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Research Paper

COMPARATIVE LIMNOLOGICAL AND PHYSICO-CHEMICAL STUDIES OF LONAR CRATER LAKE, INDIA

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Abstract

India's Lonar lake formed by the hypervelocity meteorite is the only inland salt lake in the country and the third largest in the world. The high salinity, alkalinity, micro-ecosystem, biodiversity and ecological isolation of the lake has evolved limnological status. Due to the high concentration of dissolved solids and total suspended solids caused by the flow of untreated domestic sewage and fecal waste, eutrophication of the lake is predominantly observed. The comparative study of various parameters over a period of 15 years show a many-fold increase in hypersaline, hyper-alkaline and physico-chemical parameters of lake water beyond permissible limit. The bio-available materials and metals have caused toxicity to the biological system. This paper documents the changes in the various components of the lake water and strongly requisites to take suitable measures for removing the causes of contamination for supporting the well-being and biodiversity.

Key words: Salinity, Eutrophication, toxicity, impact crater, physico-chemical.

INTRODUCTION

The Lonar lake (19 58' N and 76 31' E) is a subterranean hollow impact crater formed by hypervelocity meteorite impact in a basaltic terrain. Before the impact, the meteor has fragmented into three pieces that led to the formation of Lonar lake, Ganesh lake, and Amber Lake. The Ganesh and Amber lakes have dried now [1]. The Lonar lake lies in a nearby circular depression surrounded from all the sides by steeply rising basaltic escarpments. The target material below the excavation depth pushed down whereas strata above pushed upwards resulting lake basin closed from all sides without any outlet for water [2]. The shock metamorphic effect includes a layer of shattered or brecciated rock under the floor of the crater [3]. The remarkable shape, size, and uniqueness of crater have attracted geologist, ecologist, archeologist, naturalist, and

astronomists to study its ecosystem[4–10]. The lake is partly screened by direct sunlight at different places and at different times of the day [11]. The crater geographical and ecological isolation has evolved limnological status. The lake is known for its high salinity, alkalinity, micro-ecosystem and a wide range of plant and animal life. The saline lake, marshy area all around the lake, fresh water at the periphery, natural and manmade plantations provide special biodiversity. Inside the surrounding areas of the crater, some farmers were growing bananas, date palm, Annona squamosal and toxic chemicals due to their use of fertilizers, insecticide, a pesticide-contaminated the lake water. However, after the recent declaration of reserve forest, the farming has now been banned. Near the freshwater streams on top, the local population takes bath and wash clothes causing contamination of lake water [12]. The eutrophication of the lake has taken place due to the flow of untreated domestic sewage and garbage coming out from Lonar town. Due to the high concentration of dissolved solids and total suspended solids, the Lonar lake is the third largest natural saltwater lake in the world and is the only inland saline lake in India. The lake appears to be a unique aquatic ecosystem characterized by hypersaline, hyper alkaline and many physico-chemical parameters beyond permissible limit [13]. The lake water is blue-green in color due to the presence of algal blooms. The water now emanates strong objectionable odour. The hydrological study reveals deteriorating changes in the lake water leading towards eutrophication that led to a reduction of flora/ fauna and an increase in pathogenic organisms. Further, the lake brine supports typical microbial flora and fauna that need investigations.

The mark of an impact crater is the presence of elements like Ni, Pt, and Ir which is not usually found in the earth interior [14]. A recent study of soil samples of Lonar crater [15] reported the high content of iron (10.04 – 11.9%) and aluminum (up to 21.15%) similar to Apollo 11 sample code; 1003 (10) [16]. The presence of high titanium content (< 2%) and maskelynite i.e. a glass type of mineral at the impact site are a distinct feature of an impact crater [17]. Heavy metals and salts are a very important group of environmental pollutants which in small quantity may be essential nutrients and their larger quantity may be toxic and dangerous for human and water creatures [18]. Metals like arsenic, lead, cadmium, mercury, selenium are highly toxic even in minor quantity. The concentration of bio-available material and metals such as As, Cd, Ca, Ni, Mn, Zn, Ti, Hg, and Pb are toxic to biological systems.

Many studies have been undertaken in the past on Lonar lake pertaining to geological and geomorphological features. It has been reported that the lake inhabited a wide range of plants and animal species [19]. Studies about the water quality of the lake with respect to its physico-chemical properties and microbial fauna and flora have also been carried out [20,21]. However, published reports lack uniformity and contradictory to each other, partly may be due to seasonal impact and time/ method of sampling and analytical procedure followed. Most of the reports do not provide a detailed account of the methodology followed for analysis. Moreover, a comparative study about the water quality of the lake has never been attempted to monitor pollutant levels and document

the changes it has undergone. This work specifically reports changes in the physico-chemical properties of the water for a period of over 15 years with the purpose to protect the biotic zone. For this purpose, the lake sample collected in July' 2018 from all the four sides were analyzed and the data compared to a previous analysis reported for the year 2003, 2014 and 2016 by various researchers. This was done with the purpose to actually visualize the pollutants level during 15 years period. At least 32 different parameters about the quality of the lake water were analyzed. Besides, the quantitative analysis of heavy metals present was also carried out and the data compared with the previous report.

MATERIALS AND METHODS:-

Four samples of water from all the four sides of the lake were collected in the month of July' 2018 during the rainy season. For the analysis of many of the constituents of the lake, the methodology followed is as per the APHA 22nd edition [22]. For biological oxygen demand (BOD) method followed is as per IS3025, P-44, 1999 (R-2003) for 3 days at 27°C. For total coliform and fecal coliform the method followed is as per IS 1622 [23] and the data reported as MPN/100ml of the sample [22]. The water samples were numbered M1, M2, M3, and M4 for samples from east, west, north, and south, respectively. The result of our analysis is shown in Table 1.

Table 1:- Analysis report of Lonar lake water samples, Buldhana, Maharashtra.

Sr No	Parameters	Test methods	Results				Unit
			M1	M2	M3	M4	
1	pH (at 25° C)	APHA 22nd edition, 4500-H^+B	9.65	9.85	10.01	9.60	
2	Colour	APHA 22nd edition, 2120 B	38	38.5	37.6	37.8	Hazen
3	Turbidity	APHA 22nd edition, 2130 B	72.1	71.56	72.15	71.98	NTU
4	Odour	APHA 22nd edition, 2150 B	Objectionable	Objectionable	Objectionable	Objectionable	Objectionable
5	Total hardness as $CaCO_3$	APHA 22nd edition, 2340 C	4480	4368	4450	4475	mg/lt
6	Calcium as $CaCO_3$	APHA 22nd edition, 3500 Ca B	1006	1000	1008	1010	mg/lt
7	Alkalinity as $CaCO_3$	APHA 22nd edition, 2320 B	9046	9025	9035	9050	mg/lt

8	Chlorides as Cl	APHA 22nd edition, 4500- Cl B	10911	10900	10915	10910	mg/lt
9	Magnesium as Mg	APHA 22nd edition, 2340 B	478.70	476.0	480.23	478.80	mg/lt
10	Total dissolved solids	APHA 22nd edition, 2540 C	31600	31650	31700	31580	mg/lt
11	Sulphates as SO_4	APHA 22nd edition, 4500 E	4069	4075	4072	4065	mg/lt
12	BOD (3 days at 27° C)	IS 3025 P-44, 1999 (R-2003)	340	342	345	338	mg/lt
13	COD	APHA 22nd edition, 5220 B	704.20	700	705.25	704.35	mg/lt
14	Nitrates as NO_3	IS 3025 (P-34), 1988	123.40	122.50	123.85	123.48	mg/lt
15	Iron as Fe	APHA 22nd edition, 3500 EC B	0.72	0.70	0.75	0.73	mg/lt
16	Aluminum as Al	APHA 22nd edition, 3111 B	< 0.03	< 0.03	< 0.03	< 0.03	mg/lt
17	Boron	APHA 22nd edition, 45000 B C	1.98	1.89	1.95	2.00	mg/lt
18	Chromium as Cr	APHA 22nd edition, 3111 B	< 0.01	< 0.01	< 0.01	< 0.01	mg/lt
19	Phenolic compounds	APHA 22nd edition, 5530 C	< 0.01	< 0.01	< 0.01	< 0.01	mg/lt
20	Mineral oil	Clansibol IS; 3025 (Part 39)	< 0.01	< 0.01	< 0.01	< 0.01	mg/lt
21	Anionic detergents as inBAS	APHA 22nd edition, 5540 C	< 0.02	< 0.02	< 0.02	< 0.02	mg/lt
22	Zinc as Zn	APHA 22nd edition, 3111 B	5.20	5.15	5.23	5.21	mg/lt
23	Coppper as Cu	APHA 22nd edition, 3111 B	2.56	2.50	2.61	2.55	mg/lt

24	Manganese as Mn	APHA 22nd edition, 3111 B	< 0.10	< 0.10	< 0.10	< 0.10	mg/lt
25	Cadmium as Cd	APHA 22nd edition, 3111 B	< 0.001	< 0.001	< 0.001	< 0.001	mg/lt
26	Residual free chlorine	APHA 22nd edition, 4500- Cl B	< 0.20	< 0.20	< 0.20	< 0.20	mg/lt
27	Cyanides as CN	APHA 22nd edition, 4500 CN D	< 0.02	< 0.02	< 0.02	< 0.02	mg/lt
28	Total coliform	IS 1622, 1981 (Reaffirmed 2003)	9398	9400	9372	9385	MPN/100 ml
29	Fecal coliform	IS 1622, 1981 (Reaffirmed 2003)	4065	4060	4072	4068	MPN/100 ml
30	Total suspended solids	APHA 22nd edition, 2540 D	510.0	515.0	507.0	512.00	mg/lt
31	Fluorides as F	APHA 22nd edition, 4500 FD	2.18	2.20	2.23	2.15	mg/lt
32	Sodium as Na	APHA 22nd edition, 4500 FD	14.36%	14.86%	13.98%	14.25%	mg/lt

RESULTS AND DICUSSION:-

The pH value of water is related to carbon dioxide/ bicarbonate and carbonate equilibrium. The pH may be affected by humic substances; changes in carbonate equilibrium due to the bioactivity and by hydrostable salts. Higher pH can also be attributed to photosynthetic activity in the lake ecosystem. The pH of lake water varied between 9.65 to 10.01 pointing salinity that does not support the growth of another organism.

The color of water sample was compared with the prepared standard (5.70 units) by diluting the working standard. The colored value obtained is 38 in Hazen scale. Zero of the scale represents distilled water. The organic materials, algal growth, and impurities have contributed to the coloration of water.

The turbidity of the lake water was measured by nephelometry and the value obtained is about 72 in nephelometric turbidity units (NTU). The turbidity value indicates the high content of suspended organic matter, dissolved solids, floating solids

and dissolved gases in the lake water. The offensive odour of the lake water is due to the flow of raw sewage into the aquatic environments of the lake that enhances biological growth and consequently odour to stagnant water. Several hundred odor compounds have been reported [24–26].

The hardness of water is a variable and complex mixture of cations and anions and defined by the sum of calcium and magnesium concentrations, both expressed as $CaCO_3$ in mg/lt. In spite of high dissolved solids, the total hardness reported in the previous studies for lake water is in the range of 142 - 168 mg/lt [26]. However, in our investigation the total hardness found was in between 4368 – 4480 mg/lt indicating very high dissolved solids.

Alkalinity is the capacity of water to resist changes in pH. The main sources of alkalinity are carbonates, bicarbonates, borates, phosphates, silicates etc. The alkalinity for the lake water is very high and lies in the range of 9025-9050 mg/lt. High alkalinity is due to nil outflow of lake water and its constant evaporation specifically in hot summers. The presence of chloride can be attributed to dissolution of salt discharged from effluents. The salty taste produced by chlorides depends on the chemical composition of water. The average chloride content of water is 10909 mg/lt. Seawater has a chloride ion concentration of about 19400 mg/lt. The sodium concentration of lake water is also very high with the highest concentration reaching up to the level of 14.86% that make it unsuitable for use.

The high levels of pollutants in the lake water has caused an increase in biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved solids (DS), total suspended solids (TSS), toxic metals like Cd, Cr, Ni, Pb and fecal coliform that make it unsuitable for use. The BOD measurement at 27°C for 3 days is about 340 mg/lt and COD 704.2 mg/lt for the lake water. The presence of biologically recalcitrant substances of organic nature has caused the high value of BOD of lake water. The inflow of sewage and pollutant stream water need control with immediate effect.

Fecal coliform is a rod-shaped, gram-negative, a nonsporulating bacterium that indicates possible contamination of lake water with pathogens. The fecal coliform value of about 4065 mg/lt indicates contamination of lake water with fecal materials of human and other animals. Against coliform bacteria acceptable limit of < 1 coliform/100, the lake water has total coliform of about 9389 MPN/100 ml due to possible contamination.

The total dissolved solids of about 31600mg/lt and total suspended solids of about 510 mg/lt are too high for lake water. The lake water has very high sulfate content of about 4069 mg/lt against a limit of 250 mg/lt in drinking water. The nitrates in the water were found to be around 123 mg/lt. The high sulfate and nitrate indicate high nutrient content in the lake water due to the presence of high content of zinc, copper, boron manganese identified through the analysis of the lake water.

COMPARATIVE STUDY OF POLLUTANTS IN LONAR LAKE:-

Many studies have seen undertaken on Lonar lake water, mainly in regards to its physico-chemical characteristics and heavy metal concentrations. The major studies carried out by various researchers pertain to the year 2003 [26], 2014 [27]and 2016 [28] and data were published. However, no comparative data is available showing enhancement or depletion of pollutants levels, so far. Table 2 shows, major constituents detected in the lake water vis-a-vis the recent analysis of the lake water carried in July' 2018.

Table 2:-Major constituents detected in the lake water

Sr. No	Parameters	2003	2014	2016	2018
1	pH	9.9 - 10.1	10.0	-	9.65 - 9.75
2	Temperature	25.9° - 29.6°	25° - 30°	25.25° - 27.58°	-
3	Turbidity	-	-	-	72.10 NTU
4	Odour	Strong musty	-	-	Objectionable
5	Colour	Dark green	-	-	38 Hazen
6	Total hardness as $CaCO_3$	140 - 168 mg/lt	64 – 162 mg/lt	76.84 mg/lt	4480 mg/lt
7	Total alkalinity as $CaCO_3$	1480 - 1510 mg/lt	6437 - 9484 mg/lt	8167 - 8489 mg/lt	9046 mg/lt
8	Total suspended solids	30 - 42 mg/lt	-	-	510.00 mg/lt
9	Total dissolved solids	9670 - 9942 mg/lt	4.2 - 8.3 mg/lt	7.24 - 7.45 mg/lt	31600 mg/lt
10	Calcium hardness as $CaCO_3$	110 - 118 mg/lt	5.46 - 17.64 mg/lt	9.1 - 9.75 mg/lt	-
11	Magnesium hardness as $CaCO_3$	32 - 48 mg/lt	11.7-24.48 mg/lt	16.1-18.3 mg/lt	-
12	Chloride as Cl	2130 - 2346 mg/lt	3576.27 - 5537.29 mg/lt	4162- 4653 mg/lt	10911 mg/lt
13	COD	296 - 350 mg/lt	-	299 - 319 mg/lt	704 mg/lt
14	BOD	58 - 76 mg/lt	-	157 - 182 mg/lt	340 mg/lt
15	Sulphate as SO_4	20.60 - 29.6 mg/lt	-	0.71 - 1.66 mg/lt	4069 mg/lt
16	Phosphate as	0.49 - 0.62 mg/lt	-	1.6 - 2.62	-

	PO_4			mg/lt	
17	Dissolved oxygen (DO)	< 2.0 mg/lt	0.3 - 5.1 mg/lt	4.02 - 4.34 mg/lt	-
18	Calcium as Ca	44 - 48 mg/lt	16.0 – 90 mg/lt	36.5 – 39.06 mg/lt	1006 mg/lt
19	Magnesium as Mg	7.5 – 11.0 mg/lt	-	-	478.7 mg/lt
20	Sodium as Na	5626 - 5962 mg/lt	-	-	14.36 mg/lt
21	Potassium as K	20 – 32 mg/lt	-	-	-
22	Nitrate as NO_3	-	-	8.52-10.58 mg/lt	123.40 mg/lt
23	Total colifirm	-	-	-	9389 mg/lt
24	Fecal Coliform	-	-	-	4065 mg/lt
25	Flouride as F	-	-	-	2.18 mg/lt

From the comparative data, it was observed that the total hardness, total alkalinity, total dissolved solids, chloride content, COD, BOD, sulfate, calcium, magnesium, sodium, nitrate, fecal coliform for the lake water have increased to a very high level. The pollutants and their concentration in the Lonar lake have increased many times for want of suitable measures. The heavy metal concentration obtained during the analysis of water sample was also compared with our present data, Table 3. From the data, it is observed that the concentration of zinc, boron, copper etc in the lake have apparently increased causing toxicity.

Table 3:- Heavy metal concentration in lake water

Sr No	**Metal**	**2003**	**2018**
1	Zinc	0.138 - 0.170 mg/lt	5.2 mg/lt
2	Lead	0.120 - 0.136 mg/lt	-
3	Cadmium	0.007 – 0.018 mg/lt	< 0.001 mg/lt
4	Nickel	0.158 – 0.169 mg/lt	-
5	Cobalt	0.010 – 0.014 mg/lt	-
6	Manganese	0.070 – 0.0086 mg/lt	< 0.10 mg/lt
7	Iron	1.72 – 1.90 mg/lt	0.72 mg/lt
8	Chromium	0.246 – 0.264	< 0.01 mg/lt

		mg/lt	
9	Copper	0.018 – 0.032 mg/lt	2.56 mg/lt
10	Boron	-	1.98 mg/lt
11	Aluminum	-	< 0.03 mg/lt

CONCLUSION:-

Based on the analytical data presented, it is observed that during the studied period the lake water has polluted many folds. This is due to contamination of water by sewage flow and dirt, dust, detergents coming through the stream water. The forming around the lake has also contributed to the pollution of the water beside contamination due to fecal waste of human and animals. Suitable steps must be undertaken to remove the causes of contamination of the stagnant water to support its biodiversity.

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