

A Review on Chemical and Ecological Status of Lonar Lake

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Abstract

Meteoric impact crater Lonar Lake is located in Buldhana district of Maharashtra always remained as point of attraction among the researchers of different fields since many decades as it has rich chemical and biological diversity in it. Physicochemical qualities of water samples were analysed by many researchers and revealed that, the water is alkaline with high pH and categorised by high concentration of Alkalinity, Sulphate, sodium, Total dissolved solids, Magnesium, Chloride and Dissolved Oxygen. Due to this, interesting microbial complexity have been developed across the Lake. From this review, it is found that alkalinity has been decreased by nearly 19 percent, salinity nearby 7 percent and therefore its pH is seen to drop up to 6.2. This decrease is mainly due to process of sedimentation of salt at the bottom of the Lake. This has affected the living of Micro-organism. Many researches have been carried to study the nature of Lonar Lake from different fields. Therefore, an attempt is made to assemble important aspects of Lonar Lake from various fields. Conservation of Lonar Lake with proper management is necessary as it has uniqueness and beauty in itself.



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Introduction

Lonar Lake is located in Buldhana district which is one of the famous historical place in Maharashtra, India (19°58'N, 76°31'E). It is said that nearly before 50,000 years, there was formation of impact crater due to collision of meteor. There is vast chemical and biological diversity in it created due to meteor impact. It is very essential to study this place so it may open secrets of universe. The research on Lonar Lake began in 1823 and is discovered by C. G. Alexander

then after intense research were carried out by many researchers.¹⁻³ Previously it was believed to be volcanic crater. But there are no cracks in basaltic rocks. Also there is 150 meter below hot water springs due to volcanic boron or sulphur. But Volcano eruption should have a central cone which is not observed. But it was in 1973, it was proved to be meteoric impact crater.⁴ The asteroids between Mars and Jupiter when enter the earth's atmosphere then there is possibility of such crater. The impact causes

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the crater and its rim called ejecta blanket. It gives shock metaphors in rock. A meteor inflowing into the atmosphere of Earth can undergo disintegration. The range of impact velocity of object is from 11 to 72 km/sec. Upon impact, the meteor shock waves gets produced and it explodes violently giving out huge amount of energy. It is believed that around 50,000 years back, a huge piece of rock weighing about 2 million tonnes came from space with travelling speed of 18 km/Sec and hit the land forming the crater of 1.830 km diameter and 0.15 km deep at Lonar. There are some unique facts of this crater like the existence of rock at the crater site that has experienced shock metamorphic effects like molten rocks, deformations of crystal. Maskelynite i.e. glassy kind material is formed when mineral plagioclase of the basaltic rock is subjected high temperature and pressure. Maskelynite obtained at crater site also indicates to be meteorite impact crater. Lonar Lake is formed on basaltic terrain as similar to the terrain observed on Moon and even on the some parts of Mars. This crater provides the opportunity to explore a new and relatively unexplored area of research to compare with craters on Moon.⁵ The Lake site has cultural evidence as referred in Upanishads and Puranas. The saga has its mythology related to the devil Lawanasur. As refer to Skanda Purana, Lord Vishnu Killed the giant devil Lawanasur here. The perennial spring flows inside the Lake is assumed to be the water of River Ganga. There are twenty seven temples, three temples tanks for holy bathing three monuments and three inscriptions around the lake

and are said to be belongs to Yadavas and medieval periods and detailed study of its environmental archaeology is yet required to know the cultural heritage and the interaction of human with the lake.^{6,7} Historically, many religious fair and rituals is regular practice especially during 'Navratri' and around one lakh people visit the lake results in disturbing ecosystem and contamination of lake.^{8,9} The Lonar crater has water in it hence named it as "Lonar Lake" and is one of the major basaltic meteorite crater. The Lake water is mainly made up of rain water and a stream. The stored water in Deccan plateau in form of Dam should also have same chemistry as that of Lonar Lake as it is formed by basaltic rock but it is not so.¹⁰ Rather, The Lonar Lake water is highly saline. Aquatic life doesn't exist inside lake.

Hydro-Chemistry of Lake Water

Many researchers have analysed hydro-chemical parameters of Lake at regular interval of time since last three decades.^{1, 2, 3, 11, 12, 13, 14} The finding of the water contents can open the secrets of the meteor which is at below of the Lake water and through that contents of meteor can be presumed. We can even assume that content of the meteor may have get dissolved in the Lake water since its existence. Over the last few years, much research has examined the physico-chemical study of Lake Water as given below in the table.^{11, 12, 13, 14} We also visited Lonar and analysed few parameters in November 2019. The Lake water is very saline and contains many salts and there is no life exists inside the water.

Table 1: Above table indicates range of contents present from different part of Lakes observed as per the different recent research papers.

Contents	Values	Ref. no.	Contents (ppm)	Ref. no.
Colour	Dark – green	11	Fluoride (ppm)	0.2 11
Temperature °C	23-26	12	Phosphate (ppm)	0.63 to 1.70 11
Odour	Highly Objectionable	11-12	Sodium (ppm)	241 to 3000 11, 13
pH	6.2 to 11.2	13	Potassium (ppm)	3 to 80 11, 12
Conductivity mmho/S	12 to 18	11	Magnesium (ppm)	19 to 22 11, 12
Total Solids (ppm)	14200 to 16700	14	Calcium (ppm)	8 to 22 12, 14
Total Suspended Solids (ppm)	4240 to 5300	14	Chloride (ppm)	100 to 3338 12, 14
Total Dissolved Solids (ppm)	8900 to 12460	14	Sulphate (ppm)	40 to 400 11, 13
D.O. (ppm)	0.02 to 0.04	14	Carbonate (ppm)	168 11
B.O.D. (ppm)	0.1 to 0.3	14	Iron (ppm)	0.121 13
C.O.D. (ppm)	0.04 to 0.2	14	Manganese (ppm)	0.068 11
Total Alkalinity (ppm)	3590 to 3760	11	Copper (ppm)	0.45 By us
Total Hardness (ppm)	32 to 400	11	Salinity	2327 13

Colour

Normally the colour is yellow-green to dark green while some part of water looks like oily or precipitate type. This is due to presence of algae & other inorganic salts.

Odour

Rotten smell is mainly due to H₂S gas liberating outside. Reason behind these liberation may be that presence of SRB in water converts SO₄²⁻ ion presence in water into S²⁻.

pH is limited to the range 6.2 to 11.2. Since sea water contains different types of salts then also the pH value is limited. The salt have results from Earth's interior via volcano and hydrothermal vents. The pH of the LonarLake water diverges in the range 9.5 to 10.5. pH is very important to the productivity of aquatic ecosystems. If there were these salts present in the soil in the Lonar region which should result in saline nature of the Lake water then the same effect should be deplete in nearby bore wells or deep wells, but the natural water sources in the region do not show this type of behaviour. The presence of sulphates in excess amount in the soil results in the presence of hot water springs like the ones observed in the Konkan region but not observed in the vicinity. Therefore the saline nature and high pH of the water should not depend upon the salts present in the soil but on the chemical composition of the meteoric rock and leaking of basaltic terrain due to impact which created the Lake and the salts being dissolved in the water in due course of time. The variation of pH of the solution changes in accordance with in flow of water and evaporation of water from the Lake.

The studies of electrical conductivity of LonarLake water shows 12 to 18 mmho/S which is very high as compared with the Sea water. The salt concentration increases, so does the electrical conductivity indicating strong salinity.

The biological oxygen demand and chemical oxygen demand tests also show a very negligible value similar to salty environment. The life in such saline conditions is difficult from biological point of view. Dissolved oxygen value is also very low indicating low aquatic life existence.

Amount of sodium is very high, It is also possible that rocks like Halite, black salt and sea salt are

the main sources of sodium and chloride content which increases salinity whereas sedimentary rocks beneath the basaltic terrain got cracked up and came out during the impact resulted into the increase in the alkalinity of the Lake. Continuous leak of salts have occurred from beneath the Lake.¹⁵

Total hardness is also very high. Other contents of salts like copper, iron, Manganese etc are in measurable range and always have certain impact on the microbial content present in the Lake.

The water quality outside the Lake nearby are within permissible range and is drinkable and can be used for various domestic purpose as reported in many recent research papers.

Effect of human activities is predominantly observed in Lonar Lake. Here increase in intensity of colour of lake is observed from green to dark green because of massive growth of algae in water which is we also called as Eutrophication. Here due to human activities and pollution organic matter in pond increase and which is responsible for Eutrophication. With green colour lake water colour also change pink, red and orange according to the dominance of bacterial colonies present in lake. This organic matter becomes reason for highly objectionable odour of water of lake. The slight increasing trend observed in temperature which is due to the climatic change and global warming. pH of the water of lake is in between 6.2 to 11.2 and we know above 9 pH lethal effect observed in biosphere so in the lake due to high alkalinity limited life is observed. High alkalinity presents in water of lake which is due to may be presence of saline springs at the bottom of lake. Due to pollution Concentration of total dissolve solid and suspended solid is also found high in lake and shows increasing trends. Here dissolve oxygen shows decreasing trends means due to pollution concentration of dissolve oxygen is decrease. High alkalinity, High pH and decreasing dissolve oxygen all responsible for limited life which is observed in Lonar Lake. Due to high salt content and alkalinity the conductivity of water is also high. Due to decrease in dissolve oxygen amount the BOD and COD values are also decreases here because oxygen required for organic or inorganic impurities in water for oxidative decomposition is less so BOD and COD values are also less. Lonar Lake is closed type of lake there are inlet for this lake but no

outlet. Here water comes from various small rivers into the lake but no water flows down through the lake hence it acts as a sedimentation tank. In this lake water remain steady for many days or months so the salts present in lake may deposit or settle down at the bottom of lake and hence when we see the concentration of cations like Sodium, Calcium, Magnesium, Iron...etc. and anion like chlorides, phosphates, they shows decreasing trends. Salinity and alkalinity of lake is also decreased which affects the unique biodiversity present in lake.¹⁸ But here

sulphate concentration shows increasing trends and this increase is due to agricultural activities observed near the lake where farmers used sulphur containing Fertilizers. In case of Lonar Lake it is difficult to study how much human activities like agriculture and other pollutions affects the lake because already lake contain massive amount of different salts and organisms but agricultural activities i.e. massive use of fertilizers and pesticides in small scale must pollute the lake also polluted rivers which reaches the lake are also become source of pollution in lake.¹⁹

Table 2: Above table shows comparisons of various chemical parameters from different time from 1910 to 2020.

Chemical Parameters	1910 (Ref. 16) (%)	1955 (Ref. 01) (%)	1960 (Ref. 02) (%)	1993 (Ref. 03) (%)	2001 (Ref. 17) ppm	Present ppm
Colour	Green	----	Green	----	Green algal	Dark – green
Temperature °C	23-35	--		24-36	24-37	23-39
Odour	----	---	---	--	----	Highly Objectionable
pH	---	---	---	9.3-10.5	10.5	6.2 to 11.2
Conductivity	----	---	----	9.3-9.7 mmho/S	11.6-15.6 mmho/S	12 to 18 mmho/S
Total Solids	----	----	----	----	----	14200 to 16700
Total Suspended Solids	----	----	----	----	51-167	4240 to 5300
Total Dissolved Solids	---	----	----	----	-----	8900 to 12460
D.O.	---	---	---	----	10.8-15.8	0.02 to 0.04
B.O.D.	----	----	----	----	50-56	0.1 to 0.3
C.O.D.	---	--	---	---	265-285	0.04 to 0.2
Total Alkalinity	19.23	---	---	---	444-519	3590 to 3760
Total Hardness	----	----	----	----	117-158	32 to 400
Salinity	15 to 28				2300-2900	2327
Fluoride	----	----	----	----	-----	0.2
Phosphate	----	----	---	---	0.25-0.56	0.63 to 1.70
Sodium	39.61	41.56	15.15	15.15-27.76	2490-3840	241 to 3000
Potassium	----	----	----	----	8.16-25	3 to 80
Magnesium	0.11	0.01	0.14	1.27-5.78	3.48-3.58	19 to 22
Calcium	0.11	0.01	0.18	19.17-25.4	2.04-4.08	8 to 22
Chloride	40.78	31.52	30.87	19.17-25.4	2300-2800	100 to 3338
Sulphate	1.48	0.3	0.67	0.1-6.06	106-117	40 to 400
Carbonate	15%	22.26	7.52	19.63	256-310	168
Iron	--	----	----	----	0.46-0.51	0.121
Manganese	----	---	---	----	----	0.068
Copper	----	-----			----	0.45

Biological status always depends on the nature of surrounding. The salinity of lake will definitely have certain impact on biology of the lake.

Biology of Lonar Lake

A review of literature revealed that some microbial reports are available on Lonar Lake which indicates

aerobic and alkaliphilic bacteria are present in LonarLake. Some group of enzymes like chitinases also isolated from alkaline soil of LonarLake. Chitins were produced from life forms breakdown into variety of products like field, biomedicine and cosmetics. LonarLake is the only Lakemade by meteorite impact and shows alkaline pH 8.0 to 9.0. Therefore biochemical activity would also be so.²⁰ Actinomycetes (antibacterial agent) also isolated from marine sample of LonarLake, Actinomycetes are important part of prokaryotes which act as antibiotics. From biochemical and molecular analysis total 74 bacteria were isolated from LonarLake.²¹

Up to now same bacteria's are found in sediment and water samples. That is *proteobacteria*, *firmicutes phylum (gamma proteobacteria, alpha bacteria, actinobacteria)*, *Cyanobacteria* was observed. Same minor populated bacteria like *bacteroidetes*, BDI-5, *nitrospirae*, *Verracomicrobia* and *Alcanivorax ssp.* are also obtained which have good oil degradation capacity plants available on LonarLake have medicinal properties or use as herbal drug. Some enzyme retained active and stable at basic pH.²²

Many gene sequence recovered from LonarLake. 16SrRNA gene related to methanogenic species like *Methanocalculus*, *Methanoculleus* and *Methanosarcinales* also isolated from Lake. Helobacterials related to phylotypes gives 16S-rRNA gene. Methanosarcinales and methanomicrobials were obtained from uncultivated euryarc activity. Methanomicrobials are sulphur and non-sulphur photosynthetic bacteria and methylotrophs utilising methane.²³ Lipases and many other enzyme such as amylase, cellulose and caseinase at different pH are also isolated from LonarLake and bacterial activities were selected on basis of lipolytic activity. Isolated bacillus cereus (OCW3C1) strain used to produce lipase at basic pH to study the diversity of LonarLake. same isolates are isolated which is related to *Alkalimonas*, *Exiguobacterium*, *Pseudomonas*, *Halomonas*, *Bacillus*, *Methylophaga*, *Paracoccus*, *Rhodabaca* and *Idiomarina spp.* which produce enzyme give microbial activity those isolates belongs to *Pseudomonadaceae*, *Vibrinaceae*, *Bacillaceae* and *Habmonadaceae* families. Some heterotrophs like *Nitritalea*, *Halakaliphila*, *CecembiaLonarensia*, *Indibacteralkaliphilic* described from LonarLake.²⁴ LonarLake containing phylum firmicutes contains law gram positive like *Bacillus*, *Paenibacillus*, *Alkali*

bacillus, *Xigubacterium*, *Planococcus*, *Enterococcus* and *Vagococcus* and gram negative bacterial group like *Halomonas*, *Stenotrophomonas* and *Providencia (γ-Proteobacteria) alkali genus (beta-Proteobacteria)*, *Paracoccus (alpha-proteobacteria)*. such gram positive bacteria associated with genera that is *Cellulosimicrobium*, *Dietzia*, *Arthrobacter* and *Micrococcus*.^{25, 26}

LonarLake turned pink on March month this year due to no rain, no human activity due to lockdown period and high temperature. As a result pH and salinity increased facilitating the growth of 'Haloarchaea' microbes.

Fossils remains is also reported around the Lake which have come out during cracking of basalt terrain due to meteoric impact.²⁷

From this review it clear that salinity and alkalinity of LonarLake shows diversity. All plants available at LonarLake have medicinal properties. The soil and water shows various microbial activities that is from soil and water isolates various bacteria which is produced enzyme and other products.

When Lonar Lake was formed, some of the rocks which collided with the meteorite evaporated due to high mass and the heat which was generated during the collision and the fluids released from it were absorbed by the soil. Over the time period, microbial colonies started to form at that place. Diversity of microbes in Lonar Lake suggest that these locale harbour complex microbial foodstuff web that impact on making and intake of greenhouse gases. When Lonar Lake was formed pH of water present was 10-12. Now its pH has dropped upto 6.2 where some microorganisms adapted to that pH, temperature and still present at the part where alkalinity of lake is more, some microorganisms have migrated towards the less alkaline area because they couldn't adapt to the higher pH conditions. Alkaliphilic bacterial are known to exist at pH 11 to 13 but due to drop in value of pH, some of them adopted to new conditions whereas some of them migrated away from the Lake.²⁸ The frequent changes in water pH and alkalinity affect the microbial colonies which are present in the lake. Also because of the research gap we cannot compare the number of species which were present initially to the present parameters. This drop in Alkalinity and pH value is due to

sedimentation salts at the bottom of the Lake as the water of the Lake is motionless since its formation. Also rainfall is scanty. Rain water dissolves the salts present in the soil and brings down into the lake resulting into decrease in alkalinity and pH of soil. Seasonal variation is the only reason which gives stirring to the Lake which brings pH up to 10.5.

The lake needs to be protected from any human interference. Anthropogenic activities can interrupt the existing conditions of the lake and ecology of the lake which can possibly lead to lose the characteristic features of the Lake. The study of biochemical aspects of microorganisms is not done in details, the links between the physiological cycles of the organisms which contribute to chemical composition of the lake are poorly understood.

Another thing can be observed from most of the research papers is the commercial use of these microorganisms. One of the study shows that, alkaliphilic bacteria show inhibitory effect against pathogenic bacteria and fungi, so they can be used as control agents in future. The halophilic bacteria can be used for application in non-aqueous enzymology.²⁹ Thus the commercial aspects of these microorganisms and the enzymes they produce should be taken into consideration.

Scopes and importance of Lonar Lake

The Lonar Lake has rich chemical and biodiversity in it. It ranks third among the meteoric impact craters in the world. Many researchers have shown interest to study it and came with amazing results. Due to different flora and fauna found here, marks this Lake its uniqueness in the world and is require to conserve it. But in past, many human activities like discharge of sewage, fast town growth, hunting, animal grazing, deforestation, bathing and washing activities on river aside, agriculture inside the crater area, religious activities, tourism with no care have deteriorate the Lake and has undergone rapid environmental degradation and eutrophication and had adverse effect on Lake. In past, many errors like construction of percolation tank, roads near the crater, unsuitable plantation of exotic species inside the rim of crater, renovation of temple present in the periphery of the Lake had been done due to unawareness about the greatness of Lake. This human intervention have caused lake water pollution and much intention is needed to find

out its cause and require to fix it.³⁰ Environmental Forensic Study is yet required to know more about the contamination of Lonar Lake and its periphery by human activity so that further contamination can be prevented.³¹ But recently, due to increasing awareness about the conservation of Lake, the local people and the governing body is trying to take utmost care to maintain its ecosystem. Many researchers have recommended for preservation of Lake from deterioration. Diversion of the sewage, banning the use of fertilizer and pesticides across the agricultural field near the crater, strict restriction on animal grazing, hunting cutting of trees, ban on bathing and washing activities at fresh water spring, ban on religious activities inside the crater regular assessment of water and geographical conditions around the Lake are the key points to conserve the Lake and it should be followed by local people and governing body.³² In many parts of India, Sacred groves are perceived by the local people so that its ecosystem remains maintained for many years and endangered species are preserved.³³ It is therefore necessary to conserve the Lake in its existing state and not damage its chemistry since it has immense scientific applications. Though the key points have been highlighted, more research is yet needed to enhance preservation and maintenance of the Lake. There are some research gaps remained which are needed to find out to know whole ecosystem of Lonar Lake. Regular assessment of water and geographical conditions around the Lake are the key points to conserve the Lake and it should be followed by local people and governing body. It is very difficult to monitor contamination of lake because of High alkalinity, High concentration of chemical parameters and inexistence of aquatic life. Hence proper technique or methodology is needed to be develop to study contamination of lake. Though the recommendation on how to protect lake and its ecosystem are mentioned yet a proper and in deep implementation on management of ecosystem is yet needed. There are several old temples and monuments around the lake. Its archaeo-chemistry is yet needed to be studied. Regular assessment of Lake water with physico-chemical and microbial approach though carried out but assessment at the bottom of the lake is yet not done through which only many points of the whole ecosystem will get known. Study of Meteor piece is still uncertain. The meteor is still present or evaporated due to highly energetic impact collision is not certain. If it

is found it will be a Very less research is based on nature of soil sample around the Lake. It is said that huge amount of energy is released upon collision. The soil particles might have absorbed it and may have undergone structural changes which is yet needed to be studied. A hydrological transport model is a mathematical model can be used to simulate the Lonar Lake and to calculate its water quality parameters.³⁴ Consistent monitoring of lake is much needed today so that appropriate actions can be taken to avoid contamination.^{35, 36} More research is still required on developing the sustainable International eco-tourism, ecosystem study and applicative study of the Lake. Barringer crater at Arizona is one of the most attractive place for tourism and Lonar Lake should be made accordingly.

Conclusion

From the above data collected from different research papers, it is concluded that Alkalinity and salinity of Lonar Lake is decreased by 19 percent and 7 percent respectively since 1910. This decrease is mainly due to the fact that Lonar Lake water is still and hence salts sediments at bottom of the lake. Due to this pH also gets dropped to 6.2. This have affected living microorganism near the lake as now

rain water and small river water are only the source of water which brings salts by dissolving it from soil around the Lake. Some microbes have adapted to new conditions whereas some have migrated away from the Lake. In future, Alkalinity, salinity will be reduced further affecting the living microorganisms. Hence, Conservation of Lonar Lake is utmost necessary. The world heritage site is the only one of its kind in the world, therefore the government authorities and the public at large should take utmost care to conserve this site.

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Conflict of interest

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