media used**

The media employed for isolation of *Spirulina sp*. in Zarrouk media with pH 10.5

Zarrouk medium (Table 1)

Composition	g/l	Composition	g/l
$NaHCO_3$	16.8	$CaCl_2$	0.04
K_2HPO_4	0.5	$FeSO_4.7H_2O$	0.01
$NaNO_3$	2.5	EDTA	0.08
K_2SO_4	1.0	*Solution A5	1 ml
NaCl	1.0	*Solution B6	1 ml
$MgSO_4.7H_2O$	0.2	_ _	_ _
*Solution A5			
H_3BO_3	2.86	$CuSO_4.5H_2O$	0.079
$MnCl_2.4H_2O$	1.81	MoO_3	0.015
$ZnSO_4.7H_2O$	0.222	_ _	_ _
*Solution B6			
NH_4VO_3	22.96	$Na_2WO_4.2H_2O$	17.94
$KCr(SO_4)_4$ $12H_2O$	192.0	$TiOSO_4H_2SO_4.8H_2O$	61.6
$NiSO_4.6H_2O$	44.8	CO $(NO_3).6H_2O$	43.98

Table 1. Composition in g/l of cultural media used for analysis.

Fig. 6. The Google image of the lake

Fig. 7. View of Lonar Lake with Location of water sample sites (Lake water A-D and spring (Dhara) water E).

3. **Enrichment of samples**

The water samples are labeled as A, B, C and D and are enriched with both media in 500 ml flasks containing 250 ml media. The flasks were inoculated at room temperature 25° ± 2° C with continuous illumination of 1500 lux provided with white fluorescent lamps for two weeks.

4. **Isolation**

After second enrichment the 5% inoculum size was spread on solid media containing 2% agar. The plates were incubated at room temp 25°C with continuous illumination of 1500 lux provided with white fluorescent lamp. This procedure is repeated thrice to bring unialgal culture and can be obtained using single cell isolation. The flasks were hand shaken twice daily. The isolates were chosen according to difference in their morphological nature with in microscopic view.

5. **Pure Culture and Maintenance of Lonar Isolates**

Pure cultures are obtained using Single Cell Isolation Technique. Cultures were routinely maintained in sterilizing cotton plugged conical flasks in a culture room maintained at 25°C and illuminated under a fluorescent light intensity weekly to fresh media to keep the algae in logarithmic growth phase for use in the experiments.

Studies on Lonar lake water and distilled water with addition of N, P, K and rock-phosphate in growth medium on *Spirulina* isolates

The water collected from Lonar lake and water sterilized by autoclaving at 15 lbs for 20 min. Media with various combination of Lonar water, distilled water, N, P, K and rock-phosphate were prepared and sterilized by autoclaving at 15 lbs for 20 min. Five percent inoculum of *S. fusiformis* and *S. patensis* were inoculated into 500ml sterilized autoclavable PVC Conical flasks containing 250 ml media and grown at room temp at 25°C with illuminating under a fluorescent light intensity of 1500 lux for 14 hrs / day . Flasks were hand shaken twice daily. The pH of media is same i.e. 10.5 adjusted. The all media are in duplicate. Growth was followed at 3 days intervals by measuring the optical density at 640 nm. Every time 50 ml of culture was removed from the each media and used for analysis of pigments and growth study.

5. Hydrochemistry

The physicochemical parameters of lake water samples analyzed includes pH, Chlorides (Cl), total hardness, total dissolved Solids, Ca, Mg, Na, K, CO_3, HCO_3, SO_4, etc. (Table 2). The comparative values of these parameters from earlier researchers are given in Table 3.

The most striking feature of the lake water is its extreme salinity and high alkalinity. The pH reaches the mark over 10.5 when tested with a portable pH meter. The pH was in the range of 10.5 to 11.2 for lake water and 7.9 for the influent spring water samples. The higher values of pH may be due to the increased primary production in aquatic ecosystem of lake (Zafar, 1996 and Mohd. Mussaddiq et al, 2001) and also the high rate of photosynthetic activity will raise the pH (Parkins 1967). Dissolved oxygen (DO) ranged from 0.03 to 0.09 mg/l indicating the anaerobic conditions in the lake water. Low rate of primary production in aquatic ecosystem of lake is also indicated by the low values of BOD and COD that ranged from 0.2 to 0.7 mg/l and 0.01 to 0.04 mg/l respectively. The perennial nature of the lake may be due to this high alkalinity, so that, as evaporation proceeds, the concentration of the dissolved alkaline matter is increased and, in due course, the evaporates begin to separate out, which gradually form a more or less continuous scum over the surface of water, thereby considerably retarding the rate of subsequent evaporation.
As regards Total Dissolved Solids (TDS), the BIS (1991) maximum permissible limit is 1500 mg/lit for drinking water. The values of TDS in the Lonar lake water ranged from 13240 mg/lit to 16280 mg/l (Table 2), which are very high and well above the maximum permissible limit of BIS (1991) and (WHO 1992). The salinity of the water ranged from 8760 to 10540mg/l indicating that the water is highly brackish.

Sr. No.	**Parameters**	**BIS (1991) maximum permissib le limits**	**Sample No. A**	**Sample No. B**	**Sample No. C**	**Sample No. D**	**Sample No. E**
1	pH	6.5 – 9.2	10.2	11.2	10.5	10.5	7.2
2	Conductivity μS/cm	- -	18545	20520	19650	18960	780
3	TDS mg/l	1500	13240	16280	14612	14205	421
4	DO mg/l	- -	0.03	0.09	0.06	0.05	0.02
5	BOD mg/l	- -	0.2	0.7	0.3	0.3	0.1
6	COD mg/l	- -	0.01	0.02	0.04	0.03	0.01
7	Alkalinity mg/l	200	4112	4736	4390	4260	370
8	Salinity mg/l	- -	8760	10540	9970	9630	125
9	Chloride mg/l	1000	4883	5630	5150	4970	60
10	Ca mg/l	200	1365	1649	1510	1470	32
11	Mg mg/l	100	654	924	780	725	36
12	SO_4 mg/l	400	154	185	172	167	19
13	NO_2 mg/l	45	10	18	13	12	05

Table 2. Physico-chemical parameters of Lonar Lake water samples.

The Chloride concentration in the lake varies from 4883 to 5630 mg/lit which is well above the possible limit of 250mg /lit as given by BIS (1991). This means that the water is polluted due to organic matter and the other waste in the water. Total Alkalinity is the measure of the capacity of water to neutralize a strong acid. The alkalinity in water is generally imparted by the salts of carbonates, bicarbonates, phosphates, nitrates, together with hydroxyl ions in free state. Alkalinity less than 250 mg/lit is desirable for domestic purpose. Alkalinity values of lake water at different sampling stations (i.e. 4112 to 4736 mg/lit, Table 2) are

much greater; from this it can be inferred that the lake water is highly alkaline and it is ascribed to an interaction between sodium chloride, calcium carbonate and water stagnate over a long period of time (Malu 1999, Malu et al, 1998 and Mohd. Musaddiq et al 2001). The values of Ca (1365 to 1649 mg/lit) and Mg (654 to 924 mg/lit) are found to be very high. Hence the water is very hard and not free from pollutants in it. As the lake water is characterized by very high concentration of chlorides, calcium and magnesium so the total hardness of any water is dependent on these factors (Jain et al 1997).
Natural water contains higher levels of sulphate contributed from the rock weathering. In addition to this domestic waste, sewage and industrial effluents also add sulphate to aquatic ecosystem there by increasing organic pollution. The sulphate content in the present area is less i.e. 154 to 185 mg/lit in the lake water sample and very less in the spring water i.e. 19 mg/lit (Table 2). The nitrate content of the lake water is also low (10-18 mg/lit) as compared to the value of nitrate of spring water i.e. 5 mg/lit (Table 2).

Parameters	After Chaudhary and Handa, 1978				After Muley and Babar, 1998			
	Lake water	Dhara spring water	Sitanahani spring water	Ramgaya spring water	Lake water	Dhara spring water	Sitanahani spring water	Ramgaya spring water
pH	9.8	7.2	7.3	7.5	10.7	7.6	7.4	8.1
TDS	16170	1200	382	543	15890	986	401	497
CO2	2547	- -	- -	- -	2873	4	12	7
HCO3	1876	345	358	365	1629	97	312	377
Cl	5505	460	12	41	6123	183	25	53
SO4	129	67	4.8	14	1.38	23	3.9	8
NO3	6.1	409	13	82	7.3	138	41	63
Ca	8.9	125	33	45	10.7	73	21	34
Mg	13	97	36	43	14	59	32	41
Na	6252	92	47	75	7324	61	21	39
K	15	3.6	0.7	1.7	17	2.3	1.2	1.9

Table 3. Comparative values of physico-chemical parameters of lake water (After Chaudhary and Handa, 1978 and Muley and Babar, 1998)
All concentrations in ppm except pH

6. Microecological environment

In the present study the species of bacteria related to water borne diseases were also found in higher proportion indicating the non-potable nature of the lake water but the spring water is normal and free from bacteria. Microorganisms like *Arthospir*a and other micro algae are predominant as primary producer are present along with alkaline bacteria and fungi. Studies on the specialized micro-ecology revealed greater cognizance of these microbial forms in environmental, healthcare and industrial biotechnology. In the present investigation to understand in depth microechological status of such extreme alkaline environment presence of various types of microorganisms were recorded including Bacteria viz. *E. coli, S. aureus, Streptococcus sp., V. cholerae, V. haemolyticus, Bascillus sp. Klebesiella Sp., Ps. Aeruginosa, Methanococcus Sp.* and *azatobacter,* Algae i.e.*spirulina, clasterium, Blue green Algea (Cyanobacteria)* and *chlorella* and Fungi viz. *A. niger and Fusarium Sp.* Algal blooms and water sample were collected from the four selected sites in the lake and a spring water sample. Samples were enriched by using Zarrouk medium with adjusting the pH of the medium to 10.5 for isolation of alkaline *spirulina* sp. Three different unialgal culture were obtained using a single cell isolation technique and their morphological nature within microscopic view studied and revealed are: i) *Spirulina platensis* (*Nordst.) Gomont,* ii) *Spirulina subsalsa Oersted and* iii) *Spirulina major kutz. Ex. Gomont.* Occurrence of few species of algae and fungi indicate the characteristic nature of bioflora, which needs the further investigations and interpretation.

The composition of the Lonar water is of the $Na_2CO_3HCO_3Cl$ type. Regarding the origin of salinity and alkalinity of Lonar lake water it is argued that the evaporation of the lake water in the absence of the drain was responsible for the alkalify of the lake waters (Blandford, 1868). Lake Alkalinity is also due the conversion of sulphate ion to carbonate through the intermediate formation of 32 sulphide. All these characteristics of lake resulted into an extreme alkaline ecosystem with all different microbial type prevailing in and around the lake. Microorganisms like *Arthospir*a and other micro algae are predominant as primary producer are present along with alkaline bacteria and fungi. The results of microbiological analysis are given in Table 4.

Three different unialgal culture were obtained using a single cell isolation technique (Hoshow and Rosowski, 1975) their morphological nature within microscopic view studied and revealed:

1. *Spirulina platensis* (*Nordst.) Gomont*, as blue green spirals are more or less regularly coiled showing constricted cross walls with spiral and trichome breadth 57.12 and 8.92 respectively having spiral distance of 18.75 in microns,

2.*Spirulina subsalsa* *Oersted* a blue green spiral are regularly coiled or some times loosely coiled showing no constricted cross wall with spiral and trichome breadth 2.15 and 3.22 respectively and spiral distance of 5.35 in microns and

3. *Spirulina major* *kutz. Ex. Gomont* a blue green regularly spiraled coiled no constricted cross walls with spiral and trichome breadth 3.57 and 1.43 respectively and spiral distance of 3.57 in microns.

These isolate possess variations in their morphological characteristics as shown below (Fig. 8, plate 1, 2 and 3). Thus these organisms appear to be capable of adaptation to very extreme habitat and colonize in these type environments predominantly in which life for other microorganism is, if not impossible, but very difficult. Similar investigations showed the population of alkalophilic *S.platensis* of certain alkalophilic lakes in Africa and *S. maxima* of Lake Texcoco in Mexico In some of these lakes *Spirulina* groups as a quasimonoculture. In these African lakes in the Chad region (Iltis, 1971) has conducted an extensive survey of the phytoplankton of alkaline lakes. Species of *Spirulina* have been reported for instance from tropical waters to North Sea, thermal springs (Anagnostidis and Golubic 1966), salt ponds (Golubic, 1980).

Lonar Lake is a hyper saline environment due to presence of higher concentrations of various salts in lake water (Chuodhary and Handa, 1978; Badve et al. 1993 and Muley and Baber, 1998). The characterized salt concentration could be major reason of predominant population of cynobacteria such as *Oscillatoria*, *Synechocystis, Anabaenopsis* and *Spirulina* in the lake. It is confirmed that the cynobacterial population is regulated by the concentration of salt and become monospecific (Iltis, 1968; 1969). Hence, population of *Spirulina* is considerably more in Lonar water body representing the optimal concentrations of salts and alkalinity. An analogous situation appears to exist in the alkaline lakes of the Rift Valley in

East Afr*ica.* These lakes too are also characterized by very high pH values close to 11, and high salt concentration, particularly sodium carbonates originating from the sedimentary volcanic deposits as in Lonar Lake.

Sr. No.	Name of Microorganisms	Sample No. A	Sample No. B	Sample No. C	Sample No. D	Sample No. E
Bacteria						
1	E. coli	+	+	+	+	—
2	*S. aureus*	+	+	+	+	—
3	*Streptococcus sp.*	+	+	+	+	—
4	*V. cholerae*	+	+	+	+	—
5	*V. haemolyticus*	+	+	+	+	—
6	*Bascillus sp.*	+	+	+	+	—
7	*Klebesiella Sp.*	+	+	+	+	—
8	*Ps. Aeruginosa*	+	+	+	+	—
9	*Methanococcus Sp.*	+	+	+	+	—
Fungi						
1	A. niger	+	+	+	+	—
2	*Fusarium Sp.*	+	+	+	+	—
Algae						
1	*Chlorella Sp.*	+	+	+	+	—
2	*Clasterium*			+		—
3	*Blue green Algea (Cyanobacteria)*	+	+	+	+	—
4	*spirulina sp.*	+	+	+	+	—

+ Present, — Absent

Table 3. Microbial (bacterial), algal and fungal diversity of Lonar Lake water.

In some of the lakes, such as Nakuru, Elenenteia and the Crater Lake in which pH range from 9.4 to 11 *Spirulina platensis* and *S platensis var. minor* are predominant microorganisms present (Jenkin, 1936 Blum, 1976 and Anusuyadevi et al, 1981). Therefore, in such lakes cyanobacteria would represent more than half of the phytoplankton population. The correlation existing between salt concentration and abundance of *Spirulina* was confirmed in study on groups of lakes characterized by a salt concentration of 5 to 14 g/l (Iltis, 1971). In addition in such lakes wide fluctuations noted in the relative abundance of *S.platensis* depends on the seasonal changes during the year. Two crater lakes in Ethiopia, Lake Kilotes and Aranguadi bears micro ecological similarity with Lonar lake as both characterized by a high salt content and an alkaline pH, support a dense population of *Spirulina* (Tallings, 1973). Lake Arangudi is more similar in characteristics with Lonar lake as alkaline pH ranging near to 10.3 to 10.5 and predominance of *S. platensis* resulting in waters appears deep green. There appearance of high concentrations *Spirulina*, which is an indicator of extremely high photosynthetic, rates showing 1.2 to 2.4 g of oxygen produced/sq. meter/h.

In view to assess the possible biogeochemical effect of Lonar lake water exerted on cyanobacteria and ultimately on micro ecology of lake more investigations were carried out with growth medium using Lonar water as solvent in various eleven combination with different concentrations of N.P.K. and Rock phosphates (g/l) on the same microorganism i.e. *Spirulina* Comparative analysis involving the growth and development of Caretenoids, Phycobiliproteins , Total chlorophylls in Lonar *S. platensis* isolate and indigenous *S. fusiformis* isolate as a counterparts were conducted. Addition of rock phosphate with Lonar water used culture media showed beneficial effect on growth rate *S. platensis* and *S. fusiformis.* When results were interpreted in terms of Lonar water used combination interestingly, *S. platensis* showed advantageous effect on productivity of total chlorophyll, caretenoids and phycobiliproteins (phycocynin, allophycocynin and phycoerythrin) while indigenous *S. Fusiformis* could show highest productivity with use of distilled water in combination. Results indicates that Lonar crater's distinguished geochemical status sustains different cynobacterial and phytoplankton population altogether.

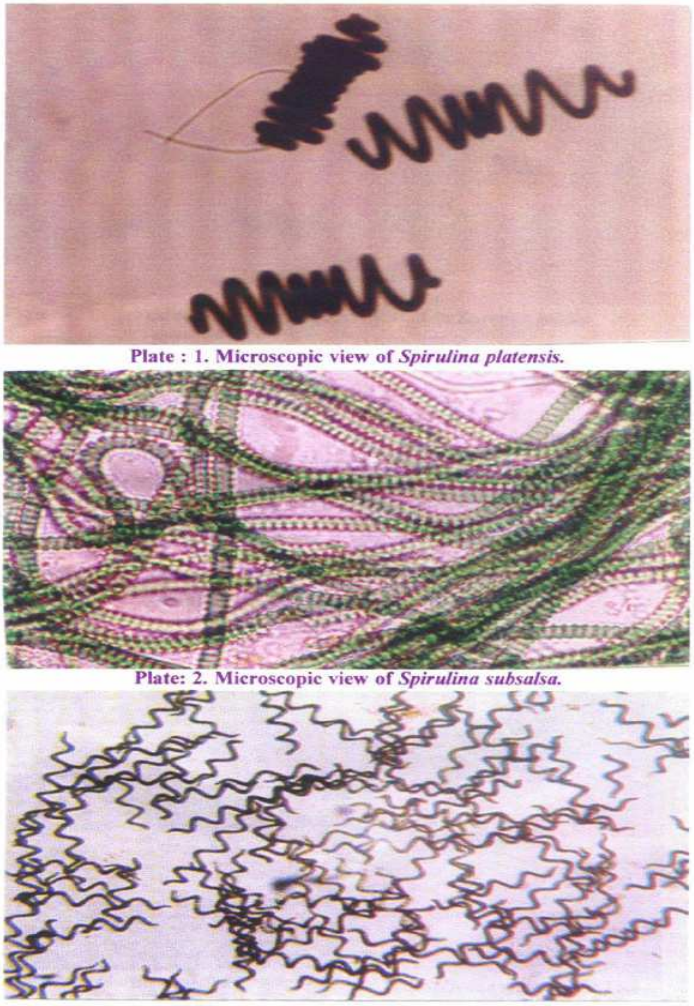

Plate : 1. Microscopic view of *Spirulina platensis.*

Plate: 2. Microscopic view of *Spirulina subsalsa.*

Plate: 3. Microscopic view of *Spirulina fusiformis.*

Fig. 8. Plate 1 – Microscopic view of *Spirulina platensis,* Plate 2 – Microscopic view of *Spirulina subsalsa* and Plate 3 – Microscopic view of *Spirulina fusiformis*

7. Conservation of Lonar lake

The most striking feature of the crater-lake is the high concentration of salts like sodium chlorides, carbonates, bicarbonates and fluorides, which come from the small streams joining the crater. As the water does not drain away these substances get collected beneath the surface. The lake shows high alkalinity (pH 10.5 to 11.2 Table 2), while the spring water is sweet and potable water with neary a neutral pH 7.2. The presence of the crater in a monotonous, arid terrain has caused localized transition in geographical, climatic and ecological parameters. Being a confined subterranean hollow, closed from all sides, the crater is protected from heavy winds, has high humidity and forms a localized temperature system partially screened from direct sunlight at places. An eco-system has evolved within the lake with the evolution of various microorganisms (Arthorospira, Spirullina, Closterium, Chlorella, Eudorina and Ankistrodesmus), bacteria and algae's, which are in abundance especially, near the side of the lakes and capable in enduring high salinity levels. It has been reported that there is a record of about 114 types of algae and distinct layers of dried algae, green algae and newly forming algae. Apart from these algae the lake is also rich in both flora and fauna. Trees of custard apple, eucalyptus, lemon grass, bamboo and teak are found. The savannah woodlands bordering the lake along with the shrubs, herbs and climbers host a wide range of animals including squirrel, monkeys, barking deer, mongoose, black-napped hare, bats, monitor lizard, snake and insects like spider and scorpion. Avian life is represented through resident and migratory birds like egret, pond heron, tailor bird, barn owl, grey hornbill, bush quail, white-necked stork, flamingo, lapwing, grey wagtail, golden oriole, crane, black-winged kite, Indian peacock, peafowl, magpie, robin, etc.

An ever-increasing population coupled with urbanization has lead to an indiscriminate invasion of human activities in Lonar. Construction activities and overcrowding of slums have affected the crater. Many streams in the rim area are polluted from regular domestic requirements such as bathing and washing using non-biodegradable detergents were dumping in these pollutants previously in the lake (e.g. Nabbi Nala stream). The streams are now diverted from the lake. Around 52 acres of land, at the base of the crater, containing a perennial spring and supported by abundant groundwater is under agriculture. Traditionally, the agricultural landholdings seemed to have affected the crater little as all land owners resided in the town and not inside the crater. However, presently, the same activity has threatened the crater soils and lake from the introduction of synthetic fertilizers, pesticides and insecticides as by-products of modern agriculture. The toxic chemicals have altered the chemical characteristics of soil and threatened the lake micro-flora to subsequent extinction. Since the lake is a captive water body, the concentration of chemicals has been on the rise causing irreversible pollution. Motorized lifting of water from the crater-lake has caused imbalances in the natural hydrological cycle. Extraction of salts and geological materials have disturbed the chemical constitution of the lake and led to the misuse of valuable resources. Other negative impacts have been from uncontrolled livestock grazing, firewood collection and occasional hunting of birds. Deforestation has damaged ephemeral plants and caused imbalances in the population and frequency of floral species. The dense natural mixed-deciduous forests, which once covered the entire basin and crater slopes providing natural refuge to animals exists, have become sparse. During 1986-91, the Forest Department sanctioned funds for afforestation within 200 acres of the crater with neem, teak, gulmohar and bamboo saplings. Unfortunately, a negative fall-out of this extensive programme was the plantation of the exotic prosopis juliflora (wild babul) leading to the growth of thorny inaccessible thickets around the crater-lake. Moreover, the foliage and fruits being ejected by the excreta of cattle spread its growth at an alarming rate gradually replacing the crater's natural vegetation and becoming an absolute menace. The rising water levels of the lake are attributed to the sewage flowing into the lake which is submerging the surrounding vegetation and corroding the temples.

The crater ecosystem can retain its unique character with immediate controls put in place through an integrated plan. For detailing the conservation and management plan, the following steps need to considered: (a) identification of the geographical area to be conserved; (b) identification of an appropriate legal status to be accorded; (c) formulation of procedures for operation; and, (d) a monitoring mechanism to review and guide the process. The Government and Non-Governmental Organizations (NGOs), voluntary agencies and institutions working towards conservation would be essential to prevent any negative fall-outs on the crater-lake. It would also be necessary to take cognizance of suggestions and complaints related to policy issues.

A large number of slum dwellers perform ablutions on the roads making them filthy. To reduce water pollution, all detergents could be banned in the Dhara the spring water complex. Similarly, garbage accumulation should be completely restricted by law. The complete protection of the ejecta blanket from agricultural activities is crucial. A ban should be imposed on the use of toxic materials as pesticides and fertilizers in the agricultural fields inside the crater. Trees and shrubs on the crater floor are being cut at an alarming rate. The deforestation and grazing activities inside the crater should be completely stopped. In order to the ecological restoration, it the vegetal cover should be improved on a large scale so that this can function as a natural buffer zone for protecting the crater ecosystem. The microflora of the crater-lake shows high degree of specialization among floral components of the ecosystem with huge economic potential for research and development.

The Lonar crater-lake should be given special status to protect and conserve its natural heritage of extraordinary significance. The area in and around the crater declared as a National Park. This will facilitate the Forest Department to exert protection and ensure effective conservation of the crater eco-system. With social justice being inevitably linked with conservation, it is important to safeguard the interests, customs and traditions of the indigenous people. Local authorities should develop a mechanism allowing all sections of the society to be partners in planning and ensure equitable share in the costs and benefits. The cultural heritage involving important values and sensitivities of the religious communities, geo-physical characteristics of the eco-system, indigenous species of diverse flora and fauna and existence of the institutional structure within which these elements coexist need to be interwoven.

8. Conclusion

Geologically, the area belongs to Deccan Basalt formations of late Cretaceous to early Eocene period. The occurrence of impact of meteorite yielded the rare mineral called the *muskelynite* (impactite mineral) indicating that the lake is of meteorite impact origin. All the physicochemical parameters of water including pH, Chlorides (Cl), total hardness, total dissolved Solids, Ca, Mg, Na, K, CO_3, HCO_3 and SO_4 are higher and very greater than the BIS (1991) and WHO (1992) maximum permissible limits for drinking and other domestic use of water. The presence of species of bacteria related to water borne diseases were also found higher indicating the non-potable nature of the lake water but the spring (Dhara) water is normal and potable. Occurrence of few species of algae and fungi indicate the characteristic nature of bioflora, which needs the further investigations and interpretation. The assemblage of geological and micro-ecological attributes of Lonar lake water makes it very interesting for researchers.

The saline crater-lake is a great storehouse of unique floral and faunal assemblages with its unique ecosystem having evolved due to its unusual hydrogeological and climatic conditions. Unplanned expansion of Lonar town characterized by unrestricted construction activities, overcrowding of slums and inadequate civic amenities and faulty infrastructure projects have endangered the crater system and hence should be avoided. The crater slopes have succumbed to soil erosion and denudation from uncontrolled grazing and overgrowth of Prosopis Juliflora. Agricultural activities have altered the texture of the crater floor and soil character. Water pollution from release of toxic substances has changed the chemical composition of the lake, lead to the extinction of flora and affected the already dilapidated temples and archaeological monuments in the lake precincts. The lake urgently needs to be accorded immediate protection and special legal status and saved and preserved for future generations to come.

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InTech Europe
University Campus STeP Ri
Slavka Krautzeka 83/A
51000 Rijeka, Croatia
Phone: +385 (51) 770 447
Fax: +385 (51) 686 166
www.intechopen.com

InTech China
Unit 405, Office Block, Hotel Equatorial Shanghai
No.65, Yan An Road (West), Shanghai, 200040, China
中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821