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Spatial variation in physicochemical parameters at different sites of a Tighra fresh water reservoir, Gwalior, Madhya Pradesh, India

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Abstract
The present study assesses the spatial and seasonal variation of physico-chemical parameters of Tighra Reservoir, a major freshwater resource near Gwalior, Madhya Pradesh, India. Water samples were collected seasonally from four representative sites (S1-S4) during summer, rainy and winter seasons over a two- year period from March 2022 to February 2024. Physical and chemical parameters, including temperature, transparency, turbidity, pH, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), alkalinity, free carbon dioxide, nitrate, sodium, and potassium, were analyzed following standard APHA methods. The result revealed marked seasonal and spatial variations in water quality. Higher turbidity, TSS, BOD and COD values were observed during the monsoon and summer seasons due to surface runoff and increased organic input, whereas winter recorded higher transparency and dissolved oxygen levels. The water remained slightly alkaline with moderate alkalinity, indicating good buffering capacity. Overall, most parameters remained within permission limits, suggesting that the reservoir water is suitable for drinking water supply, irrigation, and fisheries, though regular monitoring is essential for sustainable management.

Keywords: Tighra Reservoir, water quality, spatial variation, seasonal variation, Freshwater ecosystem

Introduction
India is endowed with extensive freshwater in the form of Lentic and lotic ecosystems. Lentic water bodies such as ponds, lakes, tanks and reservoirs, particularly perennial reservoirs, serve as vital sources of water for domestic consumption, agricultural activities, and aquaculture. These ecosystems have drawn considerable interest from ecologists because of their importance in supplying drinking water and supportive fisheries. A proper understanding of the environmental conditions existing within these water bodies is essential for the successful application of scientific approaches in aquaculture (Parveen, 2022) [8].

Reservoir play a key role to increasing fish production in country, provided enormous resources to the development of fisheries on the scientific lines. Reservoir are not one and only potential fisheries resources for future fisheries development but then also play a crucial role in man power resources development and also for generating employment source of country (Majhi, 2018) [7].

Water quality is a crucial factor for drinking, washing, irrigation, industrial needs. And may other purposes. Immoderate human obstruction and various anthropogenic activities in and around water bodies affect their physicochemical characteristics, which in turn directly affect aquatic fauna as well as phytoplankton communities. Periodic assessment of water quality generates essential data for evaluating the overall condition of the water and determining the long terms sustainability of the water body (Sontakke, 2020) [12].

This research investigates spatial variability at four representative sampling sites (S1-S4) across Tighra Reservoir using long-term monitoring data from 2022-23 and 2023-24.

Study Area
Tighra Reservoir is an important freshwater impoundments near Gwalior city, It is a lifeline ,was mostly constructed for the storage of water and its supply to the city, The reservoir lies approximately 18-23 kilometer west from the Gwalior city, which is located very near to Tighra village in the Gwalior area of Madhya Pradesh, Geographically , the reservoir is situated about 26◦12'-26◦14' N latitude and 78◦10'-78◦14' E longitude and its average elevation is around 218-220 m above mean sea level, and the reservoir is constructed by damming the Saank river. Tighra Reservoir is an important freshwater impoundment near Gwalior, Madhya Pradesh, India. Four sampling sites (S1–S4) were selected across the reservoir to capture spatial heterogeneity — representing inflow, mid-reservoir, vegetated margins, and near-outlet zones.

Methodology
Collection of water
The present investigation focuses on selected physico-chemical parameters of water to evaluate the exiting water quality at sampling locations. Water samples were collected using polyethylene-coated wide-mouth bottles of one -liter capacity. Care was taken to collect the samples from a depth of 5-10 cm below the water surface without disturbing the substratum, in order to prevent contamination by loose sediments. Sampling was conducted at four different sites during the early morning hours (9:00 am to 11:00 am) seasonally in three different seasons, Summer (March-June), Rainy (July-October), Winter (November-February) from March 2022 to February 2024.After collection, all samples were properly labeled and promptly transported to the laboratory for analysis.

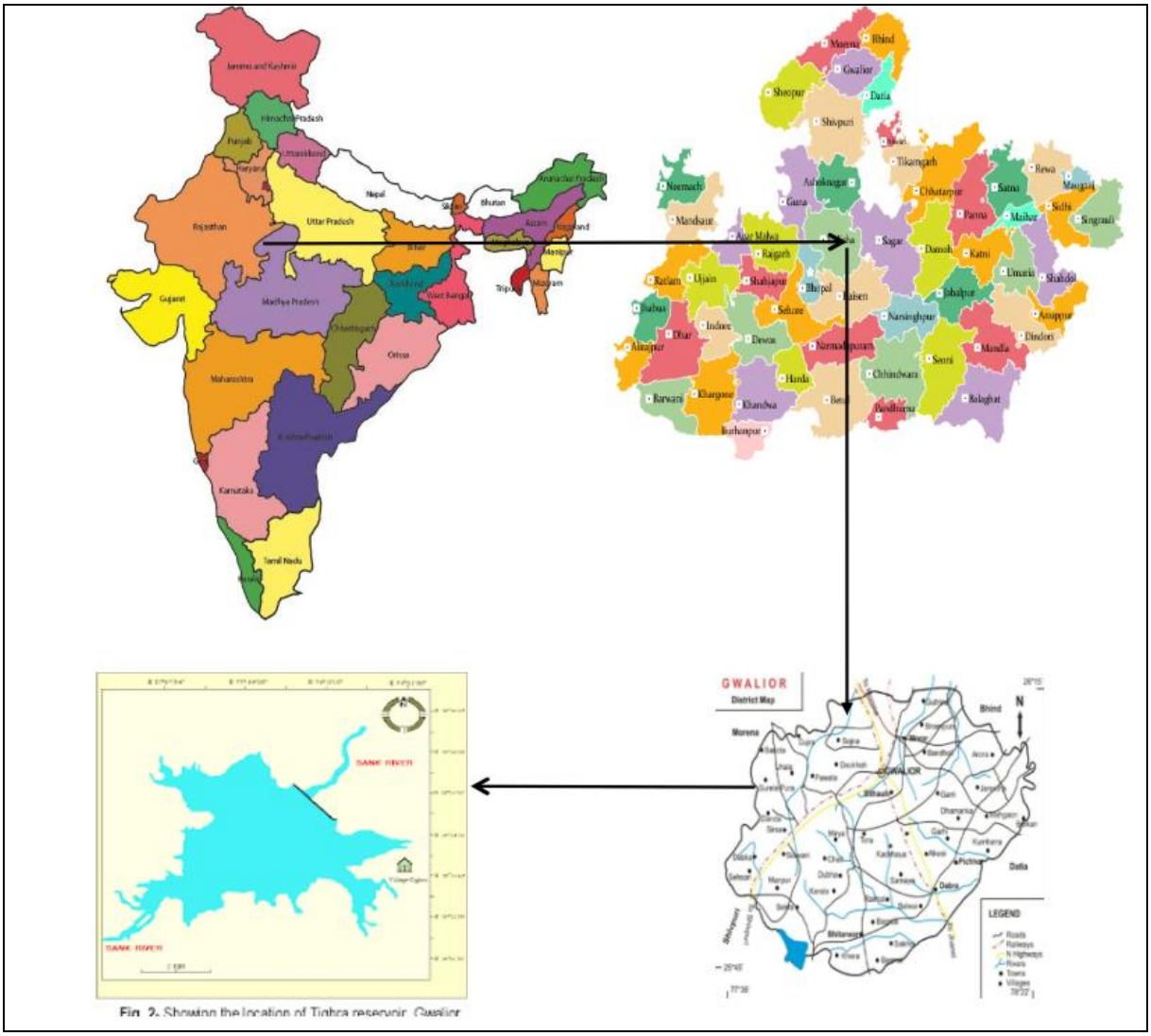

Fig 1: Tighra Reservoir, Gwalior Madhya Pradesh India

Methods

The physical parameters of water were assessed directly at the sampling sites, including atmospheric and water temperature, which were measured using a mercury thermometer. The pH was determined with a digital pH meter, while water transparency was measured using a Secchi disc at each sampling station. The remaining chemical parameters were analyzed in the laboratory after transporting the collected water samples. Total dissolved solids (TDS), total suspended solids (TSS), and biochemical oxygen demand (BOD) were estimated following standard APHA procedures, whereas chemical oxygen demand (COD) was determined using a distillation assembly. Dissolved oxygen was measured by the modified Wrinkler's method. Free carbon dioxide and total alkalinity were estimated using titrimetric methods as described in APHA. Turbidity, nitrate, sodium and potassium were analyzed in the laboratory according to the standard methods prescribed by Trivedi and Goel (1984) [14] and APHA (2023) [1].

Result and Discussion

Ambient and water temperature was clear seasonally during both year of study period (2022-23 and 2023-24), with maximum value was observed in summer and minimum in winter. Ambient temperature was exhibited from 14.9-40.1 ◦C during first year and 18.4-38.2 ◦C in second year of study. While water temperature ranged between 12.2-30.2◦C and 12.6-31.8◦C, respectively. The close relationship between water and air temperature shows atmospheric control over entire surface water heating, similar pattern was also observed for Indian reservoir by (Kumar *et al*, 2021 and Verma & Prakash, 2022) [15]. Transparency showed noticeable seasonal fluctuations, with its lowest values in rainy season highest during winter season in both years. Transparency in winter season highest at 112 cm (2022-23) and 132.8 cm (2023-24), signifying reduced suspended particles and increase light penetration. In monsoon season transparency reduced significantly due to influx of organic matter and silt, collaborating findings from (Singh *et al*., 2020 and Patil *et al*., 2023) [9]. Turbidity followed an inverse relation to transparency, reaching maximum values in rainy season up-to (10.1 NTU in 2022-23 and 13.6 NTU in 2023-24) due to surface runoff and sediment re-suspension. Similar turbidity dynamics was observed in tropical reservoir by (Sharma *et al*., 2021) [10]. TDS concentration were observed highest during summer while lowest during winter across in both the years. In raised summer TDS value (up to 275 mg/l in 2022-23 and 243mg/l in 2023-24) may be assigned to evaporation, concentration of salts and

anthropogenic activities. TDS reduced during winter season it reflects dilution as well as reduced biological activities. Similar results were given by (Rao *et al*., 2022 and Das & Mishra 2023) [3]. TSS shows maximum values during rainy season (140 mg/l in 2022-23 and 105 mg/l in 2023-24), due to influence of soil erosion and catchment runoff. While in elevated monsoon TSS has also been observed by (Jain *et al*., 2021) [5] in central Indian reservoirs. The pH of the reservoir remained slightly alkaline during the study period, ranging from (7.48-8.12 in 2022-23 and 7.39-8.11 in 2023-24). Such alkaline conditions are typical of freshwater reservoir rich in bicarbonate and its favorable for aquatic productivity. Comparable pH ranges were reported by (Tripathi & Singh 2020) [23]. Total alkalinity values fluctuate seasonally, with higher concentrations during winter and summer and lower during rainy season. This pattern suggests dilution during monsoon raise and concentration during dry season. Similar observation was documented by (Kumari *et al*., 2021) [6],

indicating the buffering capacity of reservoir waters. Dissolved oxygen concentrations were highest during winter up to (8.74 mg/l in 2022-23 and 8.43 mg/l in 2023-24) and lowest during the rainy and summer seasons. Lower temperatures and increased solubility of oxygen during winter favor higher DO levels. Reduced DO during monsoon may be due to increased organic load and microbial decomposition, as reported by (Sinha *et al*., 2022) [11]. Free CO2 levels were generally low and occasionally absent during the rainy season, reflecting high photosynthetic activity and dilution effects. Elevated CO2 during winter suggests reduced biological uptake.BOD values ranged from (1.96-4.11 mg/l in 2022-23 and 1.78-4.23 mg/l in 2023-24), indicating moderate organic pollution. Higher BOD during summer and rainy seasons suggests increased decomposition of organic matter and runoff inputs. COD values followed similar trends, with maximum values in summer (52.3 mg/l in 2022-23 and 72.6 mg/l in 2023-24), reflecting elevated oxidizable organic and inorganic matter. These observations are consistent with studies by (Pandey *et al*., 2021 and Choudhary *et al*., 2023) [2]. Sodium and Potassium concentration were relatively higher during summer and rainy seasons, likely due to evaporation and agricultural runoff. Sodium values ranged from (8.1-20.1 mg/l in 2022-23 and 11.1-27.6 mg/l in 2023-24), remaining within permissible limits for freshwater ecosystems. Nitrate concentrations showed higher values during summer and monsoon, reflecting fertilizer leaching and surface runoff from surrounding agricultural areas. Peak nitrate levels (15.4 mg/l in 2022-23 and 16.7 mg/l in 2023-24) indicate moderate nutrient enrichment but no immediate eutrophication threat. Similar nitrate dynamics have been reported by (Meena *et al*., 2022 and Gupta & Verma 2023) [4, 15]. Comparative analysis revealed slightly higher turbidity, COD, and nutrient concentrations during 2023-24, possibly due to increased rainfall intensity and catchment disturbances. However, overall water quality remained within acceptable limits, indicating stable resevoir conditions with seasonal variability primarily driven by climatic factors.

Table 1: Seasonal variation of parameters at different sites of a Tighra fresh water Reservoir in 2022-23

	Summer (March 22 to June 22)						Rainy (July 22 to October 22)				Winter (November 22 to February 23)			
S.No.	**Parameters**		**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
1.	Ambient temperature	^{0}C	38.2	39.5	39.4	40.1	34.6	35.1	33.1	32.8	15.5	14.9	15.6	15.2
2.	Water temperature	^{0}C	30.1	29.8	29.7	30.2	25.6	25.2	25.1	25.3	12.6	12.2	12.7	12.3
3.	Transparency	cm	52.5	42.8	61.6	38.2	35.6	28.9	32.7	30.7	95.6	80.7	112	98.3
4.	Turbidity	NTU	1.3	1.9	1.2	2.3	8.6	7.8	6.2	10.1	0.75	0.52	0.37	0.42
5.	TDS	mg/l	235	275	217	238	196	186	190	186	170	168	164	156
6.	TSS	mg/l	40	44	38	55	120	110	140	104	34	30	20	28
7.	pH	-	8.12	8.01	7.99	7.96	7.85	8.03	7.94	8.04	7.56	7.48	7.66	7.51
8.	Dissolved oxygen	mg/l	7.89	7.66	8.05	7.93	6.66	6.48	5.98	5.44	8.74	8.63	8.7	8.19
9.	Total alkalinity	mg/l	38.6	31.6	35.2	30.1	32.1	27.6	25.8	29.1	37.6	35.6	38.4	35.9
10.	Free CO2	mg/l	0.18	nil	0.14	0.17	nil	nil	nil	nil	0.22	0.19	0.14	0.27
11.	BOD	mg/l	4.11	3.78	3.24	3.94	3.07	3.54	3.22	3.61	2.11	2.05	1.96	2.84
12.	COD	mg/l	52.3	48.1	39.5	44.1	28.9	30.7	34.6	32.1	18.6	18.6	18.9	22.4
13.	Sodium	mg/l	14.6	15.1	13.8	20.1	10.9	12.8	19.6	11.5	19.8	13.9	8.1	15.9
14.	Potassium	mg/l	1.94	1.43	1.64	1.28	0.96	0.82	0.44	0.61	0.41	0.28	0.31	0.37
15.	Nitrate	mg/l	12.3	15.4	13.1	14.1	13.4	12.5	11.8	12.6	7.66	5.84	4.94	8.1

Table 1: Seasonal variation of parameters at different sites of a Tighra fresh water Reservoir in 2023-24

	Summer (March 23 to June 23)						Rainy (July 23 to October 23)				Winter (November 23 to February 24)			
S.N.	**Parameters**		**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**	**S1**	**S2**	**S3**	**S4**
1.	Ambient temperature	^{0}C	38.2	37.6	38.1	37.9	30.8	32.1	31.5	31.3	18.6	19.7	18.9	18.4
2.	Water temperature	^{0}C	31.8	30.4	30.5	30.1	24.1	24.5	23.9	24.7	13.1	13.2	12.9	12.6
3.	Transparency	cm	47.8	36.1	57.9	32.9	28.7	25.1	30.8	27.1	100.4	96.8	132.8	108.7
4.	Turbidity	NTU	1.5	1.3	1.1	1.6	10.3	9.6	8.9	13.6	0.56	0.66	0.28	0.39
5.	TDS	mg/l	209	243	228	220	176	181	185	180	166	163	157	159
6.	TSS	mg/l	46	53	56	64	86	101	105	100	44	23	30	35
7.	pH	-	7.89	7.93	7.91	8.07	7.99	7.89	8.04	8.11	7.42	7.68	7.39	7.47
8.	Dissolved oxygen	mg/l	7.72	7.17	7.85	7.52	6.04	6.03	6.28	5.81	8.03	8.43	8.27	8.31
9.	Total alkalinity	mg/l	30.5	38.3	33.1	36.5	28.9	32.9	37.2	34.6	28.7	39.7	29.8	31.6

10.	Free CO2	mg/l	0.27	0.12	0.18	nil	nil	0.15	nil	nil	0.31	nil	0.19	0.25
11.	BOD	mg/l	3.87	3.05	2.76	3.17	4.23	3.76	4.07	3.55	2.3	1.88	1.78	2.27
12.	COD	mg/l	72.6	61.2	52.9	58.6	43.7	51.2	48.7	40.9	32.8	22.7	26.7	30.4
13.	Sodium	mg/l	18.1	22.9	15.1	27.6	15.8	26.9	20.1	19.8	13.8	14.6	11.1	13.2
14.	Potassium	mg/l	1.52	1.84	1.64	1.42	0.45	1.12	1.06	0.85	0.61	0.45	0.88	0.32
15.	Nitrate	mg/l	9.52	13.7	8.25	13	14.8	16.7	15.8	13.3	8.36	10.5	7.3	6.2

Conclusion

The reservoir exhibits distinct seasonal and inter-annual variations in physico-chemical parameters, strongly influenced by temperature, monsoon runoff, and Anthropogenic inputs. Overall water quality suggests moderately productive and ecologically stable condition, suitable for fisheries and domestic use after conventional treatment.

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