Seasonal Behavior of Trophic Status Index of a Water Body, Bhalswa Lake, Delhi (India)

Sumit Dagar and S. K. Singh

Abstract Large and growing population and rapid pace of development have led to the degradation of natural water system. Lakes are inland bodies of water that lack any direct exchange with an ocean. Lakes may contain fresh or saltwater (in arid regions), shallow or deep, permanent or temporary lakes of all types which share many ecological and biogeochemical processes. Lake ecosystems are influenced by their watersheds, i.e., the geological, chemical, and biological processes that occur on the land and streams. Lakes play multiple roles in an urban setting. It is essential to restore and maintain the physical, chemical, and biological integrity of water bodies to achieve the required water quality, which ensure protection and propagation of fish, wildlife, plants, and also recreation in and on water. The overall goal of this study is to monitor the water quality and assess the trophic status of Bhalswa Lake in Delhi. The trophic status was assessed by using multivariate indices including Carlson Trophic Status Index (CTSI) Sakamoto, Academy and Dobson index, and USEPA-NES which primarily used total phosphorus, chlorophyll-a, and Secchi depth parameters. This study showed that the Bhalswa Lake is in moderate eutrophic condition during the monsoon and post-monsoon period.

Keywords Water quality · Lake ecosystem · Trophic status index · Phosphorus · Chlorophyll-a and secchi depth · Eutrophication

1 Introduction

The meaning of the word trophic is "related to nutrition". Trophic continuum is divided into four classes traditionally such as: (1) Oligotrophic (limited or deficient); (2) mesotrophic (medium-range); (3) eutrophic (good or great enough); and (4) hypereutophic (extensive). Multidimensional trophic concept was used before the TSI based upon the single criterion, including supply rate of organic matter to

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the lake. But that criterion was doubtful because of a single parameter determination. The optimal **Trophic Status Index** (TSI) maintains the interpretation of trophic status components found in multiparameter indicators. However, TSI still has a single variable coefficient at its ease, and it can be accomplished when interrelated with the frequently used trophic criteria. The researchers reported an empirical equation to predict the concentration of phosphorus in lakes based on awareness of phosphorus loading. The link between the amount of phosphorus and microalgae production is chlorophyll-a concentration. In 1975, if a series of predictive equations could relate several of the trophic requirements frequently used, measuring all possible trophic parameters would no longer be necessary to determine trophic position. A single trophic metrics like biomass of algae, loading of nutrients, or concentration of nutrients could be the foundation for an index from which to estimate or predict other trophic requirements through the defined interactions. Alternatively, for determining the trophic condition, one of trophic requirements can also be used.

TSI is an index that would promote communication between the public and the limnologist, which is particularly vulnerable to such concerns. Algal biomass values is a difficult term, and some variables including dry and wet weight, molecule amount, chlorophyll-a, carbon amount, and Secchi disk can generally be estimated.

2 Objectives of the Study

Following are the objectives of study:-

- To characterize Bhalswa Lake on the basis of Trophic Status Index (TSI).
- To identify the probable sources of pollutants in Bhalswa Lake.
- To suggest corrective/restoration options for improvement in lake trophic status index.

3 Methodology

The methodology of present study is according to the procedure recommended in APHA (1992) and NEERI (1991) guidelines for water quality. The lake is divided in small blocks, and samples were collected from different sampling locations for the representation of the quality of water of Bhalswa Lake. The samples were collected through boats provided by Delhi Tourism.

3.1 Trophic Status Index

Trophic Status Index (TSI) is a conventional measure or instrument used to calculate a lake's trophic status or productivity. More specifically, at a particular place and moment, it is the complete living plankton weight throughout water system, Three factors estimate algal biomass separately, (a) chlorophyll, (b) Secchi depth, and (c) complete phosphorus. There is a connection between phosphorus, chlorophyll-a (concentration of algae), and Secchi depth. This implies more food is accessible for algae when phosphorus rises, so algal concentrations rise. The water becomes less transparent when algal concentrations rises and the depth of Secchi reduces. The resulting numbers cover different components and ranges from all these three calculations, so it cannot be compared or averaged directly with each other. Three trophic status index readings used an equation to standardize them in order to make them instantly comparable. A lake's overall trophic status index (TSI) is the phosphorus median TSI, the Secchi depth TSI, and thus the chlorophyll-a TSI; therefore, considering phosphorus, Secchi depth, and chlorophyll-a, it can be considered as the lake condition. It is essential to realize that in phosphorus and algal concentration, trophic status is defined divisions of a continuum. The TSI is between 0 and 100. **Oligotrophic** 0–30 is very clear water, low phosphorus, and sparse algae. 30–50 is an intermediate phase where, owing to more accessible phosphorus, the number of aquatic plant algae increases. A TSI of over 50 defines a lake that is eutrophic, with an elevated plant and algae density that may be difficult to swim in the summer at certain times. Some lakes can be eutrophic naturally, having a TSI of 50 or higher over the last 100 years. As a consequence of human operations, other lakes have gradually risen in TSI. Not necessarily, the Trophic Status Index can be interchanged with water quality. The quality of water is subjective and depends on how the water body is to be used. A lake which is great for duck hunting is not necessarily nice for water skiing. In turn, bass fishing may not be good for a lake that is good for swimming. The different attributes with respect to different parameters of TSI are mentioned in Table 1.

The relationships are not always simple between the three TSI calculations. Carlson pointed out that highly stained lakes with large amounts of organic material submerged in them can generate elevated Secchi transparency TSI scores that do not suit the model because the water color affects the depth at which the Secchi disk falls. The type and volume of the prevalent algae population might also influence the writing of Secchi the algae types may vary in the amount of pigment they carry.

3.2 TSI Values Uses

It is possible to use TSI scores to rank lake between and within geographical areas. This categorization enables water supervisors to select lakes which may require restoration or preservation. An increasing sequence in TSI standards over many decades may demonstrate degradation in the wellness of a lake.

Table 1 Trophic status index meaning and attributes (Internet sources)

TSI	Chlorophyll-a (μg/l)	Secchi depth SD (ft)	Total phosphorous (μg/l)	Attributes	Fisheries and recreation
Less than 30	Less than 0.95	More than 26.2	Less than 6	**Oligotrophy**: Clean water, oxygen all year round at the edge of the lake, very profound cold water	Fishing in the tropics dominates
In between 30 and 40	In between 0.95 and 2.6	In between 13.1 and 26.2	In between 6 and 12	Lower ponds can become anoxic (no oxygen)	Only trout fishing in profound ponds
In between 40 and 50	In between 2.6 and 7.3	In between 6.6 and 13.1	In between 12 and 24	**Mesotrophy:** Most of the summer, water is moderately evident. May be late summer “greener”	No oxygen at the lake’s bottom leads to trout loss. Walleye may prevail
In between 50 and 60	In between 7.3 and 20	In between 3.3 and 6.6	In between 24 and 48	**Eutrophy**: Problems with algae and aquatic plants are feasible. Most of the year, “green” water	Fishing in warm water only. Bass may prevail
In between 60 and 70	In between 20 and 56	In between 1.6 and 3.3	In between 48 and 96	Blue–green algae dominate, scums of algae and issues with aquatic plants	Dense algae and plants of the aquatic. Low clarity of the water can prevent swimming and boating
In between 70 and 80	In between 56 and 155	In between 0.8 and 1.6	In between 96 and 192	**Hypereutrophy**: (Light productivity restricted). Dense macrophytes and algae	For recreation, water is not appropriate
More than 80	More than 155	Less than 0.8	In between 192 and 384	Scums of algae, few aquatic plants	Rough fish (carp) dominate; can kill summer fish

Table 2 Analytical parameters and methods used for TSI study (APHA Sources)

S. No.	Parameters	Method
1	Total phosphate	Stannous chloride method
2	Secchi disc depth	Diameter −25 cm
3	Chlorophyll-a	90% Acetone extraction method

3.3 Factors Influencing the TSI Values

The less possibility that a potentially harmful cyanobacteria will occur might stop more and more presence of phosphorus. It is recognized that perhaps the cyanobacteria typically accountable for producing contaminants are poor competitors of phosphorus, so the accessible levels must have been huge until they do anything in water. Phosphorus emissions can be reduced with well-designed stormwater runoff catchment processes, renovation of sewer facilities, changing householders and business practices (such as not utilizing phosphorus-rich chemicals on gardens), training and rewards, and replacing septic watershed structures with sewers.

The TSI is a useful tool for the management of lake water and also a useful science instrument of research where a trophic status standard is required. The TSI can serve as a trophic status assessment about many of biological and chemical elements of river system linked to the trophic status which can be compared. Outcome might be fuller and dynamic image of how these elements relate to each other and the ecosystems of the lake as a whole.

In this study, different analytical parameters are studied for the determination of WQI and TSI (Table 2).

3.4 Parameters Studied for the Evaluation of TSI

1. Determination of Secchi disc depth
2. Determination of total chlorophyll -a
3. Determination of total phosphate
4. Trophic Status Index
5. Trophic State Index (TSI)
6. Secchi depth transparency (SD).

4 Results

4.1 Determination of TSI (SD)

The values of TSI SD for Bhalswa Lake in the monsoon and post-monsoon seasons are represented in Table 3, and graphical rep. of comparison of TSI SD is shown in Fig. 1 mentioned below. The values of TSI SD for monsoon season are maximum at location S5, and it is minimum for location S1 and S13. And the value of TSI SD

Table 3 Comparison of TSI SD between monsoon and post-monsoon season

Sampling no	Monsoon TSI SD	Post-monsoon TSI SD
S1	94.74	91
S2	100.85	97
S3	101.84	65
S4	104.74	102
S5	105.73	103
S6	107.56	104
S7	105.4	97
S8	98.36	96
S9	97.37	95
S10	101.82	96
S11	94.74	90
S12	94.58	89
S13	94.74	86
Mean	100.19	93.15
SD	4.56	9.67

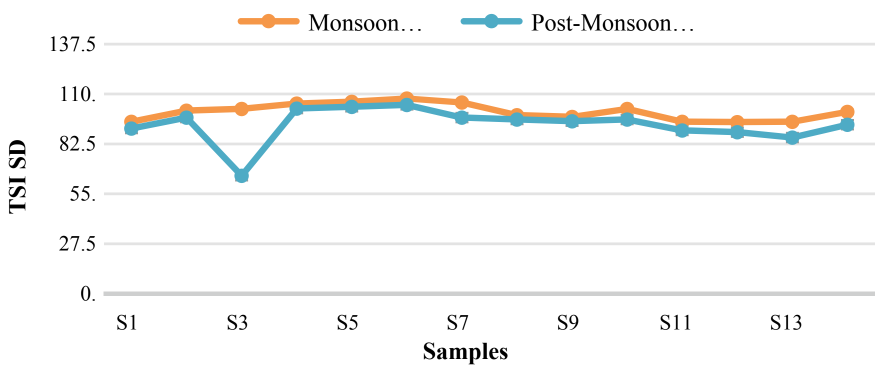

Fig. 1 Graphical representation of the comparison of TSI SD between monsoon and post-monsoon

Table 4 Comparison of TSI–TChl between monsoon and post-monsoon

Sampling no	Monsoon TSI–TChl	Post-monsoon TSI–TChl
S1	74	86
S2	30	84
S3	61	30
S4	53	30
S5	60	70
S6	67	71
S7	30	30
S8	30	30
S9	51	54
S10	75	78
S11	93	95
S12	41	30
S13	30	30
Mean	54	55
SD	19.7	25.1

for post-monsoon season is maximum at location S6, and it is minimum for location S3.

4.2 Determination of Total Chlorophyll-A (TChl)

The values of total chlorophyll-a, for Bhalswa Lake in the monsoon and post-monsoon seasons are represented in Table 4, and graphical representation of the comparison of TSI-Chl is shown in Fig. 2 as mentioned below

4.3 Determination of Total Phosphorous

The comparison of mean values of total phosphorous of all 13 locations from Bhalswa Lake was represented in Table 5 during monsoon and post-monsoon season, and graphical representation of the comparison of TSI-TP is shown below.

The graphical representation of the comparison in between the TSI-TP values in different seasons is shown in Fig. 3.

The comparison of the SD + CHL + TP/3 values for all 13 sampling locations is mentioned in Table 6 and graphical representation of the values is shown in Fig. 4.

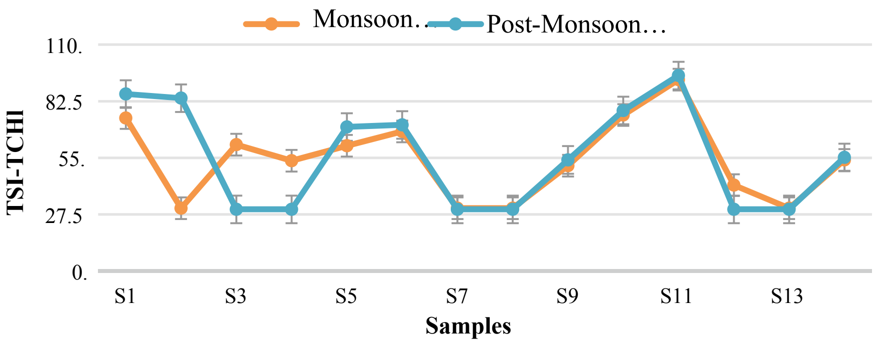

Fig. 2 Graphical representation of the comparison of TSI-TChl between monsoon and post-monsoon

Table 5 Comparison of TSI-TP between monsoon and post-monsoon

Sampling no	Monsoon TSI-TP	Post-monsoon TSI-TP
S1	133	132
S2	134	111
S3	134	111
S4	131	108
S5	136	112
S6	130	108
S7	136	112
S8	132	109
S9	135	111
S10	136	112
S11	136	112
S12	136	112
S13	133	110
Mean	134	112
SD	2	5.86

4.4 *Determination of Total TSI*

The TSI values for all different locations are mentioned in Table 7 and Fig. 5**.** The values of TSI were in between the range of 69–103, and mean values for monsoon and post-monsoon season were **96.06 ± 6.78** and **86.89 ± 10.53**, respectively. The formula used for the calculation of Carlson's Trophic Status Index is mentioned following under:

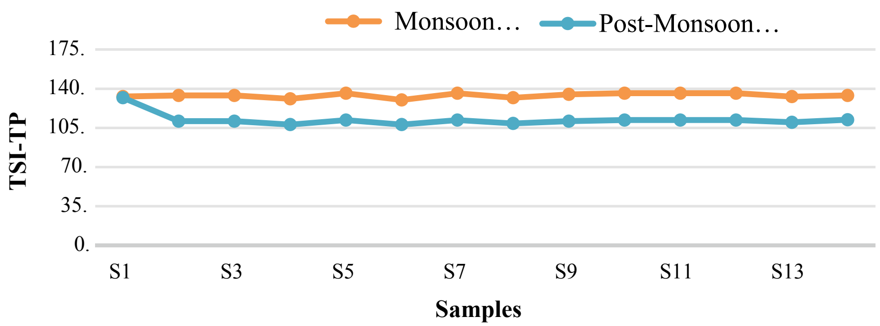

Fig. 3 Graphical representation of the comparison of TSI-TP between monsoon and post-monsoon

Table 6 Comparison of SD + CHL + TP/3 between monsoon and post-monsoon

Sampling no	Monsoon SD + CHL + TP/3	Post-monsoon SD + CHL + TP/3
S1	100.69	103.00
S2	88.47	97.33
S3	99.08	68.67
S4	96.44	80.00
S5	100.87	95.00
S6	101.80	94.33
S7	90.66	79.67
S8	86.98	78.33
S9	94.53	86.67
S10	104.54	95.33
S11	107.91	99.00
S12	90.78	77.00
S13	86.10	75.33
Mean	96.06	86.89
SD	6.781	10.539

4.5 Carlson's Trophic Status Index (C-TSI) = [TSI (TP) + TSI(CA) + TSI(SD)]/3

Mesotrophy (moderate productivity) is generally associated with index with a range in between 40–50 value; and index value more than 50 showed eutrophy status; value less than 40 are correlated with oligotrophy (low productivity). The values of the three factors, index and more than their characteristics for each parameter. Lake Bhalswa has been categorized as hypereutrophic. If it can be associated with particular occurrences within a water body, any Trophic Status Index gains value. The list of possible modifications in the body of water may happen. Some features,

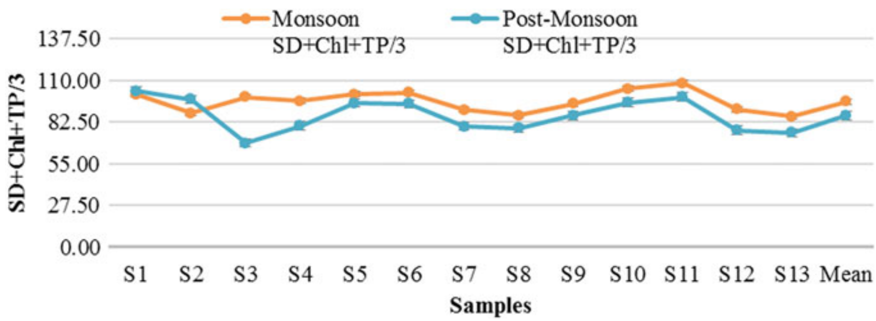

Fig. 4 Graphical representation of the comparison of SD + Chl + TP/3 between monsoon and post-monsoon

Table 7 Comparison of Carlson TSI between monsoon and post-monsoon

Sampling no	Monsoon CTSI	Post-monsoon CTSI
S1	101	103
S2	88	97
S3	99	69
S4	96	80
S5	101	95
S6	102	94
S7	91	80
S8	87	78
S9	95	87
S10	105	95
S11	108	99
S12	91	77
S13	86	75
Mean	96	87
SD	6.78	10.53

such as hypolimnitic oxygen or fish, may differ slightly and may not be linked to real TSI at times. Bhalswa Lake TSI values were discovered to be **69–103** in both monsoon season and post-monsoon season, and average TSI values were found to be **96 and 86,** respectively, for the monsoon and post-monsoon seasons. This can be ascribed to Bhalswa Lake eutrophy, where anoxic hypolimia and macrophy issues are quite feasible.

Conservation can be performed under such conditions by removing hydrophytic macrophytes and introducing hot water fish. Under these conditions, blue, green algae dominate especially that of *M. aeruginosa*, foul smell come from the water

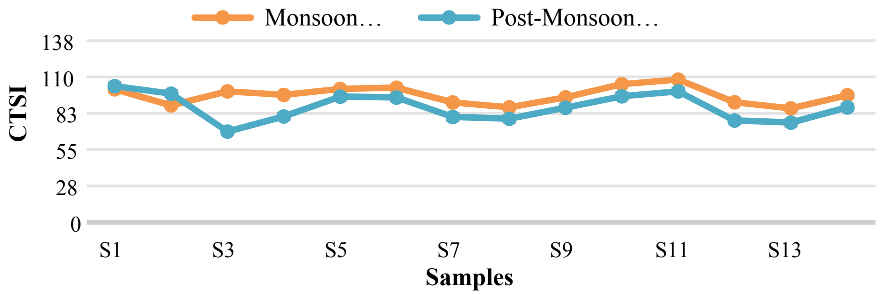

Fig. 5 Graphical representation of the comparison of Carlson TSI between monsoon and post-monsoon

and the water transparency decreases. TP increases significantly resulting in high productivity restricted, thick algae development.

5 Discussion

A close look at the lake shows that dense scums of algal, decreased macrophytes, foul smelling water lead to enormous fish murderers. It can be reduced only by draining the whole water and again refill it by harvesting rainwater. Eutrophication monitoring is a significant component of the evaluation and management of lake ecosystems. Phosphorous is initially the algae nutrient-limiting development. These results in direct and indirect biological modifications in lakes that lead to algal blooms being produced. Indirect eutrophication during the breakdown of the dead algae mass might be leads to depletion in dissolved oxygen concentration as a consequence of bacterial respiration. According to Carlson (1980), the interrelationship between the parameters can use for the assessment of quality of water for lakes. Corrective measures and lake restoration methods are crop management, live stock management, land farming, sewage water treatment, water treatment, and artificial floating islands. Suggestions from the study are that the data related to various physiochemical characteristics of water of Bhalswa Lake can be utilized as a baseline and reference value for future research work and some necessary steps can be taken on the basis of the result which is obtained from my study. Concerned authorities should take care of the lakes, necessary rules should be formed, and the violator should be charged penalty. Then only, this lake can be saved, otherwise one more lake will be lost.

6 Conclusion

Based on the above study, following conclusions can be made:-

1. The major reason may be the organic waste coming from neighboring dairies, poured directly into the Bhalswa Lake, which increases organic pollution and decreased dissolved oxygen leading to anoxic conditions in lake water, decreased DO value which is < 4, further will affect aquatic life.
2. Also lake is polluting due to inorganic waste coming from nearby landfill sites and various small factories nearby lake which are discharging their untreated waste matter directly into the lake.
3. If this process will continue, then lake will be no longer a place of recreational activity. Immediate action is needed to revive the lake. Otherwise, one more lake will be lost.

References

1. Sakshi SK, Singh Haritash AK (2017) Environmental biotechnology for control of environmental pollution. In: Proceedings of international conference on emerging areas of environmental science and engineering EAESE-2017, February 16–18, 2017
2. Shan V, Singh SK, Haritash AK (2017) Water quality Indices to determine the surface water quality of Bhindawas Wetland. In: Proceedings of international conference on emerging areas of environmental science and engineering EAESE-2017, February 16–18, 2017
3. Gour A Singh SK, Mandal A (2016) Occupational Hazard Posed to labourer operators at landfill sites. In: Proceeding of 3rd International conference on occupational and Environmental Health, 23–25 Sept 2016, New Delhi
4. Singh SK, Anunay G, Rohit G, Shivangi G and Vipul V (2016) Greenhouse gas emissions from landfills: a case of NCT of Delhi, India. J Climatol Weather Forecast
5. Gupta D, Singh SK (2015) Energy use and greenhouse gas emissions from waste water treatment plants. Int J Environ Eng-Inderscі 7(1):1–10. https://doi.org/10.1504/IJEE.2015.069251
6. Jaffar MM, Shebli MK, Mussa AKA, Hadi BH, Aenab AM, Singh SK (2015) Detection of Enterobacter sakazakii from Commercial Children Dry Milk. Journal of Environmental Protection 2015 (6), 1170–1175
7. Singh SK, DhruvKatoriya DM, Sehgal D (2015) Fixed bed column study and adsorption modelling on the Adsorptim of malachite green day from wastewater using acid activated sawdust. Int J Adv Res 3(7):521–529
8. Abtahi M, Golchinpour N, Yaghmaeian K, Rafiee M, Jahangiri-rad M, Keyani A, Saeedi R (2015) A modified drinking water quality index (DWQI) for assessing drinking source water quality in rural communities of Khuzestan Province. Iran Ecol Indic 53:283–291. https://doi.org/10.1016/J.ECOLIND.2015.02.009
9. Alam M, Pathak JK (2010) Rapid assessment of water quality index of ramganga river, Western Uttar Pradesh (India) using a computer programme. Nat Sci 8:1–8
10. Avvannavar SM, Shrihari S (2008) Evaluation of water quality index for drinking purposes for river Netravathi, Mangalore, South India. Environ Monit Assess 143:279–290. https://doi.org/10.1007/s10661-007-9977-7
11. Bhargava D, Saxena B, Dewakar R (1970) A study of the geopollutants in the Godavary river basin of India. Asian Environ 78:1–4

12. BIS (1991) Water quality standards indian standard drinking water specification, Bureau of Indian Standard, Indian Standard (10500)
13. Branchu P, Bergonzini L, Ambrosi J-P, Cardinal D, Delalande M, Pons-Branchu E, Benedetti M (2010) Hydrochemistry (major and trace elements) of Lake Malawi (Nyasa), Tanzanian Northern Basin: local versus global considerations. Hydrol Earth Syst Sci Dis 7:4371–4409. https://doi.org/10.5194/hessd-7-4371-2010
14. Chandra S, Singh A, Tomar PK (2012) Assessment of water quality values in Porur Lake Chennai, Hussain Sagar Hyderabad and Vihar Lake Mumbai. India Chem Sci Trans 1:508–515. https://doi.org/10.7598/cst2012.169
15. Chauhan A, Singh S (2010) Evaluation of ganga water for drinking purpose by water quality index at Rishikesh, Uttarakhand. India Rep Opin 2:53–61
16. Devi Prasad AG (2012) Carlson's trophic status index for the assessment of trophic status of two Lakes in Mandya district. Adv Appl Sci Res 3:2992–2996
17. Dwivedi S, Tiwari I, Bhargava D (1997) Water quality of the river Ganga at Varanasi. Inst Eng Kolkota 78:1–4
18. Fadiran A, Dlamini S, Mavuso A (2008) A comparative study of the phosphate levels in some surface and ground water bodies of swaziland. Bull Chem Soc Ethiop 22:197–206
19. Goher ME, Hassan AM, Abdel-Moniem IA, Fahmy AH, El-sayed SM (2014) Evaluation of surface water quality and heavy metal indices of Ismailia Canal, Nile River Egypt. Egypt J Aquat Res 40:225–233. https://doi.org/10.1016/J.EJAR.2014.09.001
20. Joshi DM, Kumar A, Agrawal N (2009) Studies on physicochemical parameters to assess the water quality of river ganga for drinking purpose In: Haridwar District 2:195–203