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Assessment of Water Quality and Pollution Status of Selected Lakes in the Nilgiri District

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Abstract

This paper critically evaluates how the water bodies in Nilgiri district are being effected from seasonal and chemical influence that determines water quality. Deploying different metrics like DO, BOD and COD metal accumulation and WQI of Pykara Lake, Emerald Lake, Wellington Lake and Kattery Lake have been examined by taking both water and fish samples. Wellington Lake seems to have exceeded the permissible level of metal that is highly risky in comparison with other lakes, mainly due to the hardness mainly. Tourist-driven places show higher deterioration in water quality due to rapid monsoon flush and human activities, where integrated management strategies are viable.

Keywords: Dissolved Oxygen, Total Dissolved Solids, American Public Health Association, Water Quality Index, Eco-system

Introduction

The freshwater ecosystem plays a central role in maintaining the balance of ecosystems, wildlife and providing people with water. The super sensitivity of lakes in mountainous regions is that they are unable to clean themselves to this same extent and thus depend heavily on weather and mountainous geography. Nilgiri District of the Western Ghats of Tamil Nadu is the foundation of this paper as this is a significant example because it is home to numerous natural and artificial lakes, which can provide people with drinking water, irrigation, fish, recreational areas and tourist attractions. However, due to contamination, around 1.1 billion people consume water from risky sources worldwide [1]. These lakes are also beneficial to the local economy, but with the growing leather industry, discharge into water bodies in Tamil Nadu has increased, especially from tanneries with high volume liquid and salt discharge (Figure 1).

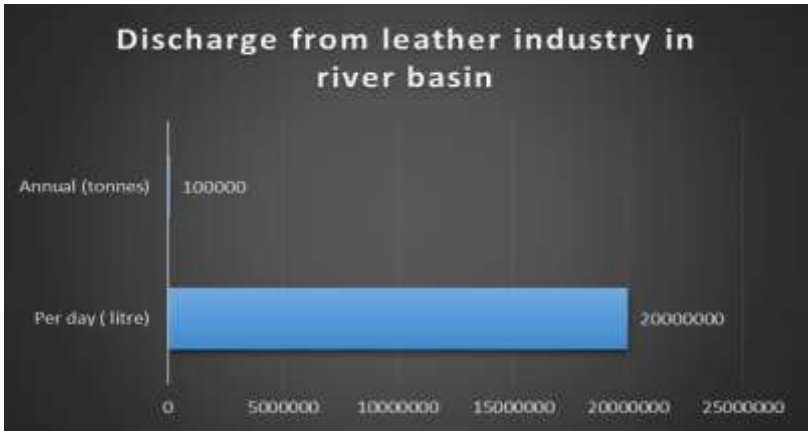

Figure 1: Discharge of liquid and salt from tanneries in the river

(Source: [2])

Over the past several years, the population in the cities has been expanding rapidly, there is an increase in tourism, farms are overflowing with runoff, and dumping of untreated sewage is going on. All these human activities have contributed to worsening water. The addition of nutrients; garbage, soap, fertilizer, and mounds of solid waste have increased the chances of eutrophication [3]. The lake water also has its cause-and-effect changes based on seasonal changes occurring due to the monsoon rains, especially after COVID-19, since when tourist influx has skyrocketed in the Nilgiris (Figure 2). Considering that a consistent monitoring of the water quality is paramount so as to notice its level of pollution, utilisation of the water in a sustainable manner and to come up with good protection schemes, we cannot overlook the monitoring.

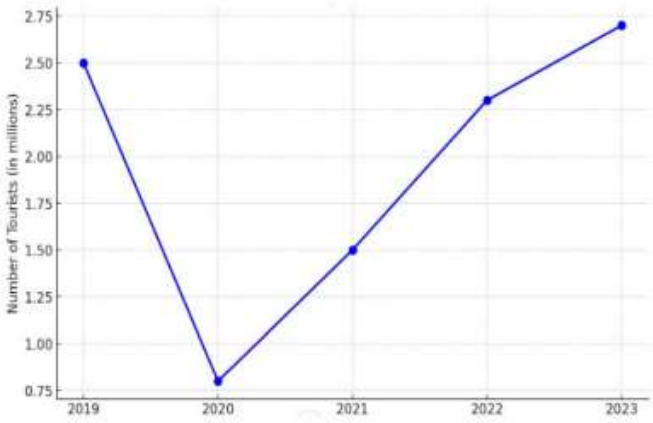

Figure 2: Tourist influx in Nilgiris

One of the most convenient methods to have a general concept of the level of health of a lake is to examine its physicochemical parameters and calculate a Water Quality Index (WQI). That will give a single score which will tell whether the lake is in good, bad, or in between [4]. This paper adopts that method in an attempt to examine the water quality and pollution condition of certain lakes within the Nilgiri.

The major objectives of this paper are the following:

1. To measure the standard physicochemical parameters of the selected lakes with the use of the standard methods
2. To observe how the water quality varies with locality and seasons,
3. To compute a WQI to map the amount of pollution; and
4. To identify the sources of pollution, and to prescribe the management activities to maintain the lakes' health.

Lakes become particularly susceptible in the hills, such as the Western Ghats due to steep slopes, intense rainfalls and increasing human movements and activities [5]. The indicators of organic pollution are the DO and BOD. The combination of low DO and high BOD typically indicates the presence of biodegradable material, which is often sewage, tourist activity or farm runoff [6]. COD higher refers to the pollutants that are chemically oxidizable and are the product of homes or factories. The excessive number of nutrients promotes the growth of algae, which might produce a smear, dissolve the oxygen and harm the fish and plants [7]. Practices conducted in India reveal that accelerated urbanisation of the lakes area causes more sedimentation, solid trash dumping, and land encroachment, which destroy the quality of water and disrupt the ecology. To some extent, lakes that are shown in Figure 3 are the centres of

tourism tend to have greater pollutants due to boats, street food stalls, and direct release of untreated sewage. It is these human pressures that undermine the inherent self-cleaning capacity of a lake, reducing its application in drinking and recreation.

Figure 3: Lakes in Nilgiri

The index of Water Quality has become a convenient tool to make complex data in a single score that shows the overall condition of the lake [8]. Past environmental scans in the Nilgiri District indicated the significance of its lakes in drinking water, irrigation, fish and a source of tourism income [9]. However, the increase in house sizes, as well as visitors, is causing concern about the decrease in water quality. Generally, the available sources demonstrate that a systematic physicochemical analysis in conjunction with WQI offers a credible method of evaluating pollution in lakes [10]. These findings reveal that human activities and land use are the primary determinants of the health of lakes.

Materials and Methods

Study area and Sampling design

The research has been conducted focusing on a few lakes within the Nilgiri District, which is located in the Western Ghats, in adherence to the guidelines of NEERI (1991) and APHA (2005). Spots were set up within every lake for observing the influences of tourism, surrounding residential discharge, and other areas that had not been transformed to determine how things vary with space [11]. The position of water samples was varied with relation to seasons to gain an idea of the change in water chemistry with time. The waiting period till the monsoon and non-monsoon seasons to sample outliers of dilution and pollution has been significant. On these points, fill the surface water in pre-cleaned bottles, and shake the bottles with the water of the same lake to ensure that the samples remain clean. Water transferred into polypropylene container which has been washed with acid (2% HNO_3) and sterilized.

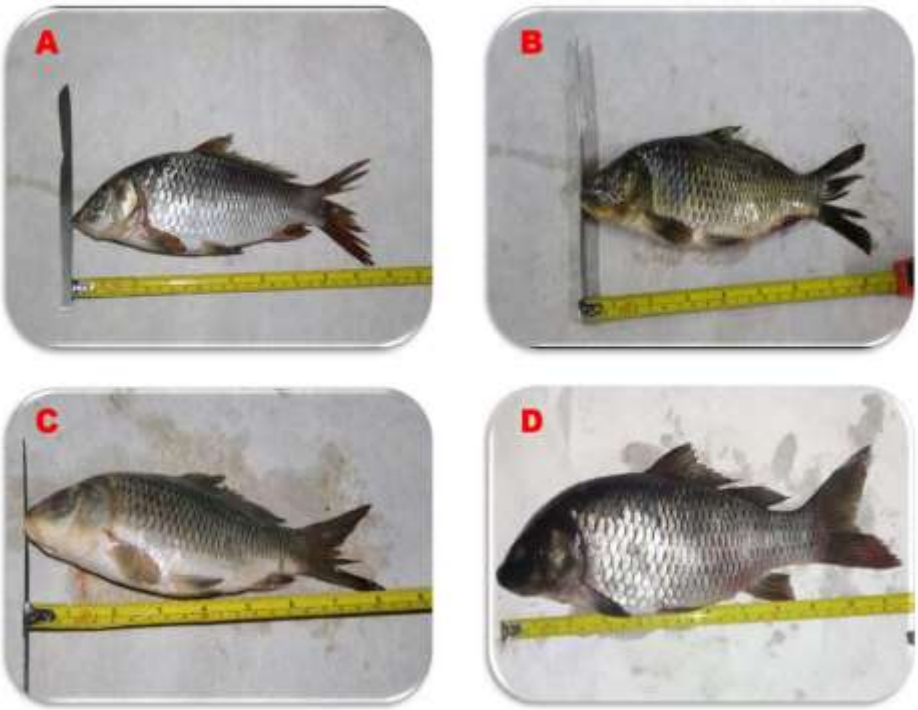

Figure 4: Fish Samples collected from lakes

Fish samples were also taken out of the chosen lakes as a measure of bioaccumulation of trace elements and testing of the transfer of contaminants in abiotic (water and sediment) to biotic compartments. Silver carp (Carassius gibelio), golden carp (Cyprinus carpio) (A, C and D) shown in Figure 4 is collected from Pykara lake, Kattery lake and Emerald lake. Golden carp (B), shown in Figure 4, on the other hand, has been collected from Wellington Lake due to the unavailability of common carp. The representative fish species often consumed by the local people and widely reported in the lakes were also chosen to make sure that it was ecologically and generally relevant to human health. To ensure that potential seasonal differences in metal accumulation would be obtained, sampling has been done in both monsoon and non-monsoon seasons [12].

The local fishermen were used to help in collecting the fish through locally authorized capture techniques (gill nets and cast nets). The samples were washed with distilled water as soon as captured so as to remove adhering debris, and then the samples were taken to the laboratory in ice boxes to ensure that the tissues were not subjected to degradation. Morphometric parameters included the weight and total length, which was observed in the laboratory and then froze at 20°Celsius for further tests [13]. To prevent contamination, stainless steel instruments were used to cut up the edible muscle tissue. Samples were then washed in deionized water, dried in the oven at 60 °C to constant weight and homogenized in a clean mortar and pestle.

Physicochemical analysis

At this point, this study used calibrated field metres to measure temperature and pH. It has been determined that the electrical conductivity (EC) measures the ionic content and the total dissolved solids (TDS) through the standard gravimetric or metre-based determinations. The Winkler method has been used to indicate dissolved oxygen (DO) and also biochemical oxygen demand (BOD) and this method was used after five days of incubation at 20 degrees Celsius. The reflux of dichromate was used in estimating chemical oxygen demand (COD). Titrimetric procedures have been applied to estimate total hardness,

alkalinity, and chloride. Standard spectrophotometric tests were carried out in case of such nutrients as nitrate and phosphate. These were all conducted in line with the standard procedure in American Public Health Association (APHA) in order to ensure that the results were accurate and reliable [14].

In order to detect elements, a dry mass of the tissue of about 1 g was acid digested using a 1:1:1 triacid digestion - Sulphuric acid (H_2SO_4), Nitric acid (HNO_3) and perchloric acid ($HClO_4$) according to recommended standards in the American Public Health Association. The samples were digested and filtered up to a set volume using deionized water. Atomic Absorption Spectrophotometry (AAS) and ICP-MS (Inductively Coupled Plasma Mass Spectrometer) were used to determine concentrations of chosen levels of heavy metals. Quality control based on the analysis was analytical by using reagent blanks, standard reference material, and triplicates [15]. The bioaccumulation patterns were compared through comparison of metal concentrations in the fish tissues to the related concentrations of the water and sediment samples. Correlation analysis was conducted to evaluate relationships between compartments as well as to evaluate the potential of trophic transfer.

Water Quality Index (WQI)

To have a general view of the water quality, the Water Quality Index has been collected based on the weighted arithmetic method. The amount of weight attached to each parameter was in accordance with the level of significance. By comparing the obtained values with the allowable ones, a quality rating of each parameter has been obtained. It has also been added the weighted scores to obtain the total WQI and then the lakes were grouped as either excellent, good, poor, and extremely poor or not suitable for drinking [16]. The analysis indicated that there were great spatial and seasonal changes across the Nilgiri lakes. In general, it appears that human activity is a large factor in defining water quality. Measurable concentration of metal substances have been found in the water samples across the lakes and reasons with high deposit level in the fish collected that shows contamination has a role in the biological interplay in the water bodies in Nilgiri.

Results

Physicochemical characteristics

All lakes maintained a constant pH of slightly acidic to moderately alkaline, which was within the drinking water limits as observed in Table 1. More alkalinity has been found in lakes with high tourist presence; however, it is most likely due to detergents and domestic runoff [17]. The EC and TDS were different. The difference in EC and TDS in Figure 5 and 6 indicated increased dissolved salts and human contributions in the lakes which receive runoffs related to the cities and farms. Water samples are taken in pre-monsoon covering March, April and May and again post-monsoon covering October, November and December to reflect on seasonal influence in water bodies.

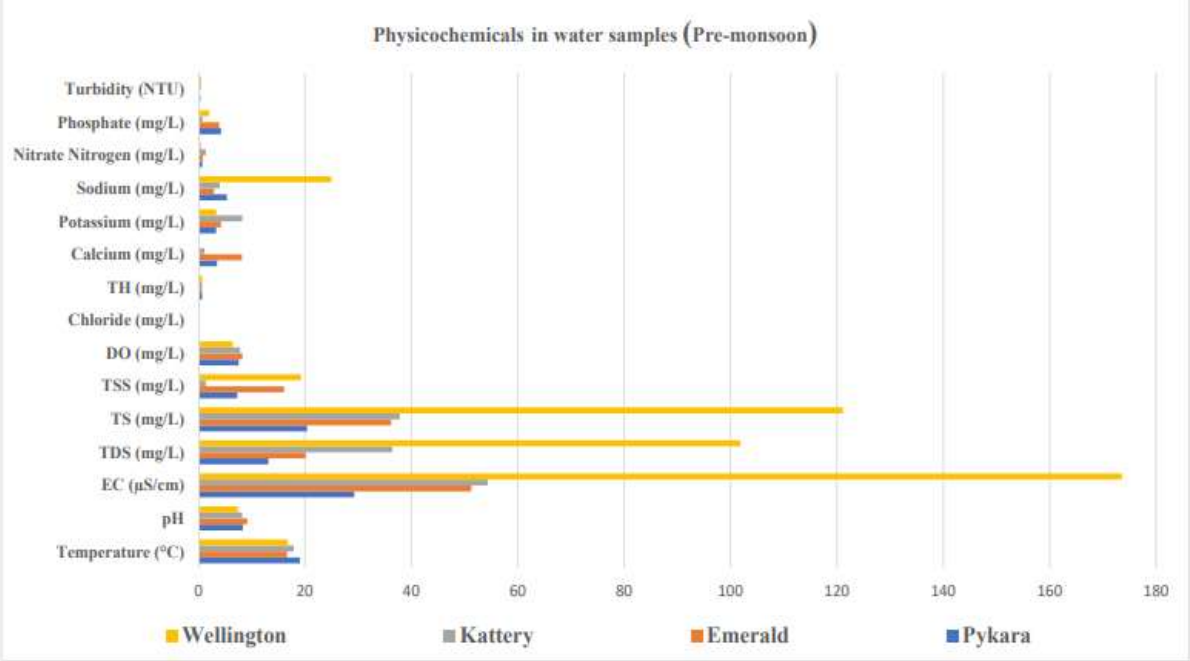

Figure 5: Physicochemicals found in water samples in pre-monsoon period

Table 1 Physicochemicals in water samples (Pre-monsoon)

Parameter	Limits	Pykara	Emerald	Kattery	Wellington
Temperature (°C)	30	19.06 ± 0.21^{a}	16.66 ± 0.35^{c}	17.93 ± 0.30^{b}	16.77 ± 0.25^{c}
Ph	6.5-8.5	8.33 ± 0.058^{b}	9.16 ± 0.23^{a}	8.2 ± 0^{b}	7.37 ± 0.06^{c}
EC (µs/Cm)	4000	29.26 ± 1.57^{c}	51.3 ± 1.65^{b}	54.37 ± 1.02^{b}	173.57 ± 3.40^{a}
TDS (Mg/L)	2000	13.13 ± 0.87^{d}	20.13 ± 0.90^{c}	36.45 ± 1.65^{b}	101.86 ± 1.37^{a}
TS (Mg/L)	BDL	20.4 ± 0.7^{c}	36.20 ± 1.22^{b}	37.82 ± 1.71^{b}	121.13 ± 1.75^{a}
TSS (Mg/L)	200	7.26 ± 0.21^{c}	16.06 ± 0.32^{b}	1.37 ± 0.06^{d}	19.26 ± 0.86^{a}
DO (Mg/L)	6	7.53 ± 0.058^{b}	8.27 ± 0.15^{a}	7.83 ± 0.11^{b}	6.43 ± 0.06^{d}
Chloride (Mg/L)	250	0	0	0	0
TH (Mg/L)	500	0.67 ± 0.02^{a}	0.62 ± 0.01^{a}	0.65 ± 0.03^{a}	0.68 ± 0.03^{a}
Calcium (Mg/L)	200	3.49 ± 0.26^{b}	8.16 ± 0.16^{a}	1.13 ± 0.15^{c}	0.13 ± 0.15^{d}
Potassium (Mg/L)	20	3.3 ± 0.1^{c}	4.23 ± 0.15^{b}	8.23 ± 0.15^{a}	3.33 ± 0.11^{c}
Sodium (Mg/L)	200	5.33 ± 0.35^{b}	2.9 ± 0.1^{c}	4 ± 0^{bc}	24.96 ± 0.91^{a}
N-Nitrogen (Mg/L)	BDL	0.7 ± 0^{b}	0.83 ± 0.05^{b}	1.36 ± 0.06^{a}	0.43 ± 0.06^{c}
Phosphate (Mg/L)	5	4.23 ± 0.07^{a}	3.92 ± 0.04^{b}	0.75 ± 0.005^{d}	1.99 ± 0.02^{c}
Turbidity (NTU)	5	0.34 ± 0.005^{c}	0.24 ± 0.005^{d}	0.43 ± 0.04^{b}	0.5 ± 0^{a}

In the pre-monsoon period, the overall concentration of total dissolved solids (TDS), electrical conductivity (EC), biochemical oxygen demand (BOD) and chemical oxygen demand (COD) in most of the lakes were comparatively very high. This was especially observed Pykara Lake which experience increased anthropogenic and tourism pressure. The level of dissolved oxygen (DO) was relatively low in pre-monsoon periods particularly in Pykara Lake pointing to a higher load of organic matter and decreased dilution ability. However, in contrast, in the post-monsoon season, the DO levels rose in all the lakes,

probably attributed to the effects of rainfall, that caused aeration and dilution caused by the rainfall as depicted in Table 2. Nevertheless, Wellington Lake exceeded the permissible limit of hardness in both pre and post monsoon seasons [18]. Therefore, water quality of this lake is not safe for consumption which could be attributed to the surface runoffs that involved agricultural residues and household wastes, raising its hardness.

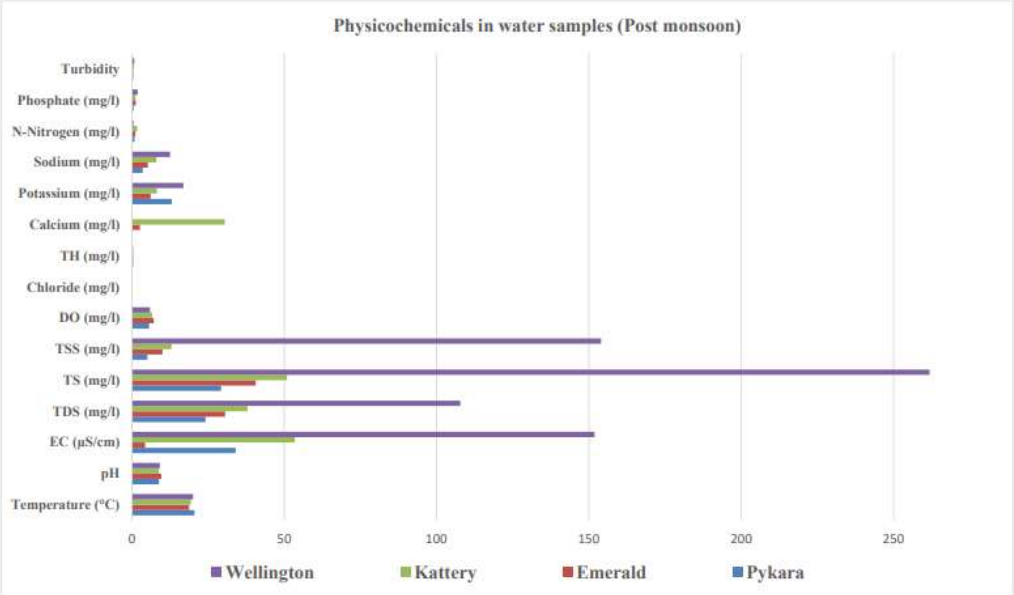

Figure 6: Physicochemicals found in water samples in post-monsoon period

COD level was also increased in contaminated locations, which is an indication of chemicals that are oxidizable by oxygen due to local activities [19]. Hardness and alkalinity were found to be moderate in the majority of the lakes, and this is an indication of the local geology. The level of chloride was typically low but rose a bit towards the populated places. The fish muscle elemental analysis was taken for the samples of Silver carp (Carassius gibelio), golden carp (Cyprinus carpio), and the results are tabulated (Table 3).

Concentrations of nutrients in lakes and indicators of pollution

There was a significant difference in the levels of nitrate and phosphates across the lakes. The concentration was greater at locations of farm runoff and sewage. There is a particular concern about the elevated phosphate, which is mostly associated with triggering an algal bloom and causing eutrophication. As a result, the quality of lake water goes down and causes deviation in BOD, COD, and DO while reducing nutrients. Another effect that was caused by the monsoon was that it increased the nutrients in the lakes through runoff. The pre-monsoon levels of nitrate and phosphates were high in lakes that had experienced settlement and tourism activities. Based on the post-monsoon measurements, the nutrient enrichment was shown in all lakes, the extent being higher in those lakes that had massive catchment disturbance. This influx at this season is a hint that monsoonal runoffs contribute to a large influence in nutrient loading.

Table 2 Physicochemicals in water samples (Post-monsoon)

Parameter	Limits	Pykara	Emerald	Kattery	Wellington
Temperature (°C)	30	20.53 ± 0.25^{a}	18.76 ± 0.30^{c}	19.33 ± 0.40^{bc}	20.1 ± 0.26^{ab}
pH	6.5-8.5	8.91 ± 0.05^{c}	9.65 ± 0.08^{a}	8.86 ± 0.06^{c}	9.13 ± 0.06^{b}
EC (µS/cm)	4000	34.06 ± 1.80^{d}	43.1 ± 0.87^{c}	53.46 ± 1.35^{b}	151.83 ± 1.98^{a}
TDS (mg/l)	2000	24.16 ± 1.30^{d}	30.60 ± 0.61^{c}	37.96 ± 0.96^{b}	107.80 ± 1.40^{a}
TS (mg/l)	BDL	29.27 ± 1.06^{d}	40.63 ± 1.02^{c}	50.93 ± 1.05^{b}	261.8 ± 1.87^{a}
TSS (mg/l)	200	5.1±0.91c	10.03 ± 1.64^{bc}	12.97 ± 1.71^{b}	153.99 ± 3.27^{a}
DO (mg/l)	6	5.66 ± 0.25^{c}	7.16 ± 0.11^{a}	6.63 ± 0.15^{b}	5.96 ± 0.06^{c}
Chloride (mg/l)	250	0	0	0	0
TH (mg/l)	500	0.4 ± 0^{ab}	0.4 ± 0^{ab}	0.46 ± 0.06^{a}	0.33 ± 0.06^{b}
Calcium (mg/l)	200	0^{c}	26.2 ± 0.4^{b}	30.46 ± 0.45^{a}	0^{c}
Potassium (mg/l)	20	13.06 ± 0.25^{b}	6.13 ± 0.15^{d}	8.23 ± 0.25^{c}	16.9 ± 0.26^{a}
Sodium (mg/l)	200	3.56 ± 0.25^{d}	5.23 ± 0.40^{c}	8.03 ± 0.15^{b}	12.5 ± 0.2^{a}
Nitrate-Nitrogen (mg/l)	BDL	0.87 ± 0.06^{c}	1.13 ± 0.11^{b}	1.73 ± 0.05^{a}	0.5 ± 0^{d}
Phosphate (mg/l)	5	0.54 ± 0.03^{c}	1.25 ± 0.04^{b}	1.24 ± 0.03^{b}	1.87 ± 0.07^{a}
Turbidity	5	0.43 ± 0.01^{c}	0.40 ± 0.01^{c}	0.66 ± 0.04^{b}	0.78 ± 0.02^{a}

Water Quality Index (WQI)

The WQI calculated puts some lakes under the category of good, given their marginally polluted results and can be used after treatment for domestic use. In high-tourism lakes, lakes were classified as moderately polluted primarily because of the high levels of BOD and COD, as well as nutrients [20]. It suggests that the tourist influx in the Nilgiri region is directly linked to the in general, the findings demonstrate that although not all the lakes remain within the acceptable water quality levels, others are gradually decreasing due to human impact. There is some evidence from seasonal patterns indicating that rainfall not only dilutes the pollutants but also carries contaminants to the lakes.

Table 3 Elements in fish samples

Analysis	Permissible Limit (µg/g)	Emerald (µg/g)	Pykara (µg/g)	Kattery (µg/g)	Wellington (µg/g)
Na (Sodium)	200	21.08 ± 7.09^{a}	11.20 ± 0.90^{b}	21.47 ± 0.6^{a}	13.55 ± 0.46^{b}
K (Potassium)	3.5	1.28 ± 0.02^{a}	1.18 ± 0.10^{a}	1.25 ± 0.05^{a}	1.27 ± 0.07^{a}
Ca (Calcium)	19	6.10 ± 0.01^{ab}	6.20 ± 0.10^{a}	5.96 ± 0.15^{b}	6.20 ± 0.10^{a}
P (Phosphorous)	2.2	1.98 ± 0.30^{a}	1.72 ± 0.07^{a}	1.66 ± 0.21^{a}	1.67 ± 0.16^{a}

The Nilgiri lakes are facing deterioration that demands continuous efforts to put stringent surveillance and control near the region so that the place remains ecologically viable for a longer period. At pre-monsoon, Pykara Lake were classified as moderately polluted since the bodies contained a high level of BOD, COD, and nutrients. During the post-monsoon season, the WQI in most lakes improved slightly owing to the effect of dilution but stress was caused by nutrients in high activity zones.

Discussion

The Physicochemical Factors and Spatial Variability

The findings showed potential spatial variations in water quality, which are closely related to the surrounding land and human activities. Alongside this, the isolated lakes were seen to have comparatively low dissolved solids, which are influenced by the reduced anthropogenic impact and increased natural hydrochemical regulation [21]. The outcomes of the Water Quality Index (WQI) are the cumulative impact of physicochemical parameters and nutrient loading that can be seen in the examined lakes. Moderately polluted lakes had high BOD, COD, dissolved solids, and concentrations of nutrients, which was manifested as high anthropogenic pressure due to tourism, domestic discharge, and disturbances in catchment. Though the post monsoon dilution effects were observed to enhance some parameters like dissolved oxygen, the effect of the external loading remains apparent and is therefore still enriching the lakes.

Elements in water samples

The concentration of elements in the water showed a noticeable difference among the lakes, which was affected by a combined influence of morphological background, hydrological transaction and possible anthropogenic involvement [22]. There are high dissolved solids and dissolved oxygen in these lakes, which are dominated by ions in the dissolved phase. Also, the trace metals showed irregular patterns of distribution with higher concentrations found in the waterbody that are closer to human activities. The spatial heterogeneities of the WQI is linked with human activity intensity and variations near the lakes, and it was observed that catchment land use has a direct effect on the overall water quality status. Seasonal variation is a reflection of the hydrological processes control the concentration of pollutants using the dilution and runoff processes. Thus, it happened that WQI does not just outline the individual parameter variability but also does a combined evaluation on such ecological stress and new/emerging degradation patterns of the Nilgiri lakes.

Correlation coefficients of water in lakes

Correlation analysis showed a significant connection between the water quality and the key variables, which develop physicochemical and biogeochemical processes. Also, the positive correlations between dissolved solids and high-water conductivity in the lakes beside and surrounding the urban areas [23]. The ionic composition and mineral concentration shape this correlation indirectly for the water.

Elements in the sediment sample

Sediment analysis showed that the benthic zone of the lake, or the bottom side, is the place where the elements from the erosion, as per the watershed systems [24]. Elemental enrichment levels are different in several lakes, which is related to the pattern of watershed disturbance, hydrodynamic forces and past pollutant conditions of the water. However, the study suggested that the enrichment of the elements in water can be controlled by remobilising the underwater chemistry and environmental conditions.

Correlation coefficients of sediment in lakes

Correlation coefficient between the sediment components and the water conductivity revealed common sources, analogous geochemical properties and transport routes in the depositional system. Also, the connection between specific metals revealed that similar lithogenic sources are controlled by sediment

size and mineralogy [25].

Elements in fish samples

The fish sample in the context of the elemental content indicates that bioaccumulation processes control the water chemistry, food chain mechanisms and physiological regulation processes [26]. Marine fish are important for maintaining the ecosystem of the lake and its habitats. The species-specific accumulation patterns assess the ecological factors. However, the fish can be used as indicators of metal availability and transformation of potential ecosystems.

Correlation coefficients of fish in lakes

The correlation among the elements in fish tissues gave indications of uptake, retention and tissue distribution. However, the positive correlations among the elements indicated an accumulation pattern, while there is a selective biological control in the low correlations. The results highlighted that interconnectivity of water, sediment and biotic compartments determines aquatic ecosystems [26].

Table: Summary of the Observed Relationship between Water Quality Parameters and the Environment

Parameter Category	Dominant Observation	Likely Driving Factors
Dissolved Solids	Elevated near settlements	Domestic runoff, tourism activities
Dissolved Oxygen	Higher during the monsoon	Rainfall, mixing, aeration
BOD and COD	Increase in disturbed lakes	Organic wastes, sewage inflows
Nutrients	Localized enrichment	Agricultural runoff, wastewater

Conclusion and Recommendation

The given study evaluated the water quality and pollution level of chosen lakes in the Nilgiri district measuring physicochemical and nutrients, metal presence and sediments, by taking water and fish samples. The results illustrated that there are observable spatial and seasonal changes which are responsible for anthropogenic processes and catchment physical features. The high levels of BOD, COD, in the samples shows dissolved solids and concentration of nutrients at some sites reflect an increase of organic content besides the onset of ecological stress. Despite the improvements of some parameters after monsoon dilution, further external input is still a concern. The Water Quality Index (WQI) is mirroring the existence of moderate level of the pollution in the affected regions. Overall, the paper shed light on the necessity of continuous monitoring, controlled land-use activities and proper watershed management measures.

Recommendations

The local authorities should be aware of the water pollution and control their activities to minimise the

vulnerable issues in lakes. Also, the land use practices around the lakes should minimise erosion, waste disposal or drainage surfaces to lakes, which have to be controlled under the governmental regulations.

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