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ENVIRONMENTAL DEGRADATION OF MALLATHALLI LAKE IN BANGALORE DISTRICT, INDIA - A CASE STUDY

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ABSTRACT

An attempt was made to carry out baseline *in-situ* analysis of Malathalli lake. The lake falls within the Vrishabhavathi lake valley and Byramangala lake series. The catchment area of the lake is about 625ha. It is located on the western fringe of Bangalore city. Assessment of physico-chemical parameters was carried out mainly for pH, dissolved oxygen, BOD, suspended solids, total dissolved solids, alkalinity, hardness, nitrates, phosphates, sulphates, sodium, potassium, fluorides and chlorides. Malathalli is a contaminated lake with indicators of organic pollution showing highly variable sources of inputs. Dissolved oxygen is within lower limits at 3.25mg/L supporting the field observation on the dwindling fish catch in the lake. Moreover, the fish diversity is also disappearing leaving only those exotic species capable of tolerating lower DO levels. The average BOD is 6.0 mg/L. The pH is also above permissible limit at 8.9 showing alkaline nature of the lake. The total dissolved solids (TDS) were above permissible levels at 508 mg/L. For total hardness, the average was at 215.5 mg/L. Average calcium hardness was 86.6 mg/L as $CaCO_3$. Inorganic ions such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) have varied concentrations during the months. The maximum sodium (Na^+) concentration was in the month of June with 400 mg/L while the lowest was in January at 95.8 mg/L. Magnesium hardness was above permissible limit at 128.8 mg/L as $CaCO_3$. This shows a trend in ionic imbalances through the months in the lake caused by artificial contamination. This can also be correlated with excessive presence of Mg^+ ions at an average 31.4 mg/L. Chlorides were also above permissible level at 262 mg/L. Occurrence of hydroxide ions in natural water is very rare, but in January, hydroxide alkalinity of 3.3 mg/L as $CaCO_3$ was found. Sulphates (SO_4^{2-}) were with overall average range of 40.3 mg/L. For phosphates (PO_4^{3-}), the average was at 4.4 mg/L. Nitrates also were within tolerable limits of ICMR and BIS. The average nitrates concentration was at 10.9 mg/L as nitrates. However, the chloride-bicarbonate ratio of 2.2 confirms the seriousness of the status of pollution in the lake.

INTRODUCTION

Bangalore city, situated on undulating lands intermittently dotted with low hills and valleys, is also known as the city of lakes. Interestingly, most of these lakes are not natural water bodies, but man-made. Had it not been for the lakes, precious rain water would have naturally flown away from Bangalore along the natural slopes into the adjoining lands. Bangalore is, in fact, an urban agglomeration, a contiguous built-up area of about 451 sq. km also known as the Bangalore Urban District. Together with the Bangalore Rural District and Malur Taluk of Kolar District, it forms the Bangalore Metropolitan Region, an area of about 1300 sq. km (Kiran & Ramachandra 1999, Krishna et al. 1996).

Lakes of Bangalore occupy about 4.8% of city's geographical area (640 sq. km) covering both urban and rural areas. Bangalore lakes have several direct use values apart from replenishing the groundwater table and influencing climate of the city. The lakes in Bangalore form a chain of hydrological connections through them. The flow of the water runs from north to south-east as well as south-west along the natural gradient of the land. During monsoon, the surplus water from the upstream lake flows down into the next lake in the chain and from there further down. This connectiv-

ity did not allow an overflow of water out of the lake into surrounding areas as the additional quantity of seasonal water was, thus, transferred to other lakes. The system, hence, served as an excellent flood controller. Supported by a network of storm water drains, these lakes, thus, trapped and stored rainwater and served as the means of rainwater harvesting for agriculture, drinking and washing (Deepa et al. 1998, Kiran & Ramachandra 1999, Ramachandra et al. 2001).

Nowadays, due to rapid urbanization, almost 135 lakes have disappeared from the map of Bangalore. Lack of proper management strategies is the major factor that has led to the deterioration of lakes. Existing lakes too are under great pressure. Today the figure rests at 81, of these only 34 are recognized to be live lakes. In terms of number of water bodies, the reduction is as high as 35.09 percent, while in terms of water spread area, it shows an 8.66 percent decrease. Sedimentation also has reduced the impounding capacity of lakes.

The shallowness of water has increased evaporation rate. This has reduced groundwater levels on account of poor permeability with more and more silt, clay deposits, trash and toxic waste accumulation in the lakes, year after year and degeneration of groundwater quality. The water table has receded considerably and the water, which was available at a depth of 80 to 90 feet, has now increased to 400 to 500 feet and at some places it has completely vanished. There are around 2000 urban lakes in the State which were basically constructed to meet urban needs of the concerned towns. A full fledged survey/demarcation/classification of lakes in the BMRDA area is yet to be completed, latest satellite imageries coupled with toposheet of Survey of India, information have indicated that approximately 18260.48 ha of water spread in 2789 lakes in BMRDA area exists. Out of the above lakes, those falling in the BDA area, number 608 with water spread area of 4572.73 ha (Chakrapani 1988, Kiran & Ramachandra 1999, Kiran et al. 1998, Krishna et al. 1996).

In the present paper an attempt has been made to carry out baseline *in-situ* analysis of Malathalli lake, which falls within the Vrishabhavathi lake valley and Byramangala lake series. The catchment area of the lake is about 625ha. The sampling points were located using Global Positioning System (GPS). Criteria of selection of sampling points were mainly based on the proximity, accessibility towards the sampling points and the different activities taking place around the lake. Assessment of physico-chemical parameters was carried out for pH, dissolved oxygen, BOD, suspended solids, total dissolved solids, alkalinity, hardness, nitrates, phosphates, sulphates, sodium, potassium, fluorides and chlorides. Toposheet, GPS and ArcGIS software tools were used to demarcate the lake boundary and the catchment area of the lake.

MATERIALS AND METHODS

Study Area: Mallathalli lake is located on the western fringe of Bangalore city. The lake is irregular in shape and covers approximately 25.9ha and perimeter being approximately 2900 meters. The main source of water is rainwater, and the inlets are at the north and north-east of the lake. Mallathalli lake falls in the Vrishabhavathi lake valley and Byramangala lake series. The catchment area of the lake is about 625ha. Digitized lake boundary from Toposheet No. 57H/5 using ArcGIS gave the area of 27.53 ha. It was observed that the lake area has reduced from 27.53ha. to 25.95ha. The

Fig. 1: Location map of Mallathalli lake.

Fig. 2: Relief map of Mallathalli lake.

Fig. 3: Drainage map of Mallathalli lake.

highest point was 900m above seal level and lowest point was 840m above seal level (Figs. 1, 2, 3, 4).

Flora and fauna of the study area: Following were the different types of plants seen in and around the lake: *Ipomoea fistulosa, Calotropis, Lantana, Datura, Bambusa, Ficus religiosa, Acacia, Cocus nucifera, Typha, Cassia auriculata, Cassia renegira, Delonix religia, Croton sparciflorus, Pongamia, Hypnus, Peltoforum, Polygonum, Azardichta indica, Musa, Duranta, Psidium, Chara, Nitella, Vallisneria, Elodea, Hydrilla* and a variety of grasses. Following were the different types of animals seen in and around the lake:

Birds: *Phalaerocorax fuscicollis* (large cormorant), *Egretta garzetta* (egret), *Dicrurus paradiseus* (drongo), *Ardeola grayii* (pond heron), *Halcyon smyrnensis* (kingfisher), *Milvus mygrans* (kites), *Columba livia* (pigeons), *Corvus splendens* (crows).

Animals: *Bos gaurus* (cattle), *Calotes versicolor* (garden lizard), *Rattus rattus* (rodents), *Rana tigrina* (frog), *Bufo malanostictus* (frog).

Insects: *Periplaneta americana* (cockroach), *Poecilocerus piclus* (grasshopper), *Gryllus domesticus* (crickets), *Oryctes rhinoceros* (beetles), *Papilio species* (butterflies), *Musca domestica* (house fly), *Drosophila melanogaster* (drosophila), *Oechophylla smaragdina* (ants), mosquitoes, millipedes, centipedes and water striders.

Pollution sources: Malathalli lake is affected by several sources of pollution including washing of clothes, animals, vehicles and even bathing, especially on the northern and eastern banks of the lake. These activities lead to pollution of the lake by soaps, detergents and organic matter, and are taking place almost all around the lake. The lake area is also misused as public toilets leading to the unhygienic environment and increasing the organic load in the lake. To the south of the lake, its banks are used as crematorium. Dumping of garbage and other wastes around the lake is taking place, which not only pollutes the lake but also spoils its beauty. To the west of the lake, there is an *Areca*

plantation surrounded by several housing encroachments. The sewage line enters the lake from north-east and eastern banks of the lake. Cattle grazing can be seen to the west and north of the lake. The volume of the lake is decreasing due to the accumulation of silt coming from the run off. There are a number of upcoming layouts around the lake, which may affect the water both quantitatively and qualitatively.

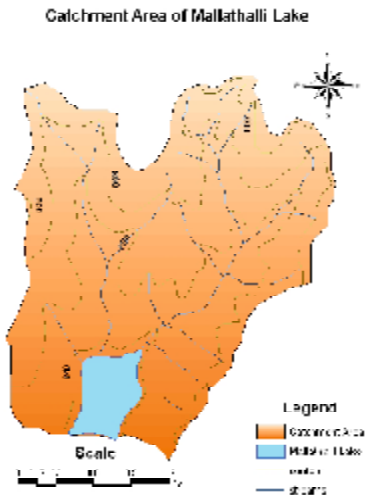

Fig. 4: Catchment area of Mallathalli lake.

Sampling preparation and collection: Basic information was collected from Toposheet No.57 H/5, Bangalore district, personal observations, questionnaire, Lake Development Authority (LDA), Karnataka State Pollution Control Board (KSPCB), and Central Pollution Control Board (CPCB). Water samples were collected in 2-litre plastic containers previously cleaned with 1:1 HNO_3. Toposheets No. 57 H/5, 57 H/9, scale 1:50000, Survey of India (SOI) were scanned, registered, edge-matched and digitized using ArcGIS, Version 9. Baseline data were created using these.

Laboratory analysis: The analysis of water samples was carried out following standard methods (APHA 1985). The determination of dissolved oxygen was made in the field, while for other parameters, the samples were transferred to the laboratory (APHA 1985, Manivaskam 2003, Babu & Tamrakar 1990). Derivation of data was done using Basic computer programme (Balasubramanian et al. 1991).

RESULTS AND DISCUSSION

The results of the study are given in Tables 1, 2 and 3. The pH ranged between 7.6 and 9.5. February and April had the maximum levels of pH at 9.5 while March had the minimum level of 7.6. Malathalli lake was found to be characteristically alkaline in nature. The pH slightly decreased after the onset of pre-monsoon showers in April and May. The pH of waters is largely governed by carbon dioxide, carbonates and bicarbonates equilibrium (Chapman 1995). This observation underscores the importance of rains in the recharging process and carrying capacity of Bangalore urban lakes.

Dissolved oxygen is an important parameter of water quality and is an index of chemical and biological processes taking place in water (APHA 1985, Manivasakam 2003). The DO values showed significant variations between the months. The maximum DO was in February with 4mg/L, while the minimum was in January at 2 mg/L. The average DO value was at 3.25 mg/L indicating significant levels of organic pollution in the lake. The average BOD was 5.56 mg/L.

Turbidity in water is due to colloidal and extremely fine dispersions. Suspended matter such as clay, silt, finely divided organic and inorganic matter, and plankton and other microorganisms contribute to turbidity (Edmondson 1959, APHA 1985, Manivasakam 2003). The values of turbidity varied between 0.1 to 5.0 NTU. The color quality was above permissible limits at 20 Hazen Units in March, April and June. January, February and May had relatively lower concentration at 10 Hazen Units. Usually, color is due to the presence of considerable amount of metallic ions, suspended matter, planktons, weeds and industrial effluents (Edmondson 1959).

Table 1: Showing total water quality parameters in Malathalli Lake Between January and June 2007.

	Max	Min	Avg.	SD.	Max	Min	Avg.	S.D	Max	Min	Avg.	S.D
		January				**February**				**March**		
pH	9.3	9.2	9.3	0.05	9.5	9.4	9.5	0.01	9.5	7.6	8.9	1.1
Turbidity	1.0	1.0	1.0	0.00	1.0	0.1	1.0	0.52	5.0	1.0	5.0	2.3
Color	10.0	10.0	10.0	0.00	10.0	10.0	10.0	0.00	20.0	20.0	20.0	0.0
TDS	382.0	297.0	330.3	45.37	481.0	451.0	470.7	17.04	668.0	660.0	664.0	4.0
TH	290.0	130.0	223.3	83.27	280.0	250.0	266.7	15.28	230.0	200.0	213.3	15.3
Cl	90.0	90.0	90.0	0.00	80.0	50.0	66.7	15.28	110.0	90.0	100.0	10.0
MH	200.0	40.0	133.3	83.27	230.0	170.0	200.0	30.00	120.0	100.0	113.3	11.5
Sodium	104.5	95.8	101.3	4.78	116.3	102.9	108.9	6.78	216.0	200.0	210.7	9.2
Potassium	25.8	19.8	23.1	3.04	21.6	21.0	21.3	0.30	28.4	27.7	28.1	0.4
Calcium	36.0	36.0	36.0	0.00	32.0	20.0	26.7	6.11	44.0	36.0	40.0	4.0
Magnesium	48.8	9.8	32.5	20.32	56.1	41.5	48.8	7.32	29.3	24.4	27.7	2.8
Chlorides	230.0	220.0	223.3	5.77	280.0	270.0	273.3	5.77	290.0	230.0	260.0	30.0
Fluorides	0.7	0.5	0.6	0.12	0.6	0.5	0.5	0.09	0.9	0.8	0.8	0.1
Sulphates	43.5	42.9	43.2	0.29	39.0	38.8	38.9	0.13	40.8	40.1	40.4	0.3
Phosphates	7.0	5.8	6.5	0.58	4.0	1.9	3.2	1.11	4.8	3.8	4.4	0.5
Nitrates	9.0	7.9	8.5	0.53	6.5	4.8	5.7	0.86	19.2	15.3	17.5	2.0
T. Alkalinity	160.0	110.0	136.7	25.17	190.0	160.0	173.3	15.28	220.0	200.0	210.0	10.0
P. alkalinity	80.0	60.0	70.0	10.00	60.0	30.0	43.3	15.28	0.0	0.0	0.0	0.0
Sus. Solids	9.0	5.0	7.7	2.31	41.0	23.0	34.7	10.12	61.0	17.0	43.3	23.2
		April				**May**				**June**		
pH	9.5	7.7	8.9	1.07	8.8	7.9	8.2	0.49	9.0	8.2	8.7	0.46
Turbidity	5.0	1.0	5.0	2.31	1.0	1.0	1.0	0.00	5.0	1.0	5.0	2.31
Color	20.0	20.0	20.0	0.00	10.0	10.0	10.0	0.00	20.0	20.0	20.0	0.00
TDS	506.0	491.0	499.3	7.64	633.0	624.0	627.3	4.93	519.0	352.0	457.0	91.43
TH	220.0	200.0	210.0	10.00	230.0	200.0	220.0	17.32	190.0	130.0	160.0	30.00
Cl	130.0	110.0	120.0	10.00	100.0	90.0	96.7	5.77	60.0	30.0	46.7	15.28
MH	90.0	90.0	90.0	0.00	140.0	100.0	123.3	20.82	140.0	100.0	113.3	23.09
Sodium	221.0	203.0	214.3	9.87	385.0	184.0	301.7	104.81	400.0	358.0	375.3	21.94
Potasium	28.9	23.3	26.8	3.07	25.7	25.0	25.4	0.36	32.5	26.5	29.8	3.06
Calcium	52.0	44.0	48.0	4.00	40.0	36.0	38.7	2.31	24.0	12.0	18.7	6.11
Magnesium	22.0	22.0	22.0	0.00	34.2	24.4	30.1	5.08	34.2	24.4	27.7	5.63
Chlorides	310.0	290.0	303.3	11.55	310.0	170.0	253.3	73.71	280.0	230.0	260.0	26.46
Fluorides	0.8	0.7	0.8	0.05	0.5	0.2	0.4	0.12	0.4	0.3	0.3	0.08
Sulphates	40.6	40.2	40.3	0.26	53.0	49.5	51.8	1.99	29.0	26.0	27.3	1.53
Phosphates	4.6	3.7	4.3	0.51	4.2	2.8	3.7	0.75	5.2	4.0	4.4	0.71
Nitrates	19.0	17.9	18.3	0.56	8.4	6.6	7.7	0.92	8.4	6.6	7.7	0.92
T. Alkalinity	210.0	200.0	203.3	5.77	350.0	170.0	240.0	96.44	150.0	110.0	130.0	20.00
P. alkalinity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	30.0	33.3	5.77
Sus. Solids	61.0	16.0	43.7	24.21	71.0	56.0	64.0	7.55	64.0	46.0	53.0	9.64

Units in mg/L except pH, turbidity (NTU), colour (Hazen units)

Maximum Total Dissolved Solids (TDS) were in March at 668 mg/L, and the minimum in the month of January with 297 mg/L. The average TDS was at 508.1 mg/L. The required desirable limit based on BIS and ICMR is 500 mg/L. A high content of dissolved solids elevate density of water, influences osmoregulation, and reduces gas solubility and utility of water for drinking, irrigation and industries (Edmondson 1959, Manivasakam 2003). For suspended solids, the maximum was in May at 71.0 mg/L, and the minimum in January at 5.0 mg/L. The average was 41.0 mg/L.

For total hardness, the average value was at 215.5 mg/L. Average calcium hardness was 86.6 mg/L. Inorganic ions such as sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}) varied during the months. The maximum sodium concentration was in the month of June with 400 mg/L while the lowest was in January at 95.8 mg/L. The average was 218.7 mg/L. Sodium ions

Table 2: Total water quality parameters in the selected sampling stations of the lake.

Parameters	Sampling Station 1				Sampling Station 2				Sampling Station 3			
	Max	Min	Avg.	SD.	Max	Min	Avg.	S.D	Max	Min	Avg.	S.D
pH	9.5	8.0	9.1	0.58	9.5	7.9	9.0	0.72	9.5	7.6	8.6	0.80
Turbidity (NTU)	5.0	1.0	1.0	2.19	5.0	1.0	1.0	2.19	1.0	0.1	1.0	0.37
Color	20.0	10.0	20.0	5.48	20.0	10.0	20.0	5.48	20.0	10.0	10.0	5.48
TDS	664.0	382.0	523.5	105.49	660.0	297.0	486.8	144.01	668.0	312.0	514.0	126.93
TH	270.0	130.0	201.7	58.11	290.0	160.0	225.0	43.70	280.0	190.0	220.0	36.33
Calcium Hardness	130.0	30.0	86.7	34.45	120.0	60.0	90.0	20.00	110.0	50.0	83.3	26.58
Sodium	400.0	95.8	231.1	133.20	358.0	107.6	217.3	90.78	368.0	116.3	251.1	101.64
Potassium	30.5	19.8	24.7	3.96	28.3	21.0	26.0	3.00	32.5	21.3	27.3	4.18
Calcium	52.0	12.0	34.7	13.78	48.0	24.0	36.0	8.00	44.0	20.0	33.3	10.63
Magnesium	48.8	9.8	28.1	13.07	48.8	22.0	32.9	10.32	56.1	22.0	33.3	12.97
Chlorides	310.0	170.0	251.7	47.50	310.0	220.0	268.3	35.45	310.0	220.0	266.7	35.02
Fluorides	0.8	0.4	0.6	0.16	0.8	0.3	0.6	0.22	0.9	0.2	0.6	0.27
Sulphates	53.0	26.0	40.4	8.70	52.8	29.0	40.7	7.67	49.5	27.0	39.9	7.34
Phosphates	6.5	3.6	4.5	1.04	5.8	4.0	4.8	0.68	7.0	1.9	3.9	1.72
Nitrates	18.1	6.5	11.1	5.41	19.2	0.0	9.9	7.38	19.0	3.5	10.0	6.55
T. Alkalinity	350.0	110.0	198.3	82.80	210.0	110.0	173.3	38.30	220.0	130.0	175.0	33.91
Sus. Solids	65.0	9.0	42.0	21.32	64.0	5.0	48.5	22.85	51.0	9.0	29.8	17.90

Units in mg/L except pH, turbidity (NTU), colour (Hazen units)

Table 3: Average physico-chemical results in Malathalli Lake Between January 2007 and June 2007.

Parameters	January	February	March	April	May	June	Average Total
pH	9.3	9.5	8.9	8.9	8.2	8.7	8.9
Turbidity (NTU)	1.0	1.0	5.0	5.0	1.0	5.0	5.0
Color (Hazen)	10.0	10.0	20.0	20.0	10.0	20.0	20.0
Total Dissolved Solids (mg/L)	330.3	470.7	664.0	499.3	627.3	457.0	508.1
Total Hardness (mg/L)	223.3	266.7	213.3	210.0	220.0	160.0	215.5
Calcium Hardness (mg/L)	90.0	66.7	100.0	120.0	96.7	46.7	86.6
Sodium (mg/L)	101.3	108.9	210.7	214.3	301.7	375.3	218.7
Potassium (mg/L)	23.1	21.3	28.1	26.8	25.4	29.8	25.75
Calcium (mg/L)	36.0	26.7	40.0	48.0	38.7	18.7	34.5
Magnesium (mg/L)	32.5	48.8	27.7	22.0	30.1	27.7	31.4
Chlorides (mg/L)	223.3	273.3	260.0	303.3	253.3	260.0	262.2
Fluorides (mg/L)	0.6	0.5	0.8	0.8	0.4	0.3	0.6
Sulphates (mg/L)	43.2	38.9	40.4	40.3	51.8	27.3	40.31
Phosphates (mg/L)	6.5	3.2	4.4	4.3	3.7	4.4	4.4
Nitrates (mg/L)	8.5	5.7	17.5	18.3	7.7	7.7	10.9
T. Alkalinity (mg/L)	136.7	173.3	210.0	203.3	240.0	130.0	182.2
Sus. Solids (mg/L)	7.7	34.7	43.3	43.7	64.0	53.0	41.0
Dissolved oxygen (mg/L)	2.0	4.0	3.7	3.4	2.7	3.7	
BOD (mg/L)	4.0	8.8	5.0	4.1	5.9	6.4	

largely make way into water medium, through weathering of rocks. High sodium content makes water salty and unfit for consumption, and makes germination of seeds difficult, which eventually affects crop yield. Potassium levels varied little with months. The maximum concentration was in June at 32.5 mg/L, and the minimum in January at 19.8 mg/L. Potassium ions occur in natural waters in far less concentration than Ca^{2+}, Mg^{2+} and Na^{+}. It imparts softness and makes water salty. Though,

found in small amounts, it plays a vital role in metabolism of fish, water environments and is an important macronutrient (Chapman 1996, Edmondson 1959).

Calcium ions were at maximum in April at 44 mg/L, while minimum in June at 12 mg/L. The overall average of calcium concentration was 34.5 mg/L. Magnesium ranged between 9.8 mg/L and 56.1 mg/L. The overall average magnesium concentrations was 31.4 mg/L. The trend in concentrations of ions in Malathalli lake followed the pattern in decreasing order: $(Na^{+}) > (Ca^{2+}) > (Mg^{2+}) > (K^{+})$.

Chloride ions are generally present in natural waters and their presence can be attributed to the dissolution of salt deposits, discharges of effluents from industries, sewage discharges, irrigation, etc. (Manivasakam 2003). This can be attributed to the fact that small scale irrigation activities are the major occupation for many villagers depending on the lake waters for their peri-urban agricultural activities. Chlorides are not generally harmful to human beings, but their cationic constituents are usually harmful. In Malathalli lake, the overall average chloride concentration was 262 mg/L.

For fluorides, the maximum concentration was in March at 0.9 mg/L, while the minimum in May at 0.2 mg/L. The overall average was 0.6 mg/L. Fluorides have dual significance in water supplies. High concentration of fluoride causes skeletal fluorosis while concentrations less than 1.0 mg/L result in dental caries. Hence, it is essential to maintain fluoride concentration between 0.8 and 1.0 mg/L.

Sulphates were within tolerable limits. The maximum was 53.0 mg/L in May, but after spell of the monsoon rains, the levels have declined to 26.0 mg/L in June showing again the importance of monsoon rains in diluting lake pollution. Overall average range was at 40.3 mg/L. For phosphates, the maximum level was in January at 7.0 mg/L, and the minimum in June at 2.8 mg/L. The average was at 4.4 mg/L. Phosphates may occur in surface or ground waters as a result of leaching from minerals or ores, from agricultural run off, and as a major constituent of municipal sewage.

Nitrates occur in ground waters mainly due to leaching losses from soils, fertilizers applied to soil, sewage, refuse dumps and industrial discharges. Nitrates, when present in high concentration in drinking water, are considered harmful to infants because of the production of 'blue baby disease'. The maximum nitrate was in March at 19.2 mg/L, and the minimum in June at 6.6 mg/L. Nitrates were well within tolerable limits of ICMR and BIS in the present study. The average nitrate concentration was at 10.9 mg/L. Overall assessment of anionic constituents in Malathalli lake follows the following trend: $(Cl^{-}) > (SO^{2-}_{4}) > (NO^{-}_{3}) > (PO^{3-}_{4}) > (Fl^{-})$

The average total alkalinity between January and June was 182.2 mg/L. Average phenolpthalein alkalinity was at 24.4 mg/L. In January, the average hydroxide alkalinity was significant at 3.3 mg/L, and carbonate alkalinity at 133.4 mg/L. In February, the carbonate alkalinity reached 86.4 mg/L, while average bicarbonate alkalinity was at 86.9 mg/L. In March, April and May, average bicarbonate alkalinity was equal to the total alkalinity at 210, 203.3 and 240 mg/L respectively. But in June, carbonate alkalinity returned to their significant levels at an average of 66.6 mg/L. Bicarbonate alkalinity in June was at 63.4 mg/L. The average chloride-bicarbonate ratio was 2.2 showing a high contamination level of the lake.

CONCLUSION

Malathalli is a contaminated lake with indicators of organic pollution showing highly variable sources of inputs. Dissolved oxygen is within lower limits at 3.25mg/L supporting the field observation on the dwindling fish catch in the lake. Moreover, the fish diversity is also disappearing leaving only

those exotic species capable of tolerating lower DO levels. The average BOD is 6.0 mg/L which is as twice the tolerance limit set under IS: 2296-1982 standards for BOD. The pH is also above permissible limit at 8.9. This shows that the lake is highly alkaline in nature. The color quality is also above the permissible level at 20 Hazen Units while the desirable limit is 5 Hazen Units (BIS 10500:1991). The TDS were above permissible levels at 508 mg/L.

Magnesium hardness was above permissible limit at 128.8 mg/L. The tolerance limit should not cross 125 mg/L (IS: 10500:1991). This shows a trend in ionic imbalance in the lake caused by artificial contamination. This can also be correlated with excessive presence of magnesium ions at an average 31.4 mg/L. Chlorides were also above permissible level at 262 mg/L, well above the permissible limit of 250 mg/L (IS: 10500:1991) and 200 mg/L as per the ICMR standards (Indian Council for Medical Research). Occurrence of hydroxide ions in natural water is very rare, but in January, hydroxide alkalinity of 3.3 mg/L was found. Chloride bicarbonate ratio of the lake was 2.2. indicating highly polluted level of the lake.

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