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Muzamil Bashir
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Rajendra Chauhan
MVM College Bhopal, Madhya Pardesh, India

Nasrul Amin
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Mohammad Farooq Mir
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Mohd Ashraf Ganaie
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Rifat Farooq
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Sauliha Tabasum
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Adil Hussain Shah
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Correspondence
Muzamil Bashir
Hydrobiology Research Laboratory, The constituent College of Cluster University Srinagar, Kashmir, India

Impact of anthropogenic pressure on water quality and their co-relations with the trophic status of Anchar Lake

Muzamil Bashir, Rajendra Chauhan, Nasrul Amin, Mohammad Farooq Mir, Mohd Ashraf Ganaie, Rifat Farooq, Sauliha Tabasum and Adil Hussain Shah

Abstract
During the present research work, "Impact of anthropogenic pressure in relation to the water quality of Anchar Lake" is the statistical presentation of strongly correlated parameters as responsible indicators of pollution due to anthropogenic pressure in famous Anchar Lake. 18 physico-chemical parameters were studied at six different selected sites of Anchar Lake. The sites were morphologically different owing to the level of influent pollutants. Eutrophication of inland water bodies has become synonymous with the deterioration of water quality, which interferes with most of its beneficial uses. Water depth was varying from 0.71 m to 1.73 m with an average of 1.28±0.07m, transparency 0.27 m to 0.93 with the mean value of 0.68±0.05 m, temperature between 3.10C and 25.60C, pH of water was on alkaline side (7.3 to 8.3), dissolved oxygen was found to be higher during autumn and winter seasons with an average dissolved oxygen content as 4.2±0.30 mg/L, free carbon dioxide ranged from 0.40 mg/L to 34.00 mg/L, Conductivity ranged from 296.4 µS/cm to 461.0 µS/cm, silicates ranged from 2.00 to 4.46 mg/L, Calcium fluctuated between 13.8 mg/L to 58.6 mg/L During this study period, the lower values of total phosphorous were recorded during autumn season and higher during warmer periods, total hardness ranged from 125.2 mg/L to 197.1 mg/L, total alkalinity ranged between 236.4 mg/L to 381.2 mg/L, Higher values of ammonical nitrogen were recorded during winter and lower during summer season, nitrate nitrogen values recorded were in the range 137.3 µg/L to 323.4 µg/L. Correlation among various parameters showed significant positive and negative trends.

Keywords: Anchar Lake, Anthropogenic pressure, Water quality, co-relation

Introduction
The Anchar lake is fluviatile in its origin; shallow basined and is situated 12 kms to the northwest of Srinagar city within the geographical coordinates of 34° 20´-34° 26´ N latitude and 74°82´ and 74° 85´ E longitude at 1584 m.a.s.l. The lake is mono basined with its main catchment comprising Srinagar city and a number of bordering villages. A network of channels from the river Sind enters the lake on its western shore and serves as the main source of water. The littorals of the lake are surrounded by a thick canopy of trees, willows and popular trees providing the base material for the manufacture of baskets, cricket bats, wood carvings, wicker work, etc. Besides numerous values of the lake in meeting human needs for survival and socio-economic development.

Water is one of the most common, yet the most precious, resource on Earth. Water is one of the important natural resources of the planet earth and essential for the survival of all forms of life. Even though 80 % of the Earth's surface is covered by water, 97 % of earth's water is saline and 3 % is fresh water. Out of 3 % fresh water, 2.14 % water is trapped in the giant glaciers and polar ice caps. Thus, not even 1% of total fresh water is available for drinking, agriculture, domestic and industrial consumption (Khadsan and Kadu 2003) [18].

The seasonal variations in physico-chemical factors have a profound effect on the distribution and population density of both fauna and flora (Mahboob, 1986, 1988 b, 1989 a; Mahboob & Sheri, 2001) [23-26]. Temperature measurements occupy a central position in limnology and one of the most important and essential parameters of aquatic habitats because almost all the physical, chemical and biological properties are governed by it. It influences the oxygen contents of water quantity and quality of autotrophs, while affecting the rate of photosynthesis and also indirectly affecting the quantity and quality of heterotrophs.

During present investigation a brief account of various parameters to be studied of Anchar lake are as under;
The physical parameters to be studied are (temperature, transparency, depth etc.) while the chemical parameters to be studied are pH, dissolved oxygen, free carbondioxide, conductivity, total dissolved salts, total alkalinity, chloride, total hardness, magnesium hardness, ammonical nitrogen, nitrate nitrogen, phosphate, biological oxygen demand and chemical oxygen demand.
The intensity and seasonal variation in temperature of water directly affect the productivity of lakes. Water temperature has direct relationship with phytoplankton population. The temperature of about 35 ºC is generally considered as maximum for survival of aquatic life. The temperature of water in a lake changes with the seasons and often varies with depth. During spring and summer, the sun warms the upper layer of the waters. As the sun continues to warm the lake surface, the temperature differences increase between the surface and deeper waters. Water temperature plays a driving role in most physicochemical processes in lakes (Fang and Stefan, 1999) [7].
Turbidity or suspended solids is the measurement of inhibition of light passing through a water sample (Landau, 1992) [20]. Turbidity is the name given to the clarity of water which is affected by the amount of the suspended solids in it and turbidity reduces the light penetrating depth, and hence, reduces the growth of the plants (Landau, 1992) [20].
The pH expresses the acidity or alkalinity of water which is determined by means of hydrogen ion (H+) and the hydroxyl ion (OH-) in water. Hydrogen ion concentration plays an important role in the biological processes of almost all aquatic organisms (Welch, 1952) [44]. Waters of around pH 7 are called as neutral. The seasonal variation in pH was mainly affected by temperature, salinity, carbonate and bicarbonate system rather than the photosynthetic activity of the primary producers (Ezz El-Din, 1990) [6].
Total dissolved solids refer to dissolved matter in water. They are very useful parameters describing the chemical constituents of the water and can be considered as a general of edaphic relations that contribute to productivity within the water body (Goher, 2002) [11]. Higher the value of dissolved solids, greater will be the amount of ions in water. A high concentration of dissolved solids increases the density of water, affects osmoregulation of fresh water organisms, reduces solubility of gases and utility of water for drinking, irrigational and industrial purposes (Boyd, 1998) [3]. Oxygen content is important for direct need of many organisms and affects the solubility and availability of many nutrients; therefore productivity of aquatic ecosystem (Wetzel, 1983) [46].
Dissolved Oxygen in water depends mainly upon temperature, concentration of dissolved salts, wave action, velocity of wind, pollution load, photosynthetic activity, and respiration rate by organisms (Ganapati, 1943; Reid, 1961; Zutshi & Vass, 1978) [9, 34, 48].
Chlorides occur naturally in all types of water.
High concentration of chloride in water is considered to be the indicator of pollution especially due to higher organic waste of animal origin or industrial effluents. Higher chloride content is due to contamination through large quantity of sewage input. Higher concentration of chloride in water is an indicator of eutrophy Kausik 1992 [16]. The nitrate and phosphate are two important constituents that immensely help in the growth of plants. If they are present in the lake they excessively promote the growth of aquatic weeds and pollute our aquatic resources. Presence of nitrate in water indicates the final stage of mineralization (Nema *et al.*, 1984) [30]. Phosphate has a few sources in nature and also acts as a regulating factor for productivity of water body. Higher concentration of phosphate is an indicator of pollution, which induce possibility of eutrophication (Singare *et al.*, 2011) [37]. Sulphate forms an important constituent of hardness and used by organisms for protein synthesis. It enters into water body by the weathering of sedimentary rocks, by bathing and washing clothes (Jain *et al.*, 1996) [14].

Materials and Methods
During the present investigation the lake was studied for a period of 18 months. The lake was divided into six collection sites on the basis of different types of substratum and ecology of the sites. As such the present lake was divided into six sites shown below
1. Sangam site, 2. Zinymar site, 3. Centre site, 4. Skims hospital site, 5. Eid-gah site, 6. Jinab shab shrine site.
All the parameters were analyzed by the following methods:

Temperature (^{0}C): The atmospheric and water temperature were enumerated through good grade mercury thermometer (0-50°C with 0.2°C least count) and thermoprobe.

Hydrogen ion concentration (pH): The hydrogen ion concentration (pH) was recorded with the help of Grip pH meter (Systronics,).

Dissolved Oxygen(mg/l): Dissolved oxygen was determined by modified Winkler's method.

Carbon Dioxide (mg/l): Free carbon dioxide was analyzed at the sites by using phenolphthalein indicator and sodium hydroxide titrant.

Total Dissolved Solids (mg/l): The total dissolved solids were determined with the help of TDS meter (DREL 2000 HACH, INDIA) and expressed as mg/l.

Determination of Total Alkalinity: For estimation of phenolphthalein alkalinity 50 ml of sample was taken in an Erlenmeyer flask and was titrated against 0.02N H_2SO_4 in the presence of phenolphthalein indicator till disappearance of pink colour.

Total Hardness (mg/l): Total hardness was determined by using titrimetric method.

Calcium Hardness (mg/l): Calcium hardness was determined by adding 1 ml of 8% sodium hydroxide solution and 0.2 g murexide indicator to 50 ml of sample and titrating it against 0.01 M EDTA (ethylene diamine tetra amino acid) titrant till the pink colour changed to purple.

Chloride (mg/l): Chloride was determined by Argentometry method (APHA, 1995).

Determination of Nitrate, Phosphate, Ammonia Nitrogen by.
Determination of Biochemical Oxygen Demand (BOD): The Biochemical oxygen demand was determined by the

sample in dark at 20° C for five days (BOD_5) in a BOD incubator.

Determination of Chemical Oxygen Demand (COD): The COD was determined by potassium dichromate consumption method.

Results

During the present research work, 18 physico-chemical parameters were studied at six different selected sites of Anchar Lake. The sites were morphologically different owing to the level of influent pollutants. Care was taken to investigate the parameters exclusively under a quality control protocol. Table 1 depicts the monthly variation in water quality parameters as mean of all the sites together and site wise fluctuation as minimum and maximum values at particular sites. Classifying the parameters to know the trophic status of the Anchar Lake is presented in table 2. Correlations of water quality parameters with the trophic status of Anchar Lake was established by the related references to support our findings.

Water temperature (°C) ranged from 7.83 to 25.2 with a mean±SD of 16.51±6.49 (*Var.* = 42.18). Olsen (1950) declared this ranges of water temperature as indicator of eutrophic state. The mean depth (m) ranged from 0.89 to 1.8 with a mean±SD of 1.34±0.26 (*Var.* = 0.06). On the other hand, transparency (m) ranged from 0.08 to 0.24 with a mean±SD of 0.16±0.05 (*Var.* = 0.002). Lee *et al*. (1981) [21] declared this ranges of transparency as indicator of eutrophic state. pH, on the other hand ranged from 7.11 to 8.02 with a mean±SD of 7.56±0.27 (*Var.* = 0.07) suggested the condition as alkaliphilous.

Dissolved Oxygen (mg/l) ranged from 5.65 to 9.06 with a mean ±SD of 7.355±1.09 (*Var.* = 1.19). declared this ranges of dissolved oxygen as indicator of hard water. Similarly carbon dioxide (mg/l) ranged from 6.25 to 14.02 with a mean±SD of 10.13±2.16 (*Var.* = 4.69). Reid and Wood (1976) [35] declared this ranges of carbon dioxide as indicator of hard water. Conductivity (µS/cm) ranged from 152.3 to 380.2 with a mean ±SD of 266.25±84.84 (*Var.* = 7198.20). declared this ranges of conductivity range in hard water. On the other hand, total dissolved solids (mg/l) ranged from 98.2 to 400.2 with a mean ±SD of 249.2±98.82 (*Var.* = 9766.76). declared this ranges of TDS as indicator of pollution.

Total alkalinity (mg/l) ranged from 50.22 to 132.7 with a mean±SD of 91.46±29.35 (*Var.* = 861.95). Spence (1964) [40] declared this ranges of total alkalinity as indicator of nutrient rich state. Similarly Chloride (mg/l) ranged from 7.98 to 19.04 with a mean±SD of 13.51±3.53 (*Var.* = 12.47). declared this ranges of chloride as indicator of polluted state of the lake ecosystem. On the other hand, total hardness (mg/l) ranged from 106.00 to 303.21 with a mean±SD of 204.6±77.44 (*Var.* = 5997.22). Fractionates of hardness showed almost the same trend at all the study sites of the lakes with slight deviations. Calcium hardness (mg/l) ranged from 62.5 to 130.11 with a mean±SD of 96.3±22.13 (*Var.* = 490.07). Likewise, magnesium hardness (mg/l) ranged from 62.5 to 130.11 with a mean±SD of 96.3±22.13 (*Var.* = 490.07). For all the three hardness parameters declared it true for hard water state of lake ecosystem.

Among the best pollution state indicators, ammonical nitrogen (mg/l) ranged from 0.05 to 0.17 with a mean±SD of 0.11±0.04 (*Var.* = 0.001). Similarly, nitrate nitrogen (mg/l) ranged from 0.2 to 0.67 with a mean±SD of 0.43±0.13 (*Var.* = 0.019). For both the cases, Vollenweider (1968) [42] declared these ranges as indicator of mesotrophic state. On the other hand phosphate (mg/l) ranged from 0.05 to 0.27 with a mean±SD of 0.16±0.07 (*Var.* = 0.006), which was declared as polytrophic state by Lee *et al* (1981) [21]. Biological oxygen demand BOD_3 (mg/l) ranged from 2.52 to 7.2 with a mean±SD of 4.86±1.36 (*Var.* = 1.86), while as chemical oxygen demand (mg/l) ranged from 32.52 to 61.2 with a mean±SD of 46.86±9.30 (*Var.* = 86.54). For both these ranges, declared the ranges as indicator of pollution. An overall perspective declared Anchar Lake as the eutrophic lake, supported by the findings of the other authors and workers worldwide.

Table 3 explains the factor loading value and explained variance of water quality parameters of Anchar Lake. Water temperature showed negative correlation with at all the three factor loading levels, while as pH showed positive correlations of 0.144 (PC1), 0.021 (PC2) and 0.816 (PC3) as the factor loading values. Except PC2 (-0.292), dissolved oxygen showed positive correlation for PC1 (0.753) and PC2 (0.024). Likewise, except PC3 (-0.612), electrical conductivity showed positive correlation for PC1 (0.657) and PC2 (0.035). Both Ca and Mg showed positive correlation as the factor loading values of pollution at all the three levels. The pollution indicators ammonical nitrogen, nitrate nitrogen and phosphate showed positive correlations at PC1 (0.764, 0.838 and 0.022) and PC2 (0.498, 0.115, and 0.712) levels and negative correlation at PC3 (-0.039, -0.147 and -0.138). BOD and COD values showed mixed correlation at different factor loading levels. Over all the Eigen values and total variance (%) showed a decreasing trend for all the loading values PC1 (4.63; 30.68), PC2 (3.01; 27.34) and PC3 (1.44; 11.8).

Table 1: Mean values of monthly fluctuation in physico-chemical water parameters of six study sites of Anchar Lake from Dec '14 to Jun '16

s	Parameters	Dec '14	Jan '15	Feb '15	Mar' 15	Apr '15	May '15	Jun '15	Jul '15	Aug '15	Sep '15	Oct '15	Nov '15	Dec '15	Jan '16	Feb '16	Mar' 16	Apr '16	May '16	Jun '16
1	Water temperature	8	8	7.83	8.5	12.17	19	21.92	24.5	25.2	24.11	18.22	13.6	10.9	9.2	8.2	9	12.25	18.65	22.3
2	Depth	0.9	0.9	1	1.1	1.33	1.67	1.11	0.93	0.89	0.89	0.92	0.94	0.94	0.97	0.99	1.15	1.29	1.8	1.21
3	Transparency	0.24	0.24	0.21	0.18	0.16	0.11	0.09	0.08	0.08	0.09	0.12	0.14	0.15	0.18	0.18	0.18	0.16	0.12	0.08
4	pH	7.25	7.21	7.18	7.17	7.2	7.4	7.52	8.02	8.01	7.79	7.56	7.5	7.39	7.3	7.21	7.19	7.11	7.5	7.65
5	Dissolved Oxygen	8.88	8.9	8.98	8.62	8.07	7.45	6.95	6.07	5.65	6.09	7.22	8.01	8.56	8.88	9.06	8.92	8.05	8.01	7.02
6	Free Carbondioxide	9.2	8.9	13.17	11.67	9.67	8.45	7.33	6.25	6.88	7.52	8.52	9.99	10.22	12.01	14.02	12.11	10.05	8.44	8
7	Conductivity	152.3	157.5	163.67	320.83	362.83	368	322.5	296	257.8	210.5	195.2	180.5	171.8	162.8	180.22	298.6	380.2	375.6	299.3
8	TDS	98.2	105.2	104.67	242.17	323.83	375.83	280.5	212.5	200.5	198.5	145.8	132.9	119.2	110.5	108.2	250.22	310.11	400.2	300.5
9	Total Alkalinity	132.7	130.8	128.67	100.83	91	62	54.98	50.28	50.22	60.22	78.99	92.57	100.9	119.2	132.22	105.2	100.1	73.2	60.5
10	Chloride	8.02	8.11	8.13	12.95	18.07	15.57	13.08	10.87	11.22	10.52	9.99	9.01	8.59	8.02	7.98	13.22	19.04	16.21	12.37
11	Total hardness	300.2	298.5	299.33	241.33	212	138.33	118.83	106	106	119.5	192.5	230.2	299.2	300.1	303.21	260.2	200.18	150.22	120.11
12	Calcium hardness	128.2	125.4	123.33	109.83	104.17	90.33	75.25	64.23	62.5	75.6	89.9	100.9	115.6	122.8	130.11	110.22	105.2	89.56	73.11
13	Magnesium hardness	33.22	33.34	33.21	24.34	19.72	11.3	8.83	7.97	7.99	7.58	8.32	12.22	19.35	29.21	35.01	25.22	18.99	11.01	9.25
14	Ammonical nitrogen	0.17	0.16	0.16	0.12	0.09	0.07	0.06	0.05	0.05	0.07	0.1	0.12	0.15	0.15	0.17	0.13	0.09	0.08	0.07
15	Nitrate nitrogen	0.55	0.54	0.54	0.45	0.38	0.27	0.3	0.2	0.2	0.2	0.31	0.42	0.49	0.55	0.67	0.49	0.41	0.31	0.3
16	Phosphate	0.27	0.25	0.25	0.21	0.13	0.08	0.07	0.05	0.05	0.11	0.16	0.18	0.21	0.23	0.27	0.22	0.13	0.09	0.06
17	BOD	2.52	2.99	3.67	4.33	4.83	6	6.43	6.92	7.2	6.29	6.01	5.65	5.02	4.62	3.88	5.01	5.22	6.52	7.01
18	COD	32.52	32.89	34.67	37.83	45.16	48.83	53	58	59.5	61.2	55.6	52.11	46.3	40.2	35.22	38.01	46.22	48.09	52.88

Table 2: Water Quality correlations with the Trophic status of Anchar Lake

			Site 1		Site 2		Site 3		Site 4		Site 5		Site 6			
S.N	Parameters	Unit	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Mean±SD	Variance
1	Water temperature	°C	7.83	25.2	7.52	26.2	8.02	25.0	8.02	26.2	7.69	24.9	8.02	26.00	16.51±6.49	42.18
2	Depth	M	0.89	1.8	0.88	1.9	0.87	1.9	0.91	2.0	1.00	2.01	1.00	2.03	1.34±0.26	0.06
3	Transparency	M	0.08	0.24	0.07	0.26	0.08	0.25	0.07	0.25	0.11	0.27	0.11	0.28	0.16±0.05	0.002
4	pH	mg/l	7.11	8.02	7.21	7.95	7.13	8.01	7.14	8.01	7.12	8.03	7.12	8.05	7.56±0.27	0.07
5	Dissolved Oxygen	mg/l	5.65	9.06	5.66	9.07	5.66	9.07	5.67	9.08	6.01	10.01	6.02	10.02	7.355±1.09	1.19
6	Free Carbon dioxide	mg/l	6.25	14.02	6.25	14.00	6.26	14.03	5.25	14.05	5.20	12.02	5.01	11.56	10.13±2.16	4.69
7	Conductivity	µS/cm	152.3	380.2	153.0	382.0	153.2	381.5	153.6	380.2	162.5	400.2	161.5	392.5	266.25±84.84	7198.20
8	TDS	mg/l	98.2	400.2	9	400.2	98.2	400.2	98.2	400.2	98.2	400.2	98.2	400.2	249.2±98.82	9766.76
9	Total Alkalinity	mg/l	50.22	132.7	50.22	132.7	50.22	132.7	50.22	132.7	50.22	132.7	50.22	132.7	91.46±29.35	861.95
10	Chloride	mg/l	7.98	19.04	7.98	19.04	7.98	19.04	7.98	19.04	7.98	19.04	7.98	19.04	13.51±3.53	12.47
11	Total hardness	mg/l	106	303.21	106	303.21	106	303.21	106	303.21	106	303.21	106	303.21	204.6±77.44	5997.22
12	Calcium hardness	mg/l	62.5	130.11	62.5	130.11	62.5	130.11	62.5	130.11	62.5	130.11	62.5	130.11	96.3±22.13	490.07
13	Magnesium hardness	mg/l	7.58	35.01	7.58	35.01	7.58	35.01	7.58	35.01	7.58	35.01	7.58	35.01	21.29±10.25	105.10
14	Ammonical nitrogen	mg/l	0.05	0.17	0.05	0.17	0.05	0.17	0.05	0.17	0.05	0.17	0.05	0.17	0.11±0.04	0.001
15	Nitrate nitrogen	mg/l	0.2	0.67	0.2	0.67	0.2	0.67	0.2	0.67	0.2	0.67	0.2	0.67	0.43±0.13	0.019
16	Phosphate	mg/l	0.05	0.27	0.05	0.27	0.05	0.27	0.05	0.27	0.05	0.27	0.05	0.27	0.16±0.07	0.006
17	BOD	mg/l	2.52	7.2	2.52	7.2	2.52	7.2	2.52	7.2	2.52	7.2	2.52	7.2	4.86±1.36	1.86
18	COD	mg/l	32.52	61.2	32.52	61.2	32.52	61.2	32.52	61.2	32.52	61.2	32.52	61.2	46.86±9.30	86.54
Trophic Status																**Eutrop-hic**

Table 3: Factor loading values and explained variance of water quality parameters of Anchar Lake

Parameter	PC1	PC2	PC3
Temp	-0.894	-0.029	-0.083
pH	0.114	0.021	0.816
DO	0.753	-0.292	0.024
EC	0.657	0.035	-0.612
Ca	0.742	0.126	0.335
Mg	0.544	0.369	0.445
Ammonical Nitrogen	0.764	0.498	-0.039
Nitrate Nitrogen	0.838	0.115	-0.147
Phosphate	0.022	0.712	-0.138
BOD	-0.042	0.791	0.34
COD	0.131	0.723	-0.031
Eigen values	4.63	3.01	1.44
Total variance (%)	30.68	27.34	11.81
Cumulative variance (%)	30.68	58.03	69.84

In order to establish the level of pollution at different sampling stations of Wular Lake, the pollution indicators were used for the assess, which revealed the level of pollution in Anchar Lake owing to the combined effect produced by different factors. The Site 1 (Sangam) showed highest pollution level, documented by indices, which include WQI (120), D (3.25), OPI (76.55) and PPI (25), which was followed by Site 2 (SKIMS hospital), which sowed water quality index value of 120, pertinent to Site 1. However Simpson's D was comparatively lower (2.89) than site 1. Similarly organic pollution index was lower (54.22) at site 2 than site 1, along with Palmer's pollution index (21). Site 3 (Jinab Shab) showed WQI of 105, D value of 2.65, OPI value of 14.84 and PPI value of 21. As compared to site 1, site 3 showed much lower index values, showing lesser pollution status. As compared to site 3, site 4 showed linearly low value for WQI (96), Simpson's D (2.33), OPI value (13.11) and PPI value (15). Site 5 (Eidgah) was comparatively less polluted than other sites with WQI value of 80, Simpson's D value of 1.78, OPI value of 12.53 and PPI value of 15. The site 6 (Centre) was treated as the optimum space within the lake with the least pollution indicators (WQI = 80; D = 1.78; OPI = 12.53 and PPI = 12). All the sites except site 6 showed highest values, which create an undesirable aquatic microcosms for the aquatic inhabitants (Table 4, fig. 1)

Table 4: Organic Pollution index values of different sampling stations of Anchar Lake

Sampling station	Name	WQI	D	OPI Value	PPI
1	Sangam Site	120	3.25	76.55	25
2	Zinymar Site	120	2.89	54.22	21
3	Centre Site	105	2.65	14.84	21
4	SKIMS hospital Site	96	2.33	13.11	15
5	Eid Gah Site	80	1.78	12.53	15
6	Jinab Shab Site	55	1.29	5.54	12

WQI = Water Quality Index; D = Shannon's Diversity Index; OPI = Organic Pollution Indicator; PPI = Palmer's Pollution Index

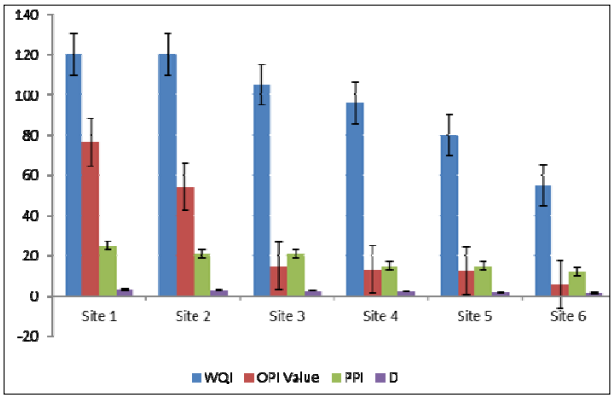

Fig 1: Organic Pollution Index values of different sampling stations of Anchar Lake

Discussion

During the present research period, variance in water temperature was recorded, with lowest and highest temperature of 7.83 and 25.2°C, with a mean of 16.51±6.49. Love and Goodwin (1959) [22] studied the effect of natural water temperature on the development of certain organisms in Georgia, Wanganeo *et al*. (1996) [43] recorded variations in pH across the water column of Nilnag lake of Kashmir. Singh *et al*. (1982) [38]; The alkaline nature of Anchar lake recorded by Jeelani and Kour (2012) [15] suggest that the water is well buffered, which lends complete support to our findings. pH of Anchar Lake water was reported as alkaline (7.3 to 8.3) by Irshad *et al*. (2012) [13]. The dissolved oxygen content was less in more polluted sites from 1 to 4, however it showed higher values in less polluted sites. During the present study, the free carbondioxide ranged from 6.25-14.02 mg/l. The higher concentration of free carbon dioxide in warmer months is indication of pollution, as witnessed by Jeelani & Kaur (2012) [15], Bhat *et al.* (2013) [2], Salim *et al*. (2013) [36], Mudasir *et al*. (2014) [29].

During present study period, more dissolved solids content was observed in first four study sites, which reported the highest organic load as well. Trivedy and Goel (1986) [41] suggested that total dissolved solids do not give a clear picture of the kind of pollution. The lowest total dissolved solids content (98.2 mg/l) was obtained during winter due to low input from catchment while the highest concentration (400.2 mg/l) was recorded in summer as a result of runoff from catchment. Similar findings have been reported by Kirubavathy *et al.* (2005) [19] and Garg *et al*. (2006b) [10] with regard to seasonal variations of TDS. Alkalinity of water is its capacity to neutralize acid and is a measure of productivity as has been suggested by Moyle (1946) [28]. Its relationship with pH of water has been investigated by Freiser and Fernando (1966) [8]; Qadri and Yousuf (1980 a,b) [32, 33] and Zutshi *et al*. (1980) [47] recorded changes in alkalinity values in relation to levels of organic wastes discharged into water, which lends complete support to our findings, with higher values of TDS in pollution hit study sites. Studies in this respect have been done by Singh *et al*. (1969) [39], An increased value of chlorides were reported in sites 1 to 4, which are more polluted than the other two sites, owing to the highr hardness values reported during the present study. Lower values of chloride were Seasonal variations in the chloride values of water have been observed by Ownbey and Kee (1967) [31].

During present research work, the increased nitrogen values at sites 1 to 4 may be attributed to sparse macrophytic vegetation and organic loading. Zutshi *et al*. (1980) [47] compared nitrate nitrogen values in nine lakes of Kashmir during limnological studies of these lakes. In this connection, higher phosphate levels observed during the present study in polluted sites gets support from the work of the authors listed. Michael (1969) [27]; Zutshi and Vass (1978) [49]; Harshey *et al*. (1982) [12]; Bruce (1958) [4] suggested the values of ammonical nitrogen as a sign of organic pollution. During the present study period, higher Ammonical nitrogen values at sites 1 to 4 demonstrates that the sites are rich in organic pollution, as compared to two other sites.

Conclusion

During the present research work: Limnological analysis, were carried as under;

Physico-chemical features

- Water temperature (°C) ranged from 7.83 to 25.2 with a mean±SD of 16.51±6.49 (*Var.* = 42.18).
- The mean depth (m) ranged from 0.89 to 1.8 with a mean±SD of 1.34±0.26 (*Var.* = 0.06).
- Transparency (m) ranged from 0.08 to 0.24 with a mean±SD of 0.16±0.05 (*Var.* = 0.002).
- pH ranged from 7.11 to 8.02 with a mean±SD of 7.56±0.27 (*Var.* = 0.07).
- Dissolved Oxygen (mg/l) ranged from 5.65 to 9.06 with a mean±SD of 7.355±1.09 (*Var.* = 1.19).
- Carbon dioxide (mg/l) ranged from 6.25 to 14.02 with a mean±SD of 10.13±2.16 (*Var.* = 4.69).
- Conductivity (µS/cm) ranged from 152.3 to 380.2 with a mean±SD of 266.25±84.84 (*Var.* = 7198.20).
- Total dissolved solids (mg/l) ranged from 98.2 to 400.2 with a mean±SD of 249.2±98.82 (*Var.* = 9766.76).
- Total alkalinity (mg/l) ranged from 50.22 to 132.7 with a mean±SD of 91.46±29.35 (*Var.* = 861.95).
- Chloride (mg/l) ranged from 7.98 to 19.04 with a mean±SD of 13.51±3.53 (*Var.* = 12.47).
- Total hardness (mg/l) ranged from 106.00 to 303.21 with a mean±SD of 204.6±77.44 (*Var.* = 5997.22).
- Calcium hardness (mg/l) ranged from 62.5 to 130.11 with a mean±SD of 96.3±22.13 (*Var.* = 490.07).
- Magnesium hardness (mg/l) ranged from 62.5 to 130.11 with a mean±SD of 96.3±22.13 (*Var.* = 490.07).
- Ammonical nitrogen (mg/l) ranged from 0.05 to 0.17 with a mean±SD of 0.11±0.04 (*Var.* = 0.001).
- Nitrate nitrogen (mg/l) ranged from 0.2 to 0.67 with a mean±SD of 0.43±0.13 (*Var.* = 0.019).
- Phosphate (mg/l) ranged from 0.05 to 0.27 with a mean±SD of 0.16±0.07 (*Var.* = 0.006)
- Biological oxygen demand BOD_3 (mg/l) ranged from 2.52 to 7.2 with a mean±SD of 4.86±1.36 (*Var.* = 1.86)
- Chemical oxygen demand (mg/l) ranged from 32.52 to 61.2 with a mean±SD of 46.86±9.30 (*Var.* = 86.54).

An overall perspective declared Anchar Lake as the eutrophic lake, supported by the findings of the other authors and workers worldwide.

Pollution Indicators

- Factor loading value and explained variance of water quality parameters of Anchar Lake
- Water temperature showed negative correlation with at all the three factor loading levels,
- pH showed positive correlations of 0.144 (PC1), 0.021 (PC2) and 0.816 (PC3)
- Dissolved oxygen showed positive correlation for PC1 (0.753) and PC2 (0.024) except PC2 (-0.292).
- Electrical conductivity showed positive correlation for PC1 (0.657) and PC2 (0.035) except PC3 (-0.612)
- Both Ca and Mg showed positive correlation as the factor loading values of pollution at all the three levels.
- Ammonical nitrogen, nitrate nitrogen and phosphate showed positive correlations at PC1 (0.764, 0.838 and 0.022) and PC2 (0.498, 0.115, and 0.712) levels and negative correlation at PC3 (-0.039, -0.147 and -0.138).
- BOD and COD values showed mixed correlation at different factor loading levels. Over all the Eigen values and total variance (%) showed a decreasing trend for all the loading values PC1 (4.63; 30.68), PC2 (3.01; 27.34) and PC3 (1.44; 11.8).
- In order to establish the level of pollution at different sampling stations of Anchar Lake, the pollution indicators were used for the assess, which revealed the level of pollution in Anchar Lake owing to the combined effect produced by different factors.
- The Site 1 (Sangam) showed highest pollution level, documented by indices, which include WQI (120), D (3.25), OPI (76.55) and PPI (25)
- Site 2 (SKIMS hospital) showed water quality index value of 120, Simpson's D (2.89), organic pollution index (54.22) and Palmer's pollution index (21).
- Site 3 (Jinab Shab) showed WQI of 105, D value of 2.65, OPI value of 14.84 and PPI value of 21.
- Site 3 showed much lower index values, showing lesser pollution status.
- Site 4 showed linearly low value for WQI (96), Simpson's D (2.33), OPI value (13.11) and PPI value (15).
- Site 5 (Eidgah) was comparatively less polluted than other sites with WQI value of 80, Simpson's D value of 1.78, OPI value of 12.53 and PPI value of 15.
- The site 6 (Centre) was treated as the optimum space within the lake with the least pollution indicators (WQI = 80; D = 1.78; OPI = 12.53 and PPI = 12). All the sites except site 6 showed highest values, which create an undesirable aquatic microcosms for the aquatic inhabitants.

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