Volume 9, Issue 5, May – 2024 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

Assessment of Water Quality of Tighra Reservoir using Weighted Arithmetic Water Quality Index (WA-WQI)

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Abstract: Water is a natural resource used for drinking, agriculture, and industry. Being a vital source of life for living beings, its quality needs to be assessed regularly and the environmental health of water resources should be maintained accordingly. This study assessed the water quality of Tighra reservoir, which is the primary source of water supply in Gwalior, M.P. For this task, the water sampling was carried out during Jun-Sep, 2023. Total 32 samples were collected to cover pre & post monsoon and monsoon season. Subsequently, the water quality parameters such as pH, Turbidity, Acidity, Alkalinity, Chloride, Hardness, Total solids (TS), Total dissolved solids (TDS), Total suspended solids (TSS), Dissolved solid (DS), Iron (Fe), MPN were determined to assess weighted arithmetic water quality index (WA-WQI). Consequently, the WQI ranges from 15.91 to 121.76 respectively. Furthermore, poor water quality was observed at SS7 followed by SS6, and SS5. However, good quality of water was observed at SS1 followed by SS2, SS3, and SS8. The seasonal distribution of WQI reveals that June (19.38-121.75) with SS7 and SS6 have poor water quality, July (16.74-66.87) with SS5, SS6, and SS7 have poor water quality, August (38.08-79.28) with SS4, SS5, SS6, and SS7 have poor water quality, September (15.91-101.11) with SS4, SS5, SS6, and SS7 have poor water quality. The aforementioned findings will surely help to local authorities to take suitable action for the upgradation water quality of Tighra reservoir.

Keywords:- *WA-WQI, Seasonal-Variance, Water Quality.*

I. INTRODUCTION

Water is an essential component for living beings that covers 71% of earth's surface out of in which only 3% of fresh water is available. It also plays important role in economic activities too. The available water resources are dynamically influenced by the exponential growth of population, industrialization and agriculture. Several activities associated with industries and agriculture use the fresh water and results polluted water as an output. All such activities put a pressure on available fresh water sources by contaminating it.

The contaminated water causes several health issues. WHO reported about 80% of human illnesses is due to water pollution. It also disturbs the aquatic life by imparting toxicity in the water that badly affect the ecosystem. Although water is a renewable resource that may be recharged by rains in reservoirs.

Reservoirs play a fundamental role by storing water to fulfill the water demand for any specific region and contribute significantly in economic status of states. Water quality in reservoir must be maintained for sustaining aquatic environment since it is directly tied to the health of the water body.

The Water Quality Index (WQI) is one of the most commonly used method for measuring the quality of water. WQI can reduce a large volume of data into a specific term and present the facts in a clear, logical manner. The WQI concept was first introduced by Horton in 1965, and later, various studies have been carried out by different researchers to understand the water quality. The weighted arithmetic water quality index method is a modified form of Horton's formula, created by Brown et al. (1970). WA-WQI, a way of assessing or classifying the quality of water type, is effective for determining the seasonal variance in conditions and providing knowledge on water quality to concerned locals and policy makers.

The main objective of this study is to conduct study on assessment of the water quality using WA-WQI. To accomplish this task, laboratory analysis was performed to determine the physical, chemical, and biological water quality parameter. This study will deliver the seasonal variation in WQI of reservoir water that will help local authority to take suitable action to improve the quality of the reservoir water.

II. STUDY AREA

Gwalior is a district of Madhya Pradesh (M.P.), situated in the northern side of M.P at 26.22^0 N latitude and 78.18^0 E longitudes with an altitude of 197 m from MSL. It covers 4560 sq. Km of geographical area with population of 14,95,487 as per Census 2011. The climate of this region is tropical nature. The pre-monsoon season dominated by the heat and humidity (April-June). The monsoon season receives an average rainfall of 700-764.4 in July-August season, however monsoon starts from mid-June and usually continues till mid-September.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

Tighra reservoir is situated at 26-12'-0" N Latitude and 78-30'-0" E Longitude with an altitude of 218.58m from mean sea level (MSL) on sank river near village tighra in Gwalior District. The dam is 24 m high at its crest, and 1341 m long and it receive water from catchment area of 414.24 sq. km.

III. METHODS & MATERIAL

A. Sample Collection

Total 32 water samples were collected from the 08 sampling locations (SS1-S8), representing almost whole area in the vicinity of dam (**Fig. 1**) during the duration of June-September, 2023 (04 Months) in the Morning hours. The detailed description about the sampling locations were clearly mentioned in the **Table 1**. Prior to collect the water samples, the plastic bottles and glass bottles were cleaned with diluted chromic acid/detergent and then with distilled water. Further, Heyroth water sampler was used to collect sample at varying depth and depth of immersion was also determined respectively. It was also ensured that the sampler water bottle was filled completely without the formation of air bubbles. However, the water sample collected in glass bottle to preserve the biological parameters. The sample handling and their transportation from field to laboratory was carried out in accordance with standard methods.

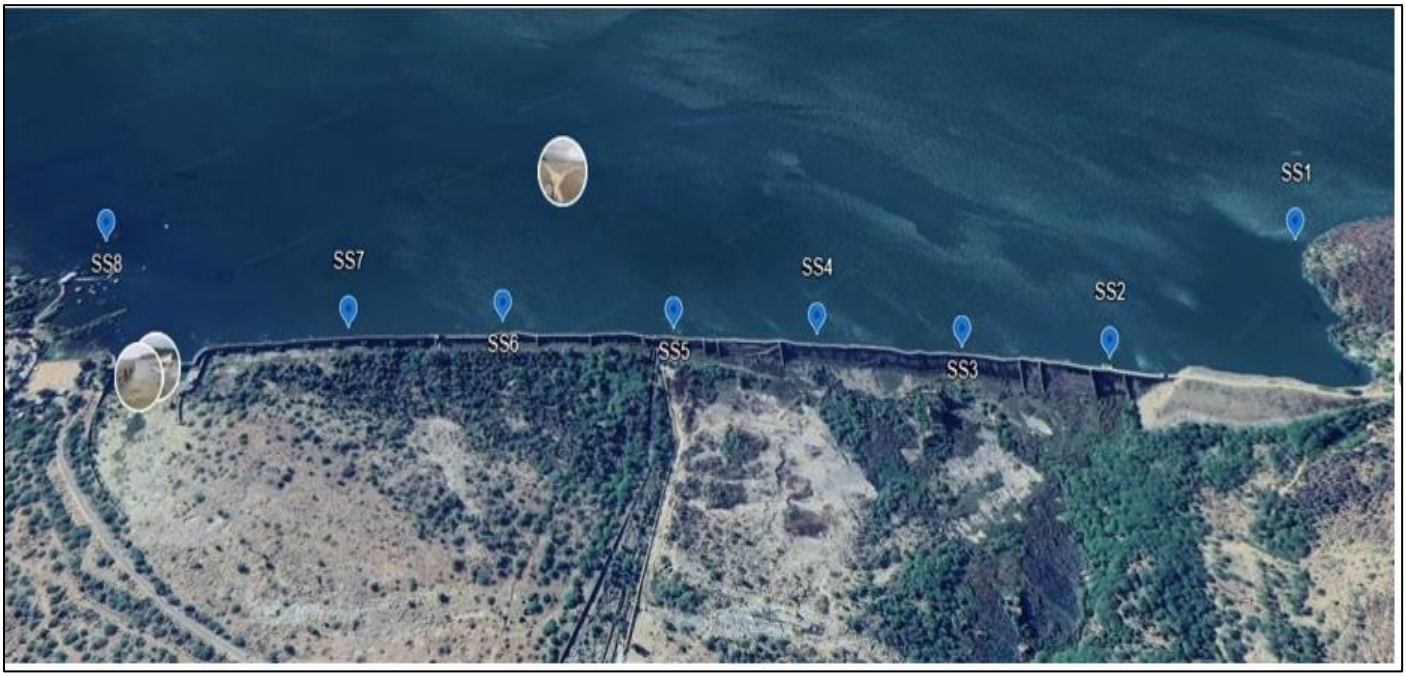

Fig 1: Ariel Visualization of the Sampling Location at Tighra Reservoir, Gwalior, M. P.

B. Laboratory Analysis

The collected samples were kept in to the refrigerator at 4^0C temperature. The samples were analyzed to determine the parameters such as Turbidity, pH, Hardness, Acidity, Alkalinity, Chloride, TSS, TDS, TS Dissolved Oxygen (DO), Iron (Fe), and biological parameter such as most probable number (MPN). The laboratory analysis for each parameter was carried out prescribed under the several parts of IS:3025. The analytical grade reagents (AR grade) were used for the preparation of intermediate reagents. It undergoes gravimetric analysis, titration method and analytical analysis. Furthermore, quality assurance and control were maintained throughout analysis. The laboratory analysis description for each parameter is mentioned in the **Table 2**.

Table 1: Detailed Description with Geographical Location of the Sampling Location

Station	Latitude	Longitude	Site Description	Depth
SS1	26013'35" N	77059'46" E	Near Mata Mandir	30 m away from this site
SS2	26013'31" N	77059'53" E	Near Farmer floating net cage area	1m deep
SS3	26013'24" N	77059'59" E	Near Farmer floating net cage area	2 m deep
SS4	26013'20" N	78000'03" E	Near Supply line	3m deep
SS5	26013'17" N	78000'06" E	Near Drainage line	4m deep
SS6	26013'13" N	78000'11" E	Infront Farmer floating net cage area	5m deep
SS7	26013'08" N	78000'17" E	Near the reservoir gate	6m deep
SS8	26012'58" N	78000'22" E	Boat club Side	30 m away from this site

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

Table 2: Description of the Laboratory Analysis of Water Quality Parameter

Parameter	Analysis Method	Unit	IS:3025
Physical, Chemical & Biological Parameter			
Total solids	Gravimetric Method	mg/l	Part 15
TDS	Gravimetric Method	mg/l	Part 16
TSS	Gravimetric method	mg/l	Part 17
Turbidity	Digital Turbidity meter	NTU	Part 10
pH Value	pH meter	---------	Part 11
Acidity	Titrimetric Method	mg/l as CaCO3	Part 22
Alkalinity	Titrimetric Method	mg/l as CaCO3	Part 23
Chloride	Titrimetric Method	mg/l	Part 32
Hardness	Titrimetric Method	mg/l as CaCO3	Part 21
DO	Titrimetric Method	mg/l	Part 38
Fe	Atomic Absorption Spectrophotometer	mg/l	Part 53
MPN	Multiple Tube Technique	No/ 100 ml	---------

C. Weighted Arithmetic WQI (WA-WQI)

The WAWQI can be considered as simplified representations of a complicated reality or models for water quality, where variables are chosen, and weighting and aggregation methods are defined. Using the most frequently measured water quality parameters, the weighted arithmetic water quality index technique assessed the water quality according to the degree of purity. The WAWQI method was used in this study, consisting of 4 steps, which are as follows:

- Parameter selection for water quality assessment.
- Quality ratings are scaled for each parameter.
- Calculation of unit weight (W_i), and W_i is inversely dependent upon the standard value (S_i) of the parameters recommended.
- Calculating the overall WQI by summing the sub-index value.

The following equations were used to calculate the WQI. Each water quality parameter's unit weight (W_i) was computed using Eq. (1-2)

$$Wi=\frac{K}{Si} \quad (1)$$

Where,
W_i : The unit weight of ith parameters.
K : Proportionality constant.
Si : Standard value of ith parameter

$$K = \frac{1}{\sum\frac{1}{S_i}} \quad (2)$$

Each parameter's quality rating scale (Qi) was calculated using Eq. 3,

$$Q = \left(\frac{V_i - V_o}{S_i - V_o}\right) \quad (3)$$

For pH and D.O the quality rating scale was determined by Eq.4,

$$Q = \left(\frac{V_i - 7}{S_i - 7}\right) \& \left(\frac{V_i - 14.6}{S_i - 14.6}\right) \quad (4)$$

Where,

V_i : Actual Concentration of ith parameter
V_0 : Ideal value of the parameter, whereas, except for pH (ideal value 7, all other parameter's ideal value is zero.

The final equation can be presented in Eq. 5

$$SIi=\frac{\sum QiWi}{\sum Wi} \quad (5)$$

$$WQI = \sum SIi$$

SIi is the sub-index of the ith parameter and i represents the number of parameters taken into consideration. In the ideal values and unit weights for the water quality variables and their standard values are shown in **Table 3**.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

Table 3: Acceptable Limits of the Water Quality Parameter as Per IS 10500:2012

Parameters	Acceptable Limit
pH Value	6.5-8.5
Turbidity	5 NTU
Acidity	200 mg/l as $CaCO_3$
Alkalinity	200 mg/l as $CaCO_3$
Chloride	250 mg/l
Hardness	200 mg/l as $CaCO_3$
Total Solids	2000 mg/l
TDS	500 mg/l
TSS	30 mg/l
DO	5 mg/l
Fe	0.3 mg/l

Table 4: Physio-Chemical Analysis of the Water Sample Collected from Tighra Reservoir

Site	Month	pH	Turbidity	Acidity	Alkalinity	Chloride	Hardness	Total Solids	T.D.S	T.S.S	DO	MPN	Fe
SS1	Jun	7	3	10	98	28	90	108	92	16	6	11	0.025
SS1	Jul	7.21	5	18	126	36	116	254	206	48	5.6	14	0.007
SS1	Aug	6.98	5	20	118	32	108	214	174	40	5.4	21	0.054
SS1	Sep	7.58	5	16	130	30	120	188	154	34	5.2	20	0.07
SS2	Jun	7.07	4	12	102	30	96	126	104	22	5.8	11	0.022
SS2	Jul	7.36	6	22	130	38	120	278	238	40	5.4	15	0.073
SS2	Aug	7	6	24	124	34	114	234	192	42	5.2	28	0.107
SS2	Sep	7.62	5	18	136	32	130	203	166	37	5	21	0.006
SS3	Jun	7.18	4	14	108	30	106	130	102	26	5.6	21	0.033
SS3	Jul	7.38	6	22	134	40	124	273	228	45	5.2	20	0.088
SS3	Aug	7.12	6	24	128	36	118	247	212	35	5	28	0.121
SS3	Sep	7.56	6	18	140	36	134	210	170	40	5	28	0.108
SS4	Jun	7.17	5	16	110	32	110	134	108	26	5.4	20	0.036
SS4	Jul	7.42	7	24	140	42	130	252	242	10	5	20	0.117
SS4	Aug	7.17	7	28	132	40	120	252	210	42	4.8	39	0.158
SS4	Sep	7.58	7	20	146	38	140	214	168	46	4.8	39	0.2
SS5	Jun	7.25	5	16	118	36	112	142	112	30	5.2	28	0.128
SS5	Jul	7.44	7	26	144	44	132	274	234	44	4.8	28	0.165
SS5	Aug	7.2	8	30	136	40	126	261	223	38	4.6	43	0.179
SS5	Sep	7.63	7	20	150	40	144	220	168	52	4.6	43	0.224
SS6	Jun	7.62	6	18	124	40	116	150	120	30	5	28	0.298
SS6	Jul	7.46	8	24	150	46	138	288	246	42	4.6	39	0.173
SS6	Aug	7.22	8	32	144	42	134	274	242	32	4.4	64	0.214
SS6	Sep	7.66	8	22	155	44	148	214	160	54	4.6	64	0.235
SS7	Jun	7.42	6	20	130	42	120	158	116	42	4.8	39	0.375
SS7	Jul	7.47	9	25	152	50	140	278	232	46	4.6	64	0.175
SS7	Aug	7.32	9	32	148	48	136	326	268	58	4.4	64	0.219
SS7	Sep	7.82	9	24	158	46	160	224	160	52	4.4	75	0.295
SS8	Jun	7.2	5	14	122	30	114	132	100	32	5.4	15	0.031
SS8	Jul	7.34	7	22	140	44	140	260	210	50	5.2	28	0.051
SS8	Aug	7.12	8	26	130	40	144	300	254	46	5	75	0.084
SS8	Sep	7.66	7	18	152	42	146	206	172	44	4.8	43	0.111

Table 5: Water Quality Rating based on WQI Values

WQI Value	Water Quality Rating
0-25	Excellent water quality
26-50	Good water quality
51-75	Poor water quality
76-100	Very Poor water quality
>100	Unsuitable for drinking purposes
>100	Unsuitable for drinking purposes

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

IV. RESULT AND DISCUSSIONS

A. *Physical, Chemical & Biological Parameters of Water Quality*

- *Total Solids:* The Total Solids of all sample ranges from 108- 326 mg/l throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 2000 mg/l. It represents that rainfall and runoff can have an impact on the movement of sediments into bodies of water. There is usually more runoff during monsoon seasons, which increases the amount of silt and suspended solids in the water.
- *Total Suspended Solids:* The TSS of all samples ranges from 10-54 mg/l throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 30 mg/l. it represents that TSS was found less during pre-monsoon season. During this season there is no inflow of water and sediments hence the water of reservoir is almost stand still having no turbulence which promotes the settlement of suspended solids. However, the maximum concentration of TSS was observed during monsoon season.
- *Total Dissolved Solids:* The TDS of all samples are ranges from 92-268 mg/l throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 500 mg/l. it represents that TDS levels are impacted by variations in precipitation, runoff, and recharge during monsoon season because of enhanced runoff and sediment movement, in monsoon seasons usually have higher TDS levels.
- *Turbidity:* The turbidity of all samples are ranges from 3-9 NTU throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 5 NTU mg/l. it represents that during monsoon season, turbidity levels tend to be higher compared to the pre-monsoon and post-monsoon periods due to increased water flow and mixing in rivers and reservoirs causing resuspension of sediment and increasing turbidity levels.
- *pH*: The pH value of all sample are ranges from 6.98-7.32 throughout all season viz, pre-monsoon, monsoon, post-monsoon. However, the permissible limit prescribed in IS 10500:2012 ranges from 6.5-8.5. It represents the reservoir water is neutral in nature and can be acceptable for the drinking purpose.
- *Acidity:* The acidity of all samples are ranges from 10-32 mg/l as $Caco_3$ throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 200 mg/l as $Caco_3$.so it represents that the variation in acidity is very less .and the acidity decreases duing monsoon months. There is no source of industrial pollution, domestic pollution in the vicinity of reservoir.
- *Alkalinity:* The alkalinity of all samples are ranges from 98-158 mg/l as $Caco_3$ throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 200 mg/l as $Caco_3$. the alkalinity slightly increases during pre-monsoon compare to monsoon and post-monsoon months due to Biological processes, such as photosynthesis by aquatic plants and algae, which increases alkalinity by consuming carbon dioxide and releasing oxygen. There are no source of industrial pollution, domestic pollution in the vicinity of reservoir.
- *Chloride:* The chloride of all samples ranges from 28 -46 mg/l throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 250 mg/l. It represents that during pre-monsoon season the chloride concentration is less compare to monsoon and post monsoon seasons. This chloride concentration due to leaching of salts. Since there is no industrial area and residential in the vicinity of reservoir therefore chances of pollution of chloride due to industrial waste and municipal waste is not possible.
- *Dissolved Oxygen (DO):* The D.O of all samples ranges from 4.4-6 mg/l throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 14.6 mg/l. it represents that samples collected near the banks (SS1- SS8 locations are at shallower depth 1m therefore the DO concentration at these locations where slightly higher. At surface the DO concentration is likely to be still higher at these locations as we move away from the banks the depth of collection of samples also increased (max up to 6m) i.e the DO level at intermediate locations where slightly less. Generally, higher temperatures and lower water flow can lead to lower DO levels due to reduced oxygen solubility.
- *Iron (Fe):* The Fe of all samples ranges from 0.01-0.38 mg/l concentration throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 0.3mg/l. At all locations the concentration of iron was found to be less than permissible value.
- *Hardness:* The hardness of all samples ranges from 90-160 mg/l as $Caco_3$ throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 200 mg/l as $Caco_3$. hardness is less during monsoon whereas hardness is comparatively high in monsoon and post-monsoon months due to rainfall leads to higher runoff from surrounding land areas into the reservoir. This runoff can carry sediment and dissolved minerals contributing to higher hardness levels in the water.
- *Most Probable Number (MPN):* The MPN of all samples ranges from 11-75/ 100ml throughout all season viz, pre-monsoon, monsoon, post-monsoon, however the permissible limits prescribed in **IS 10500:2012** is 0/100 ml. At all sampling station MPN value was found to be higher than the permissible limit i.e, less than 1/100 ml.it represents that raw water contains bacillus /coliforms bacteria which may be harmful for the public health hence disinfection must be practiced before supplying water for public consumption however MPN values are very small therefore degree of treatment from the point of view of disinfection required will be minimal.

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/IJISRT24MAY1308

B. Weighted Arithmetic WQI (WA-WQI)

The estimation of water quality index using WA-WQI for only one sample S1 for June season is demonstrated in Table 6. Correspondingly, the WQI of each sample for different seasons is calculated in a similar turbidity, acidity, alkalinity, total suspended particles, dissolved oxygen, and total dissolved solids exhibit seasonal fluctuations. Water quality is significantly impacted by the monsoon season, which is characterized by increased runoff and rainfall. The fashion and their values are shown in fig 2.

Table 6: Calculation of WQI using WA-WQI for One Sample Only

Parameters	Acceptable Limit (Si)	Constant (K)	Unit Weight (Wi)	Ideal Values (Vo)	Observed Value (Vi)	Quality rating Scale (Qi)	Sub Index (SIi)
pH	8.5	0.26	0.03	7	7	82.35	2.48
Turbidity (NTU)	5	0.26	0.05	0	3	60.00	3.07
Acidity (mg/l)	200	0.26	0.00	0	10	5.00	0.01
Alkalinity (mg/l)	200	0.26	0.00	0	98	49.00	0.06
Chloride (mg/l)	250	0.26	0.00	0	28	11.20	0.01
Hardness (mg/l)	200	0.26	0.00	0	90	45.00	0.06
Total Solids	2000	0.26	0.00	0	108	5.40	0.00
Dissolved Solids	500	0.26	0.00	0	92	18.40	0.01
Suspended Solids	30	0.26	0.01	0	16	53.33	0.46
D.O (mg/l)	5	0.26	0.05	14.6	6	120.00	6.14
Fe (mg/l)	0.3	0.26	0.85	0	0.025	8.33	7.11
Calculated WQI =	19.41						

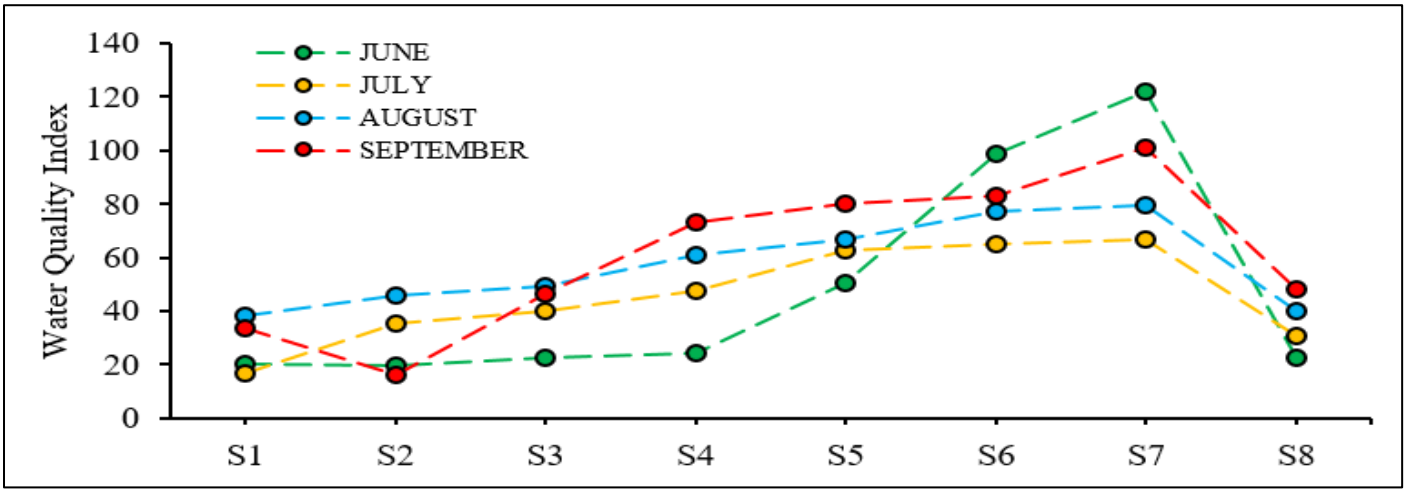

Fig 2: Water Quality Index

V. CONCLUSION

Physical chemical & Biological analysis of water samples of tighra reservoir shows that except turbidity, Iron & MPN values, all other vital parameters are with prescribed limit for drinking purpose as per IS10500:2012. However, the turbidity values and MPN values are little higher during monsoon season, and iron concentration is higher during pre-monsoon season. For most of the time the quality of water is rated as good to moderate according to WQI values. Hence minimal treatment is required to make water suitable for drinking purpose. Industrial, Recreational & domestic activities in the vicinity & catchment area of reservoir shall be restricted in future to safe guard the quality of water. Some suitable on-site measures shall be taken to control iron concentration for which a separate study of water quality is required to be undertaken.

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