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Trophic assessment of a semi-drainage Himalayan lake

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Abstract

The present study was carried to assess the water chemistry of Lake Ahansar, a semi-drainage lake situated in the district Ganderbal of Kashmir valley. Water samples from five different locations viz., inlet, outlet, littoral zones and centre were collected for a period of 9 months covering three different seasons viz., winter, spring and summer. The season wise mean values recorded for various physico-chemical parameters were: air temperature (17.4 ± 3.46 °C), water temperature (17.42 ± 0.19 °C), depth (2.37 ± 0.49 m), transparency (1.5 ± 0.1 m), dissolved oxygen (9.38 ± 0.32 mg/l), pH (8.0 ± 0.08), free carbon dioxide (9.9 ± 0.6 mg/l), chloride (13.0 ± 0.32 mg/l), total alkalinity (231.1 ± 2.1 mg/l), total hardness (317.0 ± 1.9 mg/l), calcium hardness (71.6 ± 1.7 mg/l), magnesium hardness (57.9 ± 0.8 mg/l), ammonical nitrogen (96.8 ± 1.2 µg/l), nitrate nitrogen (485.5 ± 2.6 µg/l), total phosphorous (231.0 ± 1.1 µg/l) and orthophosphate (29.8 ± 0.6 µg/l). Overall, it was established that water quality of the lake has deteriorated, when compared with earlier records.

Keywords: Ahansar Lake, water chemistry, fresh water, trophic status, physico-chemical parameters, Kashmir

1. Introduction

The fresh water lakes of Kashmir Himalayas have been playing a great role in the socio-cultural and economic status of the valley since ancient times. These lakes have been categorized into glacial, alpine and valley lakes based on their origin, altitudinal location and nature of biota and provide an excellent opportunity for studying the structural and functional processes of an aquatic ecosystem system (Zutshi *et al.* 1972; Kaul, 1977; Trisal, 1985) [55, 16, 44]. The nutrient level of many lakes and rivers has increased dramatically over the past 50 years in response to increased discharge of domestic wastes and non-point pollution from agricultural practices and urban development (Mainstone and Parr, 2002) [25]. For more than 30 years, nutrient enrichment, especially phosphorus (P) and nitrogen (N), has been considered as a major threat to the health of aquatic systems (Andersen *et al.* 2004) [3]. The physico-chemical properties of water quality assessment give a proper indication of the status, productivity and sustainability of a water body (Djukie *et al.* 1994) [10]. The changes in the physico-chemical characteristics like temperature, transparency and chemical elements of water such as dissolved oxygen, nitrate and phosphate provide valuable information on the quality of the water, the source (s) of the variations and their impacts on the functions and biodiversity. Hence, the consideration of the physico-chemical factors in the study of limnology is basis for the understanding of trophic dynamics of a water body. Moreover, the physical and chemical properties of water immensely influence uses of a water body for the distribution and richness of biota (Unanam and Akpan, 2006) [45].

2. Materials and Methods

This study was conducted for assessing the water quality status of lake Ahansar, a small fresh water, rural lake which is situated at Sumbal, Sonawari (District, Ganderbal) in the floodplains of River Jhelum about 26 km north-west of Srinagar lying within the geographical coordinates of $34^{\circ} 18' N$ latitude and $74^{\circ} 39' E$ longitude. The lake is semi-drainage type (Zutshi and Khan, 1978) [54] with a maximum depth of 4.80 m and is spread over an area of 0.80 km² located at an altitude of 1584 M.A.S.L. The lake is shallow with an extended zone of emergent vegetation all along its periphery. The water supply of the lake is maintained by underground springs spread over its basin. Besides an ephemeral irrigation channel also supplements the water mass during paddy cultivation period. The lake has a permanent outflow channel on western side which drains excessive water into River Jhelum. The shores of the lake are elevated forming a long stretch of 'Karewas' which are mostly horizontally stratified deposits

of fine grained sand. The lake is essentially ox-bow type and has probably originated by meandering of alluvial deposits.

Surface water samples were collected by hand from the sampling sites in one litre polyethylene bottles marked distinctly. For dissolved oxygen, water samples were collected in separate glass stoppered bottles of 125ml capacity and the fixation of samples was done at the site. Parameters like air temperature, water temperature, depth, secchi disc transparency were determined at the respective sampling sites and the detailed analysis for parameters like dissolved oxygen, pH, total phosphorous, total hardness, Calcium hardness, total alkalinity, Ortho-phosphate, Magnesium hardness, chloride, nitrate nitrogen ($\text{NO}_3\text{-N}$), Ammonical nitrogen ($\text{NH}_4\text{-N}$) was carried out in the laboratory by using the methods outlined in APHA (2012) [2].

Five sites were selected for the whole lake

Site 1: This site is located near the inlet of lake which is shallow and is covered with dense growth of aquatic vegetation

Site 2: This sampling site is located near the outlet of lake where water is drained out of the lake towards river Jhelum.

Site 3: This is a littoral sampling sites with apple orchards in its immediate catchment.

Site 4: This site is located towards the north of lake. It is a pelagic site and is characterized by the absence of macrophytes.

Site 5: This is the central sampling site which is the deepest part of the lake (4.8m). This site has no apparent macrophytic growth (Fig. 1)



Fig 1: Map representing overall view of sites within Ahansar Lake

3. Results and Discussion

Air temperature

Temperature is an important parameter which controls the behaviour, physiology and distribution of organism (Srivastav *et al.* 2009) [40]. Air temperature is determined by the air masses over the particular land mass, climatic condition (Hutchinson, 1967) [14], time of sample collection, climate, solar radiation and topography (Kant and Raina, 1990) [15].

The air temperature varied from a minimum of 2.8 °C at site 1 varied in the month of January to a maximum of 33° at site 3 in the month of August (Fig 2). The observed low value of air temperature in winter is related to lower solar radiation and cold breeze, while higher values during summer could be attributed to high solar radiation. Similar results were obtained in Amghass lake, Morocco (Mustapha *et al.* 2013) [30], Manasbal lake (Dar *et al.* 2013) [7], Dal lake (Lori *et al.* 2014; Malik, 2015) [23, 26], Anchar lake (Bashir *et al.* 2017) [4]. Smaller the body of water, more quickly it reacts to changes

in the atmospheric temperature and thus the water body operates as the cooling source on the microclimate of the surrounding area (Welsch, 1952) [49]. Air temperature near or over bodies of water is much different from that over land due to differences in the way water heat and cool (Wong *et al.* 2012) [52].

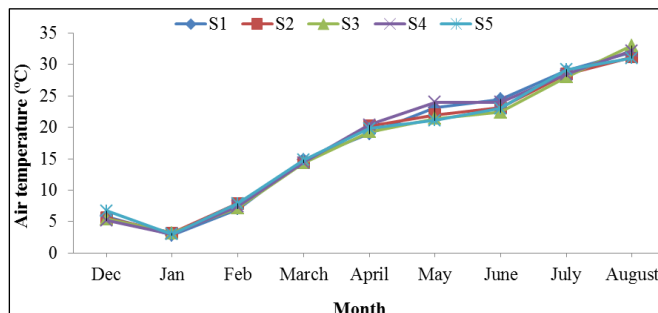


Fig 2: Monthly variation in air temperature (°C) at different sites of Ahansar Lake

Water temperature

Water temperature is of enormous significance as it regulates various abiotic characteristics and biotic activities of an aquatic ecosystem (Hutchinson, 1957) [13].

The minimum water temperature of 3.6 °C was recorded at site 1 in the month of February and a maximum water temperature of 33.1 °C was recorded in the month of August at site 3 (Fig 3). These fluctuations in water temperature could be due to the seasonal effect of winter and summer (Mustapha *et al.* 2013) [30]. Decrease or increase in water temperature mainly depends on the climatic conditions, sampling times, sunshine hours and is also affected by specific characteristics of water environment such as turbidity, wind force, plant cover and humidity (Mahmoud, 2002) [24]. As described by Ganai and Parveen (2014) [11] in their study on effect of physico-chemical conditions on the structure and composition of the phytoplankton community in Wular Lake, lower water temperature was due to cold, low ambient temperature and shorter photoperiods.

Dar *et al.* (2016) [8] recorded lower values for water temperature during winter and higher during summer in Dal Lake and attributed this to low water level, clear atmosphere and greater solar radiation. Bashir *et al.* 2017 [4] obtained similar results for water temperature in Anchar Lake.

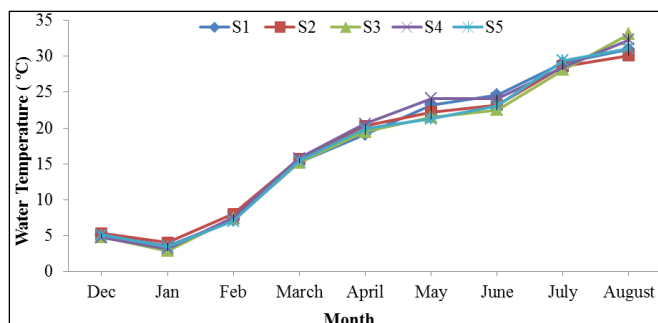


Fig 3: Monthly variation in water temperature (°C) at different sites of Ahansar Lake

Depth

The depth at site 1 varied from a minimum of 1.3 m in the month of March to a maximum depth of 4.8 (m) in the month of August at site 5 (Fig 4).

The variation in the water level fluctuations during the course of study period depended on the amount of precipitation

received in the form of rain and snow and also due to changes in the amount of water brought in by an ephemeral feeding channel. The most obvious factor that affects the productivity of a lake is its depth (Scheffer and Van Nes, 2007) [37]. Kundangar and Abubakr while studying the comparative limnology of Dal Lake observed fluctuation in water depth of Nigeen Lake and related this to the opening and closing of exit gate of Nigeen Lake, as the water level of entire gate is being regulated by the lock gate.

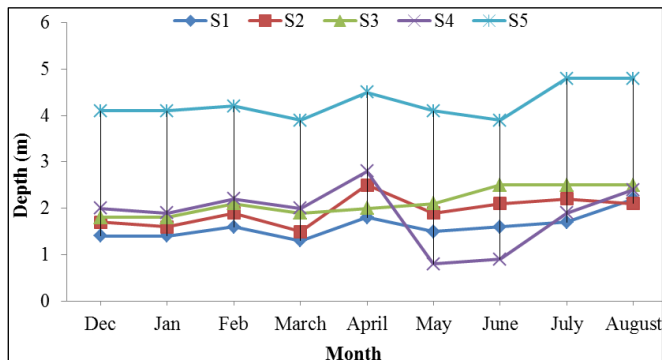


Fig 4: Monthly variation in Depth (m) at different sites of Ahansar Lake

Transparency

The transparency varied from a minimum of 0.3 (m) in the month of July at site 1 to a maximum of 2.5 (m) in the month of January at site 5 (Fig 5). Lower values of transparency during summer could be attributed to increased planktonic growth and also due to increased silt load brought in by glacial activity through an ephemeral feeding channel present in the lake during summer. Higher values during winter could be due to sedimentation of suspended soil particles and low suspended organic matter. Zutshi and Vass, 1970 [53] in their study on high altitude lakes of Kashmir are of the opinion that lower transparency values could be attributed to higher planktonic population.

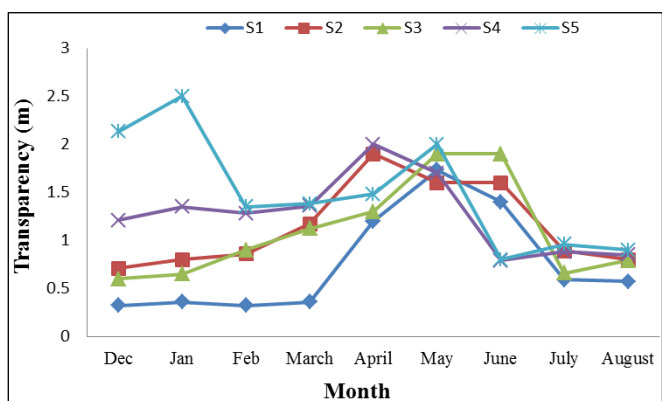


Fig 5: Monthly variation in transparency (m) at different sites of Ahansar Lake

Dissolved oxygen

Dissolved oxygen varied from a minimum of 7 mg/l in the month of August at site 1 to a maximum of 12.5 mg/l in the month of May at site 4 (Fig 6) depicting an inverse relation between dissolved oxygen and temperature. Lower dissolved oxygen in summer recorded could be due to the presence of wastes of animal origin, getting decomposed at a faster rate at higher ambient temperature there by reducing the oxygen levels of water. On the other hand, the higher dissolved oxygen in spring may be as a result of increased solubility of

oxygen at lower ambient temperature. Besides a marked variation in Dissolved oxygen content among different sites of the lake was seen. The extent of variability in dissolved oxygen concentration between the offshore and inshore areas may be dependent upon a number of factors such as temperature, decompositional activities, photosynthesis and the load of aeration (Kundangar and Abubakr, 2006) [20]. Wanganeo and Wanganeo (1991) [47] is also of the opinion that the oxygen concentration in water depends upon temperature, plankton population and the degree of sewage pollution.

As per the reports of (Vass *et al.* 1977) [46], high dissolved oxygen during spring could be attributed to low biological activity. Similar findings were reported in Almatti Reservoir, Karnataka (Hulyal and Kaliwal, 2011) [12], Nalanda lake, Srilanka (Nawarathana and Makehelwala, 2016) [31].

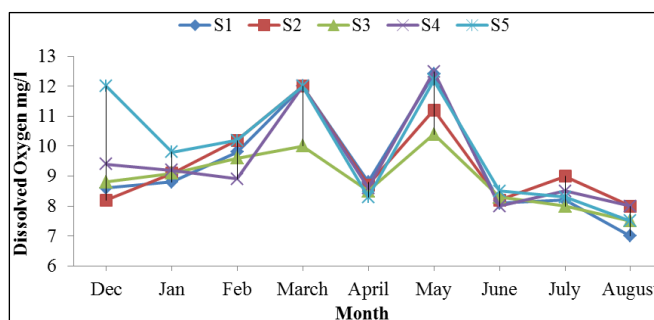


Fig 6: Monthly variation in the dissolved oxygen (mg/l) at different sites of Ahansar Lake

pH

The minimum pH was recorded to be 7.4 in the month of December with a maximum pH of 8.8 in the month of May at site 1 (Fig 7). pH is one of the important chemical characters of water explaining certain significant biotic and abiotic ecological characteristic of an ecosystem in general (Chandrasekhar *et al.* 2003) [6]. Overall alkaline pH was recorded in the lake water during all seasons of the year, a finding that has been linked to the state of eutrophication by various workers (Njenga, 2005; Mathur *et al.* 2008) [32, 28]. According to White more (1984) [51], the acidic pH (<6.5) is usually a feature of oligotrophic lakes, while the circum-neutral (6.5-7.5) and alkaline pH (>7.5) is mainly exhibited by eutrophic lakes. As per these ranges, the present lake clearly falls into eutrophic category.

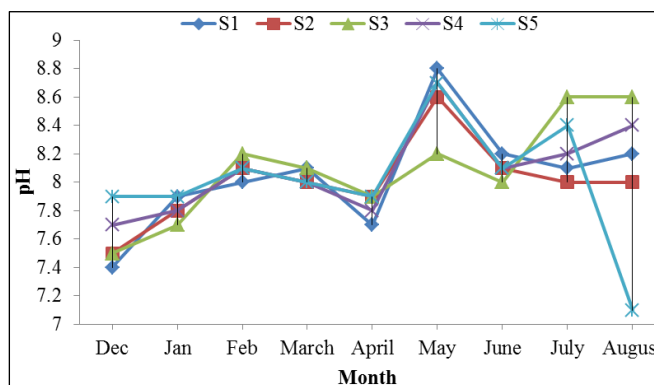


Fig 7: Monthly variation in pH at different sites of Ahansar Lake

Free CO₂

The minimum Free CO₂ was reported to be 5.5 in the month of March at site 1 and maximum of 20 mg/l in the month of April at site 4 and 5 (Fig 8). The presence or absence of the

free carbon dioxide in water is mostly governed by its utilization by algae during photosynthesis and also through its diffusion from air (Lianthuamluaia *et al.* 2013) [22]. Higher values of free carbon dioxide in the month of April could be attributed to lower utilization of carbon dioxide by green plants on account of low temperature.

Free CO₂ was reported to be absent during summer season (July) The complete absence of free carbon dioxide during summer season could be due to its complete utilization in photosynthetic activity or as a result of its inhibition by the presence of appreciable amount of calcium carbonate in water. Higher values of free carbon dioxide during spring could be attributed to lower utilization of carbon dioxide by green plants on account of low temperature.

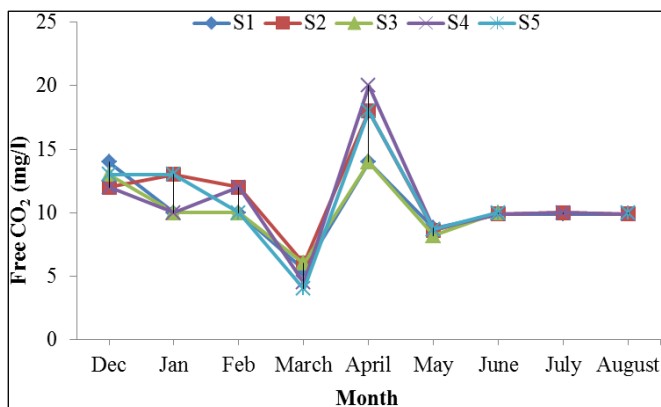


Fig 8: Monthly variation in Free CO₂ (mg/l) at different sites of Ahansar Lake

Chloride

The minimum chloride content of 7.6 mg/l was recorded in the month of January at site 2 to a maximum chloride content of 22 mg/l in the month of May at site 1 (Fig 9). Chloride content in water is regarded as an indication of organic load of animal origin from the catchment area (Kumar *et al.* 2004) [19]. Concentration of chloride in an aquatic system is an index, not only of eutrophication, but also of pollution caused by sewage and other wastewaters (Munawar, 1970) [29]. The relative increase in the chloride concentrations during hot period may be due to increase in air and water temperatures. In general, concentration of chlorides is affected by several factors, such as increased human and cattle activities. According to Sreenivasan (1964) [39], low chlorides 4-10 ppm indicate the purity of water and freedom from pollution, whereas high value of chloride is denoted as pollution of organic matter.

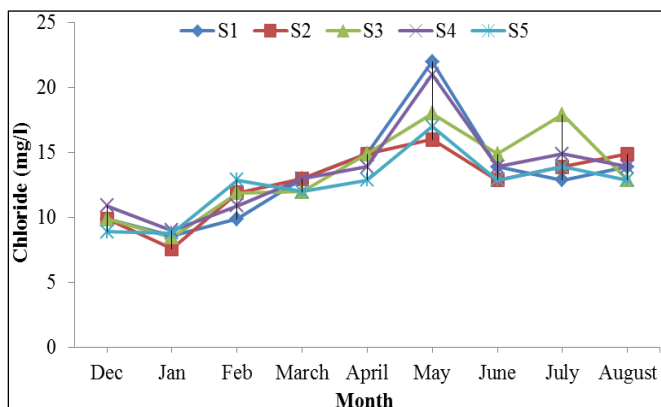


Fig 9: Monthly variation in chloride (mg/l) at different sites of Ahansar Lake

Total alkalinity

The minimum total alkalinity of site 1 was reported to be 120 mg/l in the month of May to a maximum of 385 mg/l in the month of January at site 3 (Fig 10) which could be because of increase in atmospheric temperature and the consequent increase in the photosynthetic processes in summer, alkalinity values depict a significant fall from the spring. Total alkalinity in the lake followed a decreasing trend from winter to spring months which is in line with the findings of Agarwal and Thapliyal (2005) [1] who also obtained maximum alkalinity during winter months in Bhilangana.

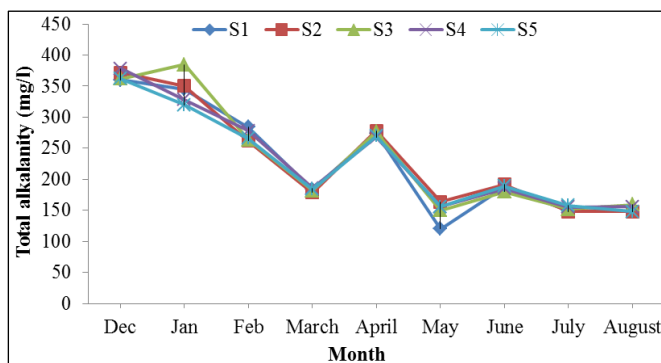


Fig 10: Monthly variation in total alkalinity (mg/l) at different sites of Ahansar Lake

Total hardness

The minimum and maximum total hardness content was reported to be 250 mg/l and 395.5 mg/l in month of June and January at sites S₃ and S₁ respectively (Fig 11). Similar results were reported by Bhat *et al.* (2013) [5] in Anchar Lake. According to hardness scale of water quality association (Lehr *et al.* 1980) [21], hardness values ranging from 0-17 mg/l is soft water, 17 to 60 mg/l is slightly hard, 60 to 120 mg/l is moderately hard, 120-180 mg/l is hard and more than 180mg/l is very hard. The present study thus clearly indicates that the water of ahansar Lake are hard.

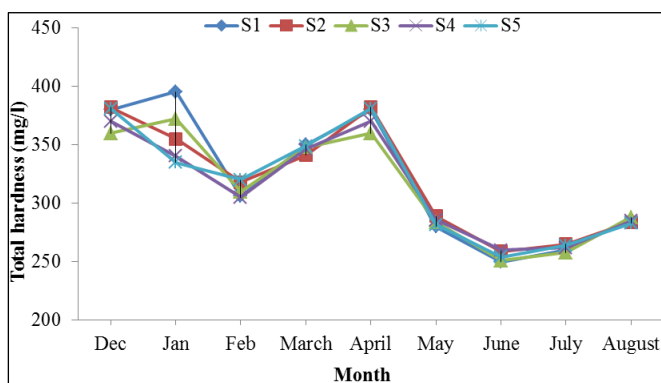


Fig 11: Monthly variation in total hardness content (mg/l) at different sites of Ahansar Lake

Calcium hardness (Ca²⁺)

Minimum Calcium hardness was reported to be 53.9 mg/l in the month of June at Site 2 and maximum value was reported 117 mg/l in the month of December from site 1 (Fig 12). Minimum values for calcium during summer could be attributed to photosynthetic activity of macrophytes attaining their peak growth during the season (Koul *et al.* 1978) [18] while as maximum values of calcium in the lake could be attributed to the lime rich catchment which brings a high calcium load along with storm waters. Similar findings were

reported in Anchar lake (Bhat *et al.* 2013) [5], reservoirs of Andhra Pradesh (Das, 2000) [9]. According to Rodhe (1949) [35], the freshwater lakes maintain a constant ionic composition i.e., $Ca > Mg > Na > K$ and $HCO_3 > SO_4 > Cl$. Applying the Rodhe's ionic composition to Ahansar lake, it is evident that the lake shows uniform ionic composition i.e., Ca (85.8 mg/l) $>$ Mg (62.5 mg/l) $>$ Cl (14.8 mg/l). Such a progression according to Rodhe (1949) [35], is characteristic for fresh waters; the dominance of Ca over other cations being probably related to its leaching from the surrounding areas.

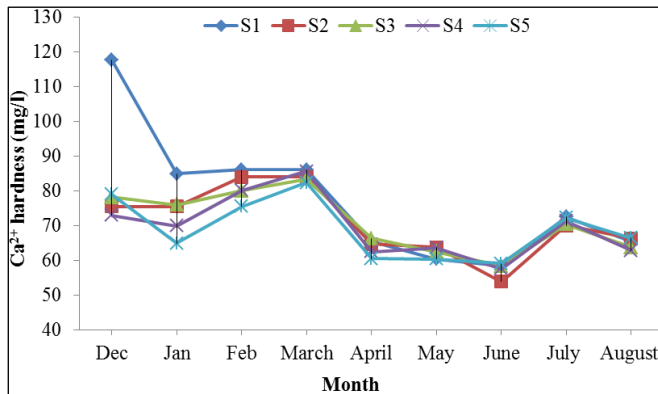


Fig 12: Monthly variation in calcium hardness (mg/l) content at different sites of Ahansar Lake

Magnesium hardness

The minimum magnesium hardness content reported to be 46 mg/l from site 1,3 and 4 in the month of July to maximum of 79 mg/l in the month of April from site 5 (Fig 13). The low concentration may be due to uptake of Mg^{2+} by plants in the formation of Chlorophyll, magnesium porphyrin metal complex and in enzymatic transformation (Wetzel, 1975). Similar results were reported by Bhat *et al.* (2013) [5] in Anchar Lake and recorded minimum value for magnesium in the month of July and maximum in the month of February.

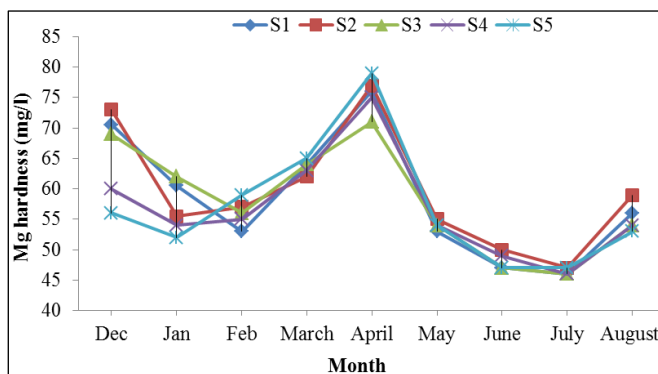


Fig 13: Monthly variation in magnesium hardness content (mg/l) at different sites of Ahansar Lake

Ammonical nitrogen (NH_4-N)

The minimum ammonia content of 76.2 μ g/l was reported from site 5 to a maximum ammonia content of 140 μ g/l in the month of December at site 2 (Fig 14). Higher values of ammonia during winter could be due to lower metabolic processes as development of plant life is very low and also due leaching from the surrounding terrestrial vegetation due to rains. Lower values of ammonia during summer could be due to the photosynthetic assimilation by autotrophs (Pandit, 1999) [33]. As has been reported by Dar *et al.* 2013 [7] in Manasbal Lake, lower values of ammonical nitrogen in winter

season were due to nitrification or direct absorption by many phytoplanktons.

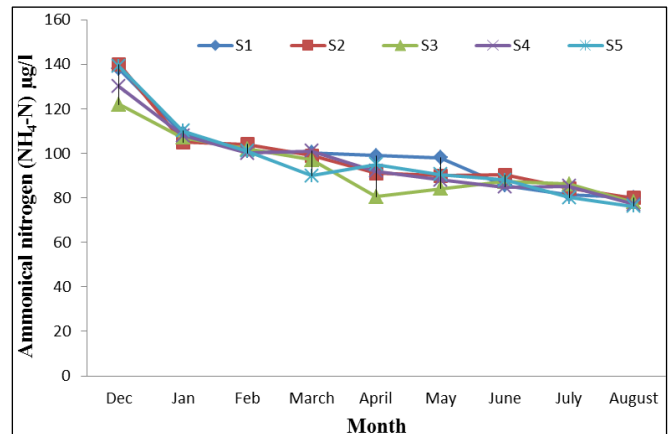


Fig 14: Monthly variation in ammonia (μ g/l) at different sites of Ahansar Lake

Nitrate nitrogen (NO_3-N)

The minimum nitrate content was recorded to be 249 μ g/l in the month of August at site 4 to a maximum of 683 μ g/l in the month of December at site 3 (Fig 15). Higher values of nitrate during winter could be due to reduced metabolic activities because of less plant cover while as minimum values of nitrate during summer could be due to its assimilation by plant growth. A higher concentration of nitrate was reported in Dal waters (Kundangar and Abubakr, 2006) [20] and (Maryam, 2017) [27].

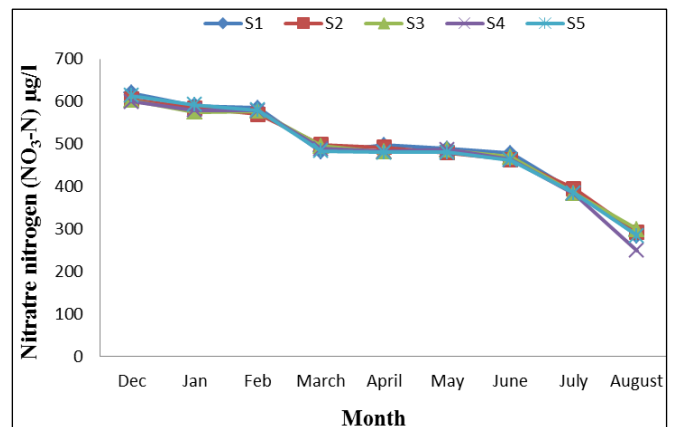


Fig 15: Monthly variation in nitrate content (μ g/l) different sites of Ahansar Lake

Total phosphorous

The minimum total phosphorous content was reported to be 183 μ g/l in month of August at S1 to a maximum concentration of 288 μ g/l in the month of December at site 4 (Fig 16). Minimum values of total phosphorous during winter season could be attributed to reduced fertilizer use in the agricultural fields surrounding its catchment while as maximum values of total phosphorous during summer season could be attributed to anthropogenic inputs of fertilizers rich in phosphate applied to the agriculture fields in lake catchment, rapid evaporation and mineralization of decomposed materials.

Similar results were reported by Khan *et al.* (2014) [17] related high phosphate concentration of Dal water to sewage contamination and perturbations caused by human inference in the catchment areas and also to the heavy infiltration by

migratory birds found in abundance in the lake during warmer months.

Generally the total phosphorous content of water bodies has been used for categorization of aquatic habitats. Toerien and Walmsley (1979) [43] suggested that 25-30 mg/l total phosphorous be regarded as the border line for eutrophy. Thornton and Nduku (1982) [42] proposed two sets of the values for delimiting the lower boundary of eutrophy, 30 $\mu\text{g/l}$ for temperate and 50-6- $\mu\text{g/l}$ for tropical lakes. Welch, 1980 [48] is also of the opinion that the presence of phosphorous in excess of 30 $\mu\text{g/l}$ in water bodies is regarded as a major nutrient triggering eutrophication.

As per the above limits, the present lake has higher values of Total phosphorous and thus falls under eutrophic category. Higher total phosphorous levels in water have been taken as indicative of pollution (Pathak and Mankodi, 2013) [34].

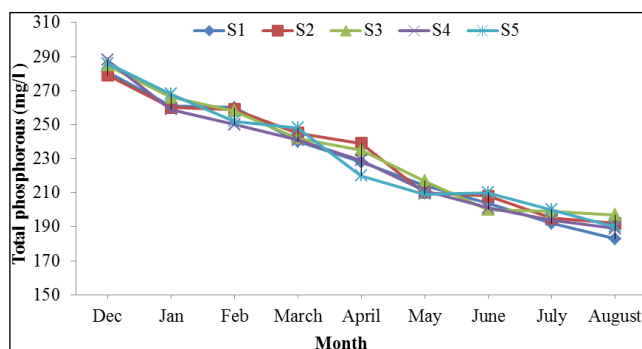


Fig 16: Monthly variation in total phosphorous content ($\mu\text{g/l}$) at different sites of Ahansar Lake

Ortho-phosphate

The minimum Orthophosphate content was reported to be 19 $\mu\text{g/l}$ in month of August at site1 to a maximum concentration of 42.1 $\mu\text{g/l}$ in the month of December at site5 (Fig 17). Higher values of orthophosphate during summer could be attributed to increased agricultural activities in the lake catchment during the season while as lower values of orthophosphate during winter season could be attributed to reduced agricultural activities in winter. Shrishail and Mathad (2008) [38] and Sunder and Khatri (2015) [41] also registered higher values during summer and lower during winter months in Khaji Kotnoor reservoir of Gulbarga region. Sawyer *et al.* (1945) [36] suggested 30 $\mu\text{g/l}$ of orthophosphate as critical level, beyond which blooms indicative of enhanced trophic status can normally be expected. In the lake basin under investigation, orthophosphate has crossed the critical level and that may be the reason for the occurrence of algal blooms seen during warmer months throughout the boundaries of the lake.

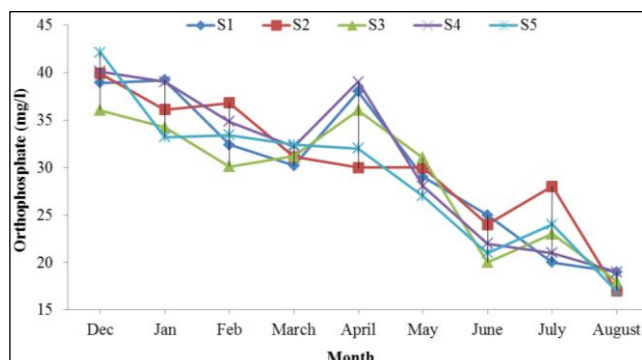


Fig 17: Monthly variation in orthophosphate content ($\mu\text{g/l}$) at different sites of Ahansar Lake

4. Conclusion

On comparing the present water quality with previous records, it was observed that the lake waters have been altered drastically in the last 30 years. Higher values of various parameters viz., ammonical nitrogen, nitrate nitrogen, total phosphorous, ortho phosphate indicate that the lake has become eutrophic. The possible reason for this is human intervention in the catchment. The uses of pesticides in the orchards around the lake directly pave way into the lake basin with run-off. Moreover, lake littorals are used for paddy cultivation which has lead to shrinking of its boundaries. Therefore, it becomes imperative for Government to develop policies to protect these aquatic ecosystems from further deterioration for human well-being.

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