Water quality assessment of Mansbal Lake in Kashmir
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**ABSTRACT**
Mansbal Lake is one of the hotspots of Kashmir tourism. Due to the negligence of concerned authorities and the greediness of humans residing proximate, the ecosystem of the lake is highly disturbed and compromised. The current study emphasizes and attempts to analyze the various significant physico-chemical parameters of the lake. For studying overall pollution load on water of the lake, water samples were collected from five different sites of lake. These samples were collected on monthly basis for seven consecutive months by following the methods given in. Fourteen important physico-chemical parameters were analyzed and results were recorded. The study was made to speculate the involvement of humans in the degradation of natural resources and the impact of pollution on the population residing in the nearby areas. The population of catchment area is directly or indirectly dependent on this lake for livelihood. So, it is necessary to conserve this natural resource for the present and future generations to survive and fulfill their daily needs. Some of the studied parameters revealed that the sites where human settlements are existing are contaminated showing worse water quality. Almost 80% of the lake seems covered under the substantial amount of weeds, because of the presence of a high concentration of nutrients and other favorable elements and heavy eutrophication. Some toxic elements in excess quantity were found in the water of the lake, which makes it unsuitable for domestic uses. Sewage outlets, agricultural drainage, waste disposal, shrinking up of land, and practice of stone quarrying and functioning of limestone kilns in catchments are recognized as the main sources of pollution in the Mansbal lake. The present study impulses the requirement of curative procedures for purification and protection of this lake.

**Introduction**
The Valley of Kashmir is renowned all over the world for its natural attractiveness and also for its beautiful collection of lentic and lotic freshwater bodies including lakes, rivers, ponds, springs, and streams. These resources in the form of freshwater bodies are not only significant for ecological, socio-economic, and cultural heritage, but also act as the chief source of income and for the upliftment of the local economy. The people residing near these freshwater bodies are mainly dependent for food, fodder, and drinking water on these natural resources directly or indirectly. Water is an essential natural resource given to planet earth and maintains the survival of all the living creatures on it (Bashir et al., 2016). Unfortunately, as an outcome of many unethical and unplanned anthropogenic actions, these freshwater bodies of Kashmir have become ecologically unbalanced due to which many water bodies have lost their natural charisma and have got worsened to a greater degree during the last few decades (Ali, 2014). The objectionable human activities have caused heavy pollution and nutrient loading into water bodies due to which the water quality as well the aquatic life of these water bodies have severely been affected (Li et al., 2007; Odada, Olago, Kulindwa, Ntiba, & Wandiga, 2004). The undesirable variations in Physico-chemical characteristics of water have become an important cause behind the degradation of the aquatic ecosystem (Kim, Park, Hwang, Jun, & Choi, 2001). The growing population, increasing urbanization, industrial and agricultural development have greatly resulted in the deterioration of natural water bodies (Dar, Bhat, Rashid, & Dar, 2020). The first natural resources targeted in the line of development are these water bodies because water is the basic need of life. Currently, natural water resources are in a grave threat of getting deteriorated as a result of illegal encroachments, unplanned urbanization, and industrial development (Singh & Singh, 2007). It is an alarming situation and a great matter of concern to make out the limnological studies on these freshwater bodies. These water bodies were once pouring life to the planet earth. But, at present, these water bodies are on the edge of destruction because of pollution load, encroachments, and urbanization. The process of aging of these water bodies is taking an accelerated speed because of these anthropogenic activities due to which water quality as well as the aquatic life in these lakes are on the verge of vast
deterioration (Gul et al., 2021; Rashid & Romshoo, 2012). These water bodies have not only become unfit for humans but have also become a serious menace to aquatic species of flora and fauna and there is a very important need to manage and save these water bodies from further deterioration. If suitably managed, these water bodies can be constructively used for various amusing, working as well as domestic purposes (Dar, Mir, Bhat, & Bhat, 2013). This study has been made to check out the pollution status of the monomictic lake (Mansbal Lake) of the Jammu and Kashmir by collecting the water samples from various sites of the lake and studying their physicochemical parameters. These natural water bodies act as reservoirs and store a large amount of water that can be used for drinking, irrigational, industrial, and various other purposes (Tantary & Rafeq, 2013). The lakes in the valley are thickly covered with the macrophytes (plants, mainly marine plants) because during the favorable season of growth of plants majority of nutrients are present in the tissues of these macrophytes. The problem of pollution in these lakes is mainly the addition of plant nutrients particularly nitrogen and phosphorous derived from anthropogenic activities of waste disposal and sewage, and run-off from agricultural lands at an increased rate. According to (Shah, Pandit, & Shah, 2019), Kashmir Himalayan lakes were intensely influenced by human activities from catchment areas and quality of these waterbodies is degrading at an alarming rates in which eutrophication seems to be the main cause. On observing the lakes of Kashmir valley, the accumulation of major plant nutrients, mainly nitrogen and phosphorus, consequents from human wastes, detergents, fertilizers, agricultural practices, etc. at a very faster rate are reflected as the means of pollution (Tanveer, Arnold, & Mishra, 2018). These nutrients have been primarily responsible for the growth in organic production particularly in the form of thick macrophytes which overall result in the degradation of water quality of the lakes (Reshi, Sharma, & Najar, 2021). Therefore, Mansbal Lake has been tagged as the eutrophic lake, because of the presence of an eminent amount of nutrients and phytoplankton. Below are the figures of the two most polluted sites of the lake (Figure 1 and 2).

Materials and methods

Study area

Manasbal Lake is situated in District Ganderbal in the Union Territory of Jammu and Kashmir in India. The lake catchment has primarily rural surroundings and is bordered by three villages viz., Jarokhabal from the west, Kondabal from the north-eastern side, and Ganderbal on the south. As far as the health and dynamism of the Lake Manasbal is concerned, the village of Kondabal is much essential amongst these villages. Kondabal name itself advocates is the place of kilns (ovens) and mines (“Kond” and “bal” are Kashmiri terms, meaning Oven/Kiln and place respectively). Being socio-economically weak, most of the inhabitants in this area are placed below the poverty line. The latitudes 34°14’ – 34°16’ N and longitude 74° 40’ – 74°43’ E, demarcates the definite location of Manasbal catchment of about 22 km² area and the lake covers 2.80 km2 in oblong shape with an altitude of about 1583 m (a.s.l). Maximum depth of lake is recorded 13 m, and is stated as the deepest lake in India (Tantray & Singh, 2017). Manasbal Lake enjoys warm summer and cold winter climate. The lake has no major or permanent inlet but has an out-let which links the lake with River Jhelum. Precipitation and the presence of inland springs are main source of water supply to the lake. Figure 3 shows the overview of the Mansbal Lake and Figure 3 shows the map of the study area with sampling sites.
Figure 3. (a) Image showing Overview of Manasbal Lake. (b) Map showing Study Area with Sampling Sites.
Presently, eutrophication is considered one of the biggest threats to the lake ecosystem. The continuous burden of growing settlements in the lake periphery and the problem of upstream agricultural activities, stone quarries, and limestone kilns are suspected as the prime convicts to the problem. A study made by (Rashid, Farooq, Muslim, & Romshoo, 2013) also publicized the cause for worsening of the lake as an excess load of nutrients and silt load from the nearby catchment due to the long-time practicing of stone quarrying and haphazard urbanization.

**Sampling and analysis**

From June 2019 to December 2019, the samples of lake water were taken in the starting days of each month at five sampling sites. These water samples taken were analyzed as per the standards designated by (APHA, 1998). Water temperature, pH, and turbidity were analyzed at the field site. Rest of the tests were performed at laboratory with proper technicality and standard measures.

**Sampling sites**

For the present study, five sampling sites were selected in the Manasbal Lake to collect the water samples. These sampling sites were selected on each side of the lake as shown in Figure 3 (map of the study area). These sites were selected on the basis of interaction between people and the lake as the catchment area is directly dependent on the lake water for their daily needs. All the sampling sites are directly or indirectly influenced by the people and people directly use this water from those sites on daily basis.

- **Site I** (Littoral site) the site was selected on the bank of Manasbal garden termed as Manasbal ghat site. Figure 4 shows the Mansbal ghat site.
- **Site II** Kondabal, the site is seen as the most disturbed one, because of the pollution load present there. Figure 5 shows the Kondabal site.
- **Site III** (Central limnetic site) the samples were taken from the central area of lake. Figure 6 shows the Central limnetic site.
- **Site IV** The site was selected at Hanji Mohalla, located on the opposite side of Kondabal of lake. Figure 7 shows the Hanji Mohalla site.
- **Site V** (Outlet) the site was selected at the outlet of Manasbal Lake near Naninar village on the southwest side of lake. From this side, the lake drains into the river Jhelum through a small channel (Naninar channel) at Nesbal (a small hamlet). Figure 8 shows the outlet site.

**Results and discussion**

The checkup of ecologically important Physico-chemical characteristics/parameters of water is of prime concern
Air and water temperatures

Air and Water temperatures are simply the measure of how hot or cold the air or water is, and they are the most commonly measured weather parameters. In this study, both these parameters were measured with the help of a mercury thermometer and the readings were taken at the sampling sites. The results showed clear monthly variations of temperatures at different sites. The maximum air and water temperatures were recorded at site 2, ranged between a maximum of 31.2°C in June, 7.6°C in December, and a maximum of 28.4°C in June, 6.8°C in December, respectively. The lowest values were recorded at site 3. The reason here for the highest temperatures can be simply related to the depth of water, as site 2 in the Mansbal lake has minimum depth in the lake and so the volume of water in connection with air at this site. Another reason for the increase in the temperatures can also be assigned with the addition of sewage and an increase in anthropogenic activities near this site. Human disturbances, such as urbanization and discharge of sewage in the waterbodies have greatly influenced the temperatures of water in the waterbodies and thus have also affected the flora and fauna. Here, it can be seen that there is a very close relationship between air and water temperatures and this relationship agrees with the results of (Zutshi, Subla, Khan, & Wanganeo, 1980).

Turbidity

Turbidity is the measure of relative clarity of a liquid. It is an optical characteristic of water and is a measurement of the amount of light that is scattered by material in the water when a light is shined through the water sample. The higher the intensity of scattered light, the higher the turbidity. Material that causes water to be turbid include clay, silt, very tiny inorganic

in the acquisition of an ecological understanding of the status of any waterbody. The results of Physico-chemical parameters of water samples collected from Manasbal Lake are represented in Table 1.

![Figure 7](image1.jpg) Image showing Hanji Mohalla Site.

![Figure 8](image2.jpg) Image showing Outlet Site.

Table 1. June and December values of physico-chemical parameters at five different sampling sites of Mansbal Lake.

| S. No. | Parameters                        | Site 1 Manasbal ghat | Site 2 Kondabdal | Site 3 Central | Site 4 Hanji Mohalla | Site 5 Outlet | Guideline Values (drinking/irrigation purpose) |
|-------|-----------------------------------|----------------------|-----------------|----------------|----------------------|--------------|-----------------------------------------------|
|       |                                   | Jun   | Dec  | Jun   | Dec  | Jun   | Dec  | Jun   | Dec  |                                   |
| 1     | Air Temperature (°C)              | Mercury         | 30.5 | 7.3  | 31.2 | 7.6  | 29.8 | 7.2  | 30.7 | 7.4  | 30.1 | 7.3 |                             |
| 2     | Water Temperature (°C)            | Mercury         | 26.3 | 6.4  | 28.4 | 6.8  | 25.2 | 6.3  | 26.8 | 6.4  | 26.0 | 6.6 | 18.8–24.5°C                   |
| 3     | Turbidity (m)                     | Secchi Disc     | 2.0  | 3.0  | 1.8  | 2.5  | 2.6  | 3.8  | 2.0  | 3.0  | 2.4  | 3.6 | 4–6 m                         |
| 4     | Dissolved Oxygen (mg/L)           | Winklers Azide Method | 3.8  | 7.6  | 3.5  | 7.3  | 5.0  | 8.5  | 3.6  | 7.5  | 4.5  | 8.2 | 6.5–8.0 mg/L                  |
| 5     | Free Carbon dioxide (mg/L)        | Titrmetric      | 2.5  | 12.3 | 2.7  | 12.7 | 2.1  | 11.9 | 2.4  | 12.5 | 2.3  | 12.2 | 5.5–9.0 mg/L                  |
| 6     | Electrical Conductivity (µS/cm)   | Electroometric  | 340  | 188 | 392  | 196 | 268  | 170 | 356  | 190 | 272  | 172 | Below 200 µS/cm                |
| 7     | pH                                | pH meter        | 8.8  | 8.0  | 8.9  | 7.9  | 8.2  | 7.6  | 8.6  | 7.8  | 8.4  | 7.9 | 6.5–7.5                       |
| 8     | Chloride (mg/L)                   | Titrmetric      | 86   | 154 | 89   | 219 | 58   | 129 | 82   | 196 | 59   | 131 | Below 200 mg/L                |
| 9     | Total Alkalinity (mg/L)           | Titrmetric      | 158  | 260 | 180  | 290 | 154  | 210 | 170  | 266 | 164  | 220 | 20–200 mg/L                   |
| 10    | Total Hardness (mg/L)             | EDTA Titrmetric | 145  | 110 | 212  | 170 | 120  | 90  | 188  | 131 | 126  | 96  | 18–60 (moderately hard)       |
| 11    | Calcium (mg/L)                    | EDTA Titrmetric | 30.2 | 18.4 | 37.4 | 22.2 | 27.6 | 15.4 | 32.0 | 18.2 | 28.9 | 16.8 | 0.75–75 mg/L                  |
| 12    | Total Phosphorous (µg/L)          | Spectrophotometric | 180  | 110 | 252  | 182 | 158  | 92  | 209  | 146 | 205  | 140 | 5–30 µg/L                     |
| 13    | Ammonical Nitrogen (mg/L)         | Spectrophotometric | 6.0  | 9.5  | 11.8 | 19.2 | 3.8  | 8.9  | 10.6 | 16.4 | 9.8  | 12.2 | 0.25–325 mg/L                 |
| 14    | Nitrate Nitrogen (mg/L)           | Spectrophotometric | 10.8 | 18.2 | 12.8 | 29.2 | 4.2  | 11.0 | 9.5  | 19.5 | 8.4  | 16.2 | Below 10 mg/L                 |
and organic matter, algae, dissolved colored organic compounds, and plankton and other microscopic organisms. One of the most important test for analyzing water quality is measuring its turbidity index that indicates the transparency of water measuring, how much amount of sunlight scattered through the water. It refers to the haziness of fluid/water caused by the presence of a large number of individual particles that are mainly invisible to the naked eye. In the present study, the turbidity in Mansbal Lake is measured using the Secchi disk, as it is very useful in measuring the turbidity in lakes, reservoirs, channels, etc. During the present study, the values recorded from site 2 in the Mansbal Lake were 2.5 m in December, and 1.8 m in June was lowest among all the sites selected and can be related to the heavy pollution from the catchment area and excess growth of phytoplankton in the lake. Similar results were put forward by (Naik, Rashid, & Balkhi, 2015), in his study, that low transparency is because of the presence of excessive adjourned matter, and humus fetched in due to anthropogenic activities in the nearby area. Another study from (Bhat et al., 2013), revealed that the silt spawned by the disturbances in the lake bottom as a consequence of hurly-burly flood water which comes from heavy rains. Turbidity were maximum in December as revealed from the data collected, indicating that the disturbances in lake and growth of phytoplankton are low during the winter months and the presence of low suspended organic matter. These results have also been supported by (Sinha, Kumar, Srivastava, Mishra, & Choudhuri, 2002; Zutshi et al., 1980), in their studies.

Dissolved oxygen

The quantity of oxygen present in lake water is said to be as its dissolved oxygen content. The living organisms present in the water utilize this oxygen for their survival, as oxygen is one of the essential element for the survival of living organisms excluding some bacteria. Dissolved oxygen depends upon the water quality of a given waterbody. Measurement of DO in the present study was done with the help of Winkler’s Azide method, resulting in the presence of greater DO levels in winter as compared to the summer. This condition clearly indicates the inverse relationship of DO with temperature and agrees with the findings of (Naik et al., 2015). The highest values were recorded from the central limnetic site and there was less concentration of dissolved oxygen at sites 2 and 3. The higher temperature indicates the lower DO levels as solubility decreases with temperature and the mechanisms involved in DO mutation in water are respiration, photosynthesis, and diffusion (Kulkarni, 2016). The lowest levels of DO at Site 2 of Kondabal area are due to the presence of human habitats near the lake. The sewage and other waste products from these habitats directly move into the lake. For decomposition of these wastes, oxygen is needed by various organisms. This statement goes well with conclusions of (Tantray and Rafiq, 2013). The solid waste and plastic items from the catchment area directly slide into the lake affecting the penetration of the sunlight which in turn can result in a decrease in the primary productivity. This decrease can cause a reduction in the Dissolved Oxygen and increasing biological oxygen demand. Another study by (Vass, 1980), advocates the higher concentration of Dissolved oxygen during winter because of lower biological activity.

Free carbon dioxide

CO₂ is present in the environment as free carbon dioxide and being soluble in water, it gets easily dissolved in water. CO₂ is also being utilized in the water by phytoplanktons, present in different quantities and if the amount of dissolved carbon dioxide surpasses its normal range, the water becomes acidic in nature (formation of H₂CO₃). In the present study, the free CO₂ was measured by using the titrimetric method, and the study revealed that the higher level of free CO₂ was present in December (winters) and at site 2 (Kondabal), the free CO₂ level was recorded higher than at other places. Shah and Pandit (2012) have also observed a higher concentration of CO₂ in winters. Site 2 and Site 3, largely occupied with human settlements excludes the maximum amount of sewage and other organic matter directly into the lake and can result in a higher concentration of CO₂ toward winter because the carbon dioxide content of water depends upon the water temperature and decomposition of organic matter. (Shah et al., 2019), in his study also has advocated these changes due to anthropogenic activities near waterbodies.

Electrical conductivity

Conductivity (or specific conductivity) of water (or electrolyte solution) is a measure of its ability to permit electric flow. EC can be used for assessing the trophic status and pollution load of waterbodies (Shastree, Islam, Pathak, & Afshan, 1991). During the current study, the peak values of EC were recorded at Kondabal site 2 in June, and it can be related to the presence of high pollution load in the water due to the presence of a large catchment area near. By using specific conductivity as an index, values exceeding 200 μS/cm indicate a greater level of nutrient loading (Rawson, 1960). EC of water depends upon the temperature and evaporation. The higher the temperature, the higher the evaporation and solute concentration,
and then the higher EC. It can be seen that the Kondabal site of Lake shows a slight increase in temperature in June affecting by slight increase in EC values. This agrees with the findings of (Rajib, Ranjan, Kumar, & Debojyoti, 2006).

Hydrogen ion concentration (pH)

pH (power of hydrogen/ hydrogen ion activity or concentration) scale is used to analyze the acidity or basicity of a given solution/liquid. The scale measures the values from 1 to 15, values below 7 pH are categorized as acidic, while above 7 pH as basic and 7 pH denotes as neutral. Hydrogen ion concentration (pH) is well defined as the decimal logarithm of the reciprocal of the hydrogen ion activity (Covington, Bates, & Durst, 1985). pH that maintains the acidic or basic property, is a vital characteristic of any aquatic ecosystem since all the biochemical activities and retention of physicochemical attributes of the water are greatly dependent on the pH of the surrounding water (Jalal & Sanal Kumar, 2013). In the present study, the pH values ranged between 8.9 pH and 7.6 pH showing alkaline nature of water, indicating the lake was well buffered during this period of study. The highest pH values in all the months were recorded at Kondabal site 2 because of the calcium intrusion and heavy pollution load from the near catchment area. This inconstancy in pH values can be attributed to the influence of the variations in photosynthetic and decomposition rates of organic matter due to high pollution, and this statement also goes well with the findings of (Shah, Pandit, & Shah, 2017).

Chloride

Chloride is formed when the element chlorine (Cl) gains an electron or when a compound such as a hydrogen chloride (HCl) is dissolved in water or other polar solvents. In the present study, the chloride content in Manasbal Lake ranged between 21.9 mg/L and 5.8 mg/L, and maximum values were recorded in June. The highest values were recorded from the Kondabal site and Hanji Mohalla site, because of the addition of sewage and high pollution load from the catchment area. The presence of Chloride in water witnesses the organic load of animal origin from the catchment area (Thresh, Beale, & Suckling, 1943). Exceed in the concentration of chloride in an aquatic system is a notion, not only of eutrophication but also of pollution-induced by sewage and other wastewaters (Munawar, 1970, 1974). The presence of chloride content in lake water near the Kondabal site may also be due to the siltation of pestilential run-off from adjacent fields, stone mines, and lime furnaces. Chlorides mainly originate from inorganic salts like NaCl, KCl and CaCl₂, etc. which are normally provided by soil, natural layers of chloride salts, domestic sewage, and animal wastes (Gopalkrushna, 2011).

Total alkalinity

The chief species accountable for alkalinity are carbonates, bicarbonates, hydroxide ions, ammonia, organic acid etc., alkalinity acts as a buffer against rapid pH change (Lodh, Paul, Karmakar, & Das, 2014). According to the study made by Yousef (1995), that the water of Manasbal Lake has alkaline nature and hard water because of the presence of carbonates and bicarbonates of calcium and magnesium. In the present study total alkalinity ranged between 290 mg/L and154 mg/L, showing highest values at Kondabal site 2 and Hanji Mohalla site 3. The values were minimum during June and maximum during month of December, determine that total alkalinity in water body follow a decreased trend from winter to summer months. The Total alkalinity values in all the study sites during the study period ranged from 154 mg/L to 290 mg/L. This was due to extreme photosynthetic activity eliminating free as well as bound carbon dioxide from bicarbonates and same results were found by (Dar et al., 2013) in his study.

Total hardness

The presence of high mineral content in a water describes it as hard water and water with low content as soft water. Hard water becomes as soon as water seeps over deposits of limestone, chalk, or gypsum which are basically made up of calcium and magnesium carbonates, bicarbonates, and sulfates. In the present study, the total hardness of water was high at all the sites of the lake, ranging between 212 mg/L and 90 mg/L. The maximum values were recorded all over during June. The highest values of total hardness at Kondabal site 2 seem to be related to the percolation of Ca²⁺ and Mg²⁺ ions into lake waters due to the presence of stone quarries and lime kilns in the adjoining area. The hardness of water may also happen due to the occurrence of cations of Ca²⁺, Mg²⁺, Fe³⁺, etc. (lodh et al., 2014). The lake is also surrounded by the human settlements and the sewage outlets possessing soap and detergent wastewaters and agricultural run-off directly drain into the lake which can also increase the hardness of the water. According to (Satya & Narayan, 2018), the hardness of water may be due to the entrance of direct pollution from settlements and industrial discharge. The water of Manasbal lake is placed in the category of very hard waters, because of the values of hardness exceed the value of 180 mg/L, according to the hardness scale of Water Quality Association, a hardness value below 17 mg/L is soft water, 17 mg/L to 60 mg/L is slightly hard, 60 mg/L to 120 mg/L is moderately hard, 120 mg/ L to 180 mg/L is hard and above 180 mg/L is very hard.
**Calcium**

In freshwater and saltwater, calcium is present in the form of $Ca^{2+}$ ions. The hardness of water is mainly dependent on the contribution of calcium in it. During current study, the concentration of calcium ranged between 37.4 mg/L and 15.4 mg/L, recording the highest values at Kondabal site 2. The occurrence of high calcium content in Manasbal Lake is because of the presence of rock mines and kilns in the Kondabal area, where the production of gypsum is being carried out. Manasbal Lake has been quoted as a marl lake by (Sarah, Jeelani, & Ahmed, 2011). According to the study made by (Bhateria & Jain, 2016), rivers, streams flowing over limestone, $CaCO_3$, gypsum, $CaSO_4$, $2H_2O$, and other calcium-holding rocks, result in the presence of a high concentration of calcium in it. Another study carried out by (Rashid et al., 2013), revealed that the petrogenesis of the catchment area of Manasbal Lake is subjugated by bedded limestone. The outlets and waste products of these kilns and factories directly drain into the Manasbal Lake, thus polluting it by increasing the concentration of calcium.

**Total Phosphorous**

A phosphate is a chief form of phosphorous existing in lake waters. Orthophosphates and Polyphosphates are the common forms of phosphorous found in aqueous solutions. The most important sources of phosphorous in the aquatic ecosystems are domestic sewage, agricultural run-off containing fertilizers and ecosystem are industrial wastes (Gopalkrusna, 2011). The current study revealed, the Phosphorous concentrations ranged between 252 μg/L and 92 μg/L, showing maximum concentration at Kondabal site 2, because of the presence of human habitats near the lake and run-off of agricultural wastes directly into the lake from nearby agricultural fields, thus resulting in the higher productivity of phytoplankton. (Gul et al., 2021), also concluded that higher concentrations of total phosphorous is a sign of pollution. Phosphorous moves in the lakes through domestic wastewater, accounting for the augmented eutrophication (Vyas, Mishra, Bajapai, Dixit, & Verma, 2006) and the increased concentration of Phosphorous in lakes resulted in greater phytoplankton productivity. (Welch, 1980 & Gul et al., 2021) found that higher occurrence of phosphorous in waterbodies leads to more eutrophication.

**Ammonical nitrogen**

Ammoniacal nitrogen (NH$_3$-N) is used to calculate a portion of ammonia, a venomous waste product frequently found in landfill leachate (Aziz, 2004), and in discarded produces, such as sewage, liquid manure, and other liquid organic waste products (Manios, Stentiford, & Millner, 2002). Ammonia can be fatal for humans and can create an imbalance in the water systems. During this study, the concentration of Ammonical Nitrogen in Manasbal Lake ranged between the maximum of 19.2 mg/L and a minimum of 3.8 mg/L, showing the declining trend from June to December because of the growing process of photosynthesis by phytoplanktons inside the lake. The values of ammonical nitrogen were quite high at site 2 (Kondabal). Use of fertilizers in agricultural fields of the catchment area and the presence of domestic sewage in the lake has resulted in the highest concentrations of Ammonical nitrogen in December and lower concentrations in August (Gul et al., 2021). Ammonical nitrogen has been stated to be the ideal nitrogen for the productivity of phytoplankton (Wetzel, 2001).

**Nitrate Nitrogen**

The most and frequent form of inorganic nitrogen inflowing toward freshwater is nitrate and is mainly from sewage, groundwater, and precipitation and is usually found in low concentration (Wetzel, 1983). It can directly mix up into water resources as a result of agricultural run-off containing nitrate from fertilizers and its presence depends upon the activity of nitrifying bacteria in any aquatic ecosystem. In the present study, the concentration of Nitrate Nitrogen in Manasbal Lake was lower in June and showed a declining trend toward December. The values of nitrate-nitrogen ranged between a maximum of 29.2 mg/L and a minimum of 4.2 mg/L. The maximum values were recorded from the Kondabal site 2 can be endorsed by the higher inputs of nitrogenous wastes, sewage, and agricultural runoff from the nearby farmlands and catchment area. One of the biggest threats to the Kashmiri lakes is unwarranted nitrogen inflow due to runoff from the agricultural fields (Shah et al., 2019). The escalation of nitrate-nitrogen in the lake can be associated with the oxidation of ammonical nitrogen to nitrate also agreed with the findings of (Quastle & Scholefield, 1951; Toetz, 1981). The presence of a heavy growth of phytoplankton in the lake can also be due to the high concentration of Nitrate.

**Impacts on health of people in catchment area**

Health hazards linked with the contaminated water include diverse infections and ailments such as respiratory diseases, cancer, diarrheal, and cardiovascular diseases. The people living proximate to the water resources directly fed upon these resources and use that water in their daily lives. If the water gets polluted, it will directly affect the daily life of people residing near to it and will have very harsh consequences to deal with. At present, the whole world is facing the adverse consequences of water pollution and is severely affecting the health of human beings at a global level (Haseena et al., 2017).
Similar problems are being faced by the inhabitants in the catchment area of Manasbal Lake, the people are suffering from several waterborne diseases among which diarrhea, vomiting, skin, and respiratory diseases are common. The abnormal glitches in the physicochemical parameters in this freshwater body have affected severely the health aspects of people and have mainly attacked the children and the old age population. The results recorded during the study period revealed that changes in these parameters may be responsible for the deteriorating health conditions of people using this resource in their daily lives. Along with that, guideline/reference values have also been mentioned in the table no. 1. These values can be helpful while assessing and treating this contaminated water. These values should be taken into consideration while using the water for different household and irrigational activities.

**Remedial/restorative Measures**

The Manasbal Lake is bothered by a lot of malaises, chiefly rising out of anthropological intrusions equally from the exterior as well as from the interior of the lake. The utmost evils the lake is fronting, comprise unrestricted infringements by transforming the open water areas into the moving/ floating vegetable gardens and consequently into perpetual landmass, and building of housing settlements. Another main problem the lake is fronting right now is huge eutrophication, which needs to be addressed at an early. In the year 2007, the Government of Jammu and Kashmir formulated the Wular-Manasbal Development Authority (WMDA), which undertook the restorative measures for the welfare of Manasbal Lake. WMDA took several methods for lake rehabilitation and to improve the overall environment of the lake, but on the ground, results don’t come up with satisfactory results. Some common measures/suggestions enlisted below can be taken for the restoration and improvement of the general environment of the lake:

- An active checking mechanism for inspecting the Manasbal lake Preservation Programme which should consist of prominent limnologists, researchers, experts who have been closely associated with lake studies during the last two decades, besides engineers, foresters, and academicians.
- Promoting the research and development activities through on-line monitoring devices as in foreign countries.
- Appropriate management practices should be formulated with an estimation of existing threats to water biodiversity as well as fish and waterbird species as per wetland acts.
- Awareness drives through NGOs and educational institutions should be done with strict adherence to the water act 1974. These programs should actively involve the local population residing near the lake and educating them about the consequences of water pollution.
- Government authorities can enforce legitimate controls on the land use and release of nutrients into the lake, to restrict uses with direct or indirect pollution effects. Prioritization of the works for Manasbal Lake and the accomplishment of works on a specified time frame.
- Approach of drainage basin alteration which involves mainly the treatment and seizure of nutrients and sediments before reaching the lake. It involves the management practices the same as used for soil erosion to interrupt the movement of sediments primarily during runoff, including the practice of terracing, grassed waterways, crop residue management, and creation of shelterbelts. The main problem of sediment load entering Manasbal Lake is witnessed on the Kondabal and Outlet sides of the lake, because of the presence of brick kilns and agricultural lands, respectively.
- Diversion of wastes can be practiced which is a commonly used measure for enhancing the water quality of eutrophic lakes. Manasbal Lake experiences sewage effluents as a major source of Lake Eutrophication. The approach will surely result in the improvement of water quality like an increase in transparency, species diversity, a decrease in phytoplankton biomass, and harmful chemicals.
- Lake deepening or dredging, that is, pulling up and elimination of macrophytes has been extensively used in streams, lakes, and reservoirs. The method is used where macrophytes are a substantial result of eutrophication.
- Aeration of lake sediment method can be practiced, which prevents anaerobic conditions from occurring and will result in improvement in water quality by oxygenation method (addition of pure oxygen to water).

**Conclusion**

The study is expected to deliver a dais for advanced research to reconniter the possible role of anthropogenic actions as signs of pollution. The immense rate of pollution caused by anthropogenic activities is interlinked with many parameters. Among the selected sites, site 2 (Kondabal) and site 3 (Hanji Mohalla) where highly disturbed and the most deteriorated water quality is found, because of the presence of human habitats nearby. Apart from variation in the water temperature, turbidity, free CO₂, EC, pH, chloride, total alkalinity, total hardness, calcium, total phosphorous, ammonium nitrogen, and nitrate nitrogen, Manasbal Lake has other problems, like illegal
encroachment, shrinking up of lake area, which needs to be focused at early. At Kondabal site, some of the parameters taken showed very high (abnormal) values than guideline values, such as, free CO₂ is 12.7 mg/L, EC is 392 μS/cm, pH 8.9, chloride 219 mg/L, total alkalinity 290 mg/L, total hardness 212 mg/L, total phosphorous 252 μg/L, nitrate nitrogen 29.2 mg/L. It is now or never a situation for us to save these natural resources, otherwise, in the coming time, we will be unable to use any kind of commodity provided by these lakes. Sound management policies and techniques should be adopted to procure them from further degradation and deterioration. In a broad-spectrum, the water quality of the lake is getting worse due to the presence of a high concentration of chemicals/derivatives of calcium, phosphorous, nitrogen, and chloride, which directly or indirectly influence the other parameters of water quality thus polluting it and the pollution of water can directly or indirectly be linked with the diseases from which the population of the nearby area is suffering by using the water from this resource. The abnormal changes in these parameters are related to the incidence of various water-borne diseases in the area.

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