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Trophic State Index for Euphrates River Passing Through Samawa City

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Abstract: This study is conducted in order to investigate the trophic state index of Euphrates River flowing through the Samawa city. The present study includes monthly samples collected from three sites (S1: before the Euphrates river enter Samawa center, S2: is located in the Centre of Samawa city, S3: is located at the south of the second site) during the period from April to September, 2020. The study included measurement of some physical and chemical parameters such as Secchi disc, Chlorophyll-a- and total phosphorus. The results showed that TSI (Chl-a) ranging between 4.97-39.39, TSI (SD) ranged between 45.94-81.84, TSI (TP) between 5.81-21.82 and CTSI between 26.18-45.87 with maximum value in September and lowest value in July. The average physiochemical parameters (+-standard deviation) were 7.32 (0.42), 2627.22 (583.94), 5.69 (1.06), 9.5 (3.43), 5.15 (2.05), 1.70 (0.96), 0.57 (0.27), 157.5 (11.69), 1323.88 (259.41), respectively for pH, EC, DO, BOD5, NO_3, NO_2, PO_4, TA, and TDS. Euphrates River is classified as mesotrophic by the CTSI. Statistical analysis showed that positive correlation (p-value 0.01) between the index and (Chl-a-, TP, SD, pH and total alkalinity) while other parameters did not have any correlation with the index. TSI can be used as a baseline for trophic comparisons between the numerous chemical and biological elements of rivers that are connected to trophic status.

Key words: Carlson's trophic state index, Secchi disc, total phosphorus, chlorophyll-a, physio-chemical parameters.

Introduction

One of the dynamic systems that can change there character numerous times along its path is a river, due to the reason of physical changes such as geological structure and slope (Bulut et al., 2010). The continuous and horizontally unidirectional rivers carry a significant load of materials in particle and dissolved stages from both "anthropogenic and natural sources". These materials make their way downstream, where they are subjected to extensive biological and chemical alterations (Bakan et al., 2010). These changes may have an impact on the quality and quantity of river water, as well as biodiversity services tailored to the river ecosystem's natural environment (Pimenta et al., 2012).

Eutrophication is a worldwide problem with water quality in aquatic habitats (Sutcliff and Jones, 1992). It's a long and drawn-out procedure (Zbierska et al., 2015). As a result, it isone of the most difficult problems for ecologists and limnologists to solve (Bell and Kalff, 2001).

Although eutrophication is a natural process of water ecosystem succession, it can be accelerated by increased fertiliser input, resulting in Cyanoprokaryota blooms and pollution (Bays and Crisman, 1983; Gulati, 1983; Hsieh et al., 2011).

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The essential importance of issues linked to eutrophication of water bodies and water quality degradation necessitated a thorough assessment of the "trophic state" of water bodies. TSI and environmental condition of the water body can only be objectively assessed if the "chemical, physical, and biological" aspects of the water body are described as broadly as possible (Fruh et al., 1966).

Trophic status of a water body is inextricably linked to the water quality and biological integrity of inland waters (Adamovich et al., 2016), the action of the aquatic ecosystem refers to the available energy of the food network and serves as the foundation (Dodds, 2007; Shi et al., 2019). Over the years, a quantitative description of trophic states has emerged. The trophic status index (TSI), first proposed by Carlson 1977), derived using "Chl-a-, TP and SD", is one of the most extensively used approaches in inland water categorisation (Chl-a). To improve the TSI and expand its application to other waters, more water quality parameters, such as total nitrogen, were employed (Aizaki et al., 1981), "biochemical oxygen demand", or "chemical oxygen demand" (Zuoyong and Huijun, 1993). The Organization for "Economic Co-operation and Development (OECD)" suggests another technique for classifying freshwater lakes, on the basis of TP & Chl-a concentrations (Hatvani et al., 2020). Transparency, algal biomass and nutrient levels (TN, TP) are used to determine these trophic classifications (Carlson, 1977; Carlson and Havens, 2005; Walsh et al., 2016).

Trophic State Index, developed by Carlson (1977), is a widely used and approved index for estimating the limiting nutrient that causes eutrophication (Nalamutt and Karmakar, 2014), and it was adopted by Environmental Protection Agency (EPA) (2000).

The total weight of biomass in a water body at a particular time and location is referred to as a trophic condition. The biomass is formed in response to biological and nutrient inputs in the waterbodies. CTSI primarily uses three factors to generate a trophic index: total phosphate (TP), transparency, and chlorophyll-a (Chl-a). The river is classed as Hypereutrophic, Mesotrophic,Oligotrophic, or Eutrophic based on CTSI values. The TSI is used to determine the productivity or trophic status of the River, which is a standard metric or method. At a given time and location, it is the total weight of living algae (algae biomass) in a body of water. Total phosphorus, Secchi depth, and chlorophyll-a are used to assess algal biomass independently. These three metrics of water quality are linked. Because there is more food available for algae as phosphorus levels rise, algal numbers rise as well. The water gets less translucent as algae concentrations rise, and the Secchi depth drops (Chaurasia and Gupta, 2016).

To evaluate TSI on Carlson's model, many studies have certified this as follows:

Dodds (2006) suggested in his study that phosphorus, nitrogen, and carbon are the most important nutrients, which regulate the autotrophic state in flowing waters.

Bolgrien et al. (2009) observed that the three large reservoirs of the Missouri River were characterised as mesotrophic to eutrophic, phosphorus (P) limited, and generally supporting cold water habitat (bottom waters 5 mg/L) in midsummer.

Rodrigues et al. (2015) studied the Piracicaba River and Itapeva Stream, they found that TSI varied from mesotrophic to eutrophic in the river and in the stream from ultra oligotrophic to mesotrophic.

Chaurasia and Gupta (2016) found that Mandakini River was oligotrophic at site 1 and mesotrophic at site 2 to 5, respectively, and they indicated that site 2 to 5 needs conservation from being eutrophic.

Because there are no previous studies in the study area, the current study aimed to analyse some physiochemical parameters and the trophic status of the Euphrates River in Samawa city.

Table 1: Details of sampling sites

No.	*Location*	*Sampling sites detail*	*Latitude and longitude*
1	S1	Before Euphrates river enter Samawa center	31.39748 N and 045.19188 E
2	S2	Located in the centre of Samawa city about 7 km from S1	31.31508 N and 045.29405 E
3	S3	Located at the south of the second site about 6 km from S2	31.29327 N and 045.45613 E

Materials and Methods

"Euphrates" River is Western Asia's longest river. It enters the Iraqi land and flows south till it reaches Al- Muthanna region, passing through various towns like Al-Hilal, Al-Majed, Al-Samawa, Al-Khidhir and Al –Drajae. The length of the Euphrates River in Al-Muthanna province is about 110 kilometers, with a water depth of about 10 meters and a width of 100-120 meters (Figure 1; Table 1).

Three sites in the Euphrates River were sampled in triplicate on a monthly basis (April-September 2020)

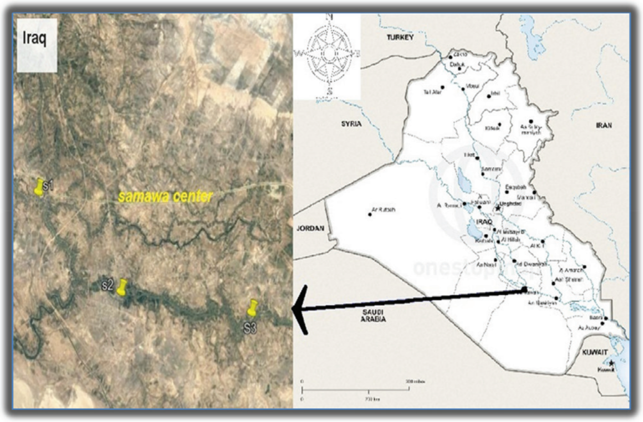

Figure 1: Study site in Euphrates River.

The Carlson's Trophic State Index (TSI) was calculated using the following formulae:

TSI for Secchi Disc Transparency (SDT) TSI = 10[6 -ln SD/ln 2]

TSI for Chlorophyll - a (Chl- a) TSI = 10[6 –(2.04 - 0.68 ln(Chl- a))/ln 2]

TSI for Total Phosphate (TP) TSI = 10[6 –(ln 48 /TP)/ln 2]

Carlson's Trophic State Index (CTSI) = [TSI (SDT) + TSI (Chl-a) + TSI (TP)]/3

(Figure 1). Carlson's trophic status index (CTSI) was calculated using three parameters; Secchi disc (SD) readings, which refer to water clarity, were acquired immediately in the field by using a "20" cm diameter disk, water samples for chlorophyll-a (Chl-a), and total phosphorus (TP) was collected in an ultra-clean (1 litre) sampling bottle. According to APHA (2005), TP was analysed using "digestion block" followed by the ascorbic acid technique. The acetone method was used to estimate chlorophyll-a, then measured with a spectrophotometer (APHA, 2005).

A portable multimeter (Multi 350i/3500i, Germany) was used to immediately measure pH, TDS, and EC in the field. Biological oxygen demand (BOD5) was measured in the laboratory using a BOD5 incubator, total alkalinity according to Lind (1971) dissolved oxygen (DO), nitrate (NO_3), nitrite (NO_2), phosphate (PO_4) (APHA, 2005).

The variance analysis (ANOVA) test was applied to data for determining the statistical differences and Pearson correlation coefficients were used to determine relationships between the measured environmental variables and CTSI. Statistical analysis was performed using the SPSS package (v.25).

Results and Discussion

The trophic progression of water bodies from oligotrophic to eutrophic states a gradual process in nature. The change from one trophic stage to another is based on the conversion in the degree of nutrient inflow and the productivity in the lake (Chaurasia and Karan, 2014).

The experimental data of the samples analysed in all three selected sites were tabulated parameters. The results showed that there were monthly variations in Secchi depth, total phosphorus, Chl-a, and CTSI computed (Figure 2 a-c).

The results showed that SD had a mean 0.64 (±0.73), TP had a mean of 0.35 (±0.13), and Chl-a had a mean of 0.78 (±0.83) (Figure 2 a-b). In September, the highest TSI values based on Chlorophyll-a were reported. The highest TSI (chl-a-) is observed in September (39.3), this may be attributed to various factors, such as increasing water temperature, high intensity of incident radiation, in addition to, nutrients input from surrounding agricultural lands (Duan et al., 2007; Santos et al., 2014). Chlorophyll a is used to estimate the amount of phytoplankton or algae in an aquatic

Table 2: The classification of river according to Carlson and Simpson (1977)

S. No.	*CTSI Value*	*Trophic Level*	*Attributes*
1.	>30	Oligotrophic	Clear water, oxygen throughout the year in the hypolimnion.
2.	30-40	Oligotrophic	A river will still exhibit oligotrophy, but some river will become anoxic during the summer.
3.	40-50	Mesotrophic	Water moderately clear, but increasing probability of anoxia during the summer.
4.	50-60	Eutrophic	Lower boundary of classical eutrophy: Decreased transparency, warm-water fisheries only.
5.	60-70	Eutrophic	Dominance of blue-green algae, algal scum probable, extensive macrophyte problems.
6.	70-80	Eutrophic	Heavy algal blooms possible throughout the summer, often Hypereutrophic.
7.	<80	Eutrophic	Algal scum, summer fish kills, few macrophytes.

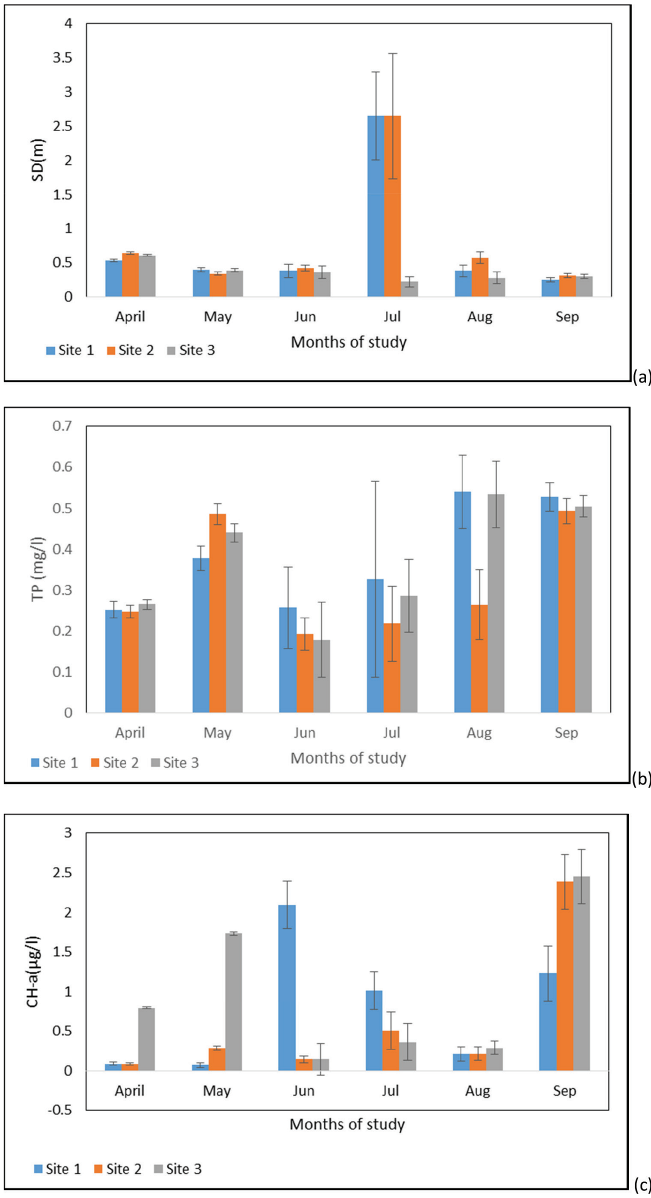

Figure 2: Monthly variation in (a) Secchi Disc (m), (b) total phosphorus concentration (µmol/L), and (c) chlorophyll-a (µg/L), in study sites.

system. It is a useful parameter for determining the biological productivity of a water body (Mahesh et al., 2014)

The highest and lowest TSI (SD) are observed in July (45.9 and 81.84). The transparency is correlated with increases in phytoplankton density (higher content of chlorophyll-a and a decrease in light penetration (Zbierska et al., 2014). The Secchi disk depth variation is essentially the measure of the optical clarity of the water. It is a function of the presence of suspended solids, excessive floating vegetation or algal bloom and the turbulence caused by rainwater (Sharma and Shardendu, 2012). Phosphorus is less abundant compared with other nutrients and it is a limiting factor for phytoplankton growth.

Euphrates river's Carlson trophic state index value ranged from 26.18 to 45.87, the maximum value of CTSI was in September (Autumn) while the lowest values were in June (Summer) (Figure 3) (Table 3), this result agrees with Bolgrien et al. (2009). The status of eutrophication is intimately linked to photosynthesis, which is the main force behind seasonal changes in several biotic activities and physiochemical parameters (Xie, 2006).

The average (± standard deviation) of physical and chemical parameters were 7.32 (±0.42), 2627.22

Table 3: Trophic state index value in study sites

Month	*Site*	*TSI (Chl-a)*	*TSI (TP)*	*TSI (SD)*	*CTSI*
	1	29.17	10.82	69.02	36.34
April	2	29.17	10.53	66.43	35.38
	3	28.32	11.55	67.01	35.62
	1	4.79	16.67	73.21	31.56
May	2	18.39	20.3	75.56	38.08
	3	35.97	18.86	73.58	42.8
	1	37.83	11.11	73.95	40.96
June	2	11.59	6.9	72.51	30.33
	3	11.59	5.81	74.73	30.71
	1	30.68	14.54	45.94	30.38
July	2	23.88	8.73	45.94	26.18
	3	20.58	12.65	81.84	38.36
	1	15.57	21.82	73.95	37.11
August	2	15.57	11.49	68.1	31.72
	3	18.39	21.66	78.36	39.47
	1	32.59	21.49	80	44.69
September	2	39.09	20.5	76.89	45.5
	3	39.39	20.85	77.36	45.87

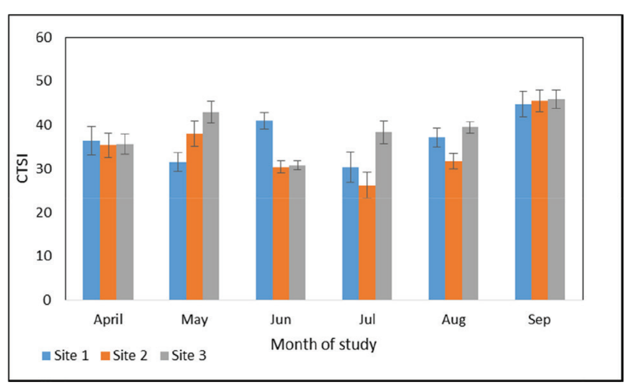

Figure 3: Show Carlson's Trophic State Index (CTSI) in study sites.

(±583.94), 5.69 (±1.06), 9.5 (±3.43), 5.15 (±2.05), 1.70 (±0.96), 0.57 (±0.27), 157.5 (±11.69), 1323.88 (±259.41), for pH, EC, DO, BOD5, NO_3, NO_2, PO_4, TA, TDS, respectively. As noted, pH and total alkalinity recorded the highest value during Autumn, due to the high content of bicarbonate in the Iraqi water (Al-Azawey, 2012; Ali and Al-Mahdawi, 2015). High conductivity was also found due to significant amounts of organic matter and pollutants discharged in the water body, according to Molin et al. (2007). The opposite fluctuation pattern of dissolved oxygen, temperature, and biological oxygen demand can be seen, with the highest value of oxygen recorded in April and the highest value of BOD5 was recorded in the summer (Huo, 2013; Essien and Umoh, 2013).

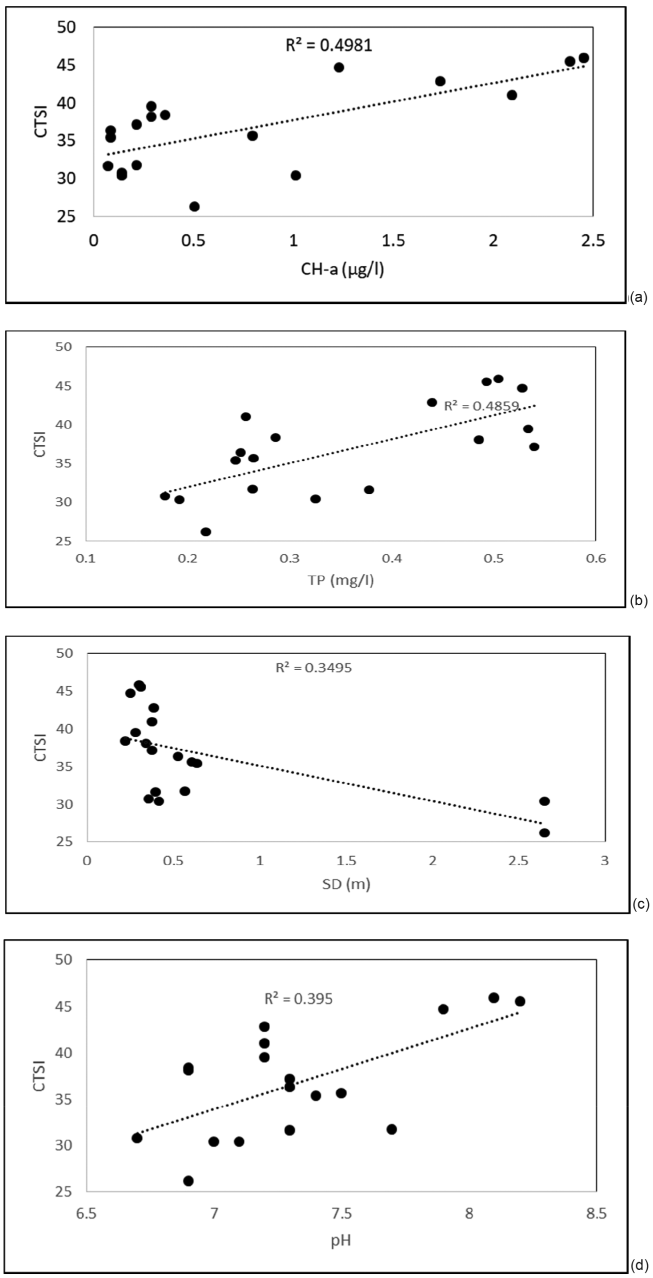

Figure 4: The correlation between CTSI and some physiochemical properties in study sites of Euphrates River.

CTSI has a positive correlation (p-value 0.01) with Chlorophyll-a, Total Alkalinity (TA), Total Phosphorus (TP), Secchi disc (SD), and pH (Figure 4a-d).

According to Table 2, the water of the Euphrates River is mesotrophic, which means that it is relatively clear but has a higher risk of anoxia during the summer. This issue in the river is due to raw sewage, surface runoff, and agricultural land runoff (Wojtkowska and Bojanowski, 2018).

Conclusions

From April to September (2020) at several chosen sites, the physicochemical parameters were used to monitor the trophic state index of the Euphrates river. In the current study, we found that the highest TSI values based on total phosphorus and SD were recorded in the summer months of July and August and the highest TSI values based on Chl-a were recorded in the fall months of September and October, respectively. The lowest values were recorded in the spring. The CTSI had its highest value in the autumn and its lowest value in the summer.

It was observed that sites (S1, S2 and S3) during September and S1 and S3 during June and May, respectively, were found in Mesotrophic condition, while found in oligotrophic condition in other months. TSI is a useful scientific tool for research projects requiring an objective measure of trophic status as well as a useful tool for river management. This index can be used as a baseline for trophic comparisons between the numerous chemical and biological elements of rivers that are connected to trophic status.

References

Adamovich, B.V., Zhukova, T.V., Mikheeva, T.M., Kovalevskaya, R.Z. and E.V. Luk'yanova (2016). Long-term variations of the trophic state index in the Narochanskie lakes and its relation with the major hydroecological parameters. *Water Resources*, **43(5):** 809-817.

Aizaki, M., Otsuki, A., Fukushima, T., Hosomi, M. and K. Muraoka (1981). Application of Carlson's trophic state index to Japanese lakes and relationships between the index and other parameters. *Proceedings-International Association of Theoretical and Applied Limnology*.

Al-Azzawi, M.N., Nashaat, M.R. and D.S. Ahmed (2012). The Limnological characteristics of the Tigris River at the Baghdad city. *In:* The 4th conference on Environmental Science–Babylon University (pp. 48-57).

Ali, H.A. and M.M. Al-Mahdawi (2015). Phytoplankton diversity and pollution index in North Part of Euphrates River, Iraq. *Iraqi Journal of Science*, **56(3B):** 2223-2236.

APHA. (2005) Standard methods for the Examination of Water and Wastewater, Editor A.D. Eaton, 18th ed., American Public Health Association, Washington.

Bakan, G., Özkoç, H.B., Tülek, S. and H. Cüce (2010). Integrated environmental quality assessment of the Kızılırmak River and its coastal environment. *Turkish Journal of Fisheries and Aquatic Sciences*, **10(4):** 453-462.

Bays, J.S. and T.L. Crisman (1983). Zooplankton and trophic state relationships in Florida lakes. *Canadian Journal of Fisheries and Aquatic Sciences*, **40(10):** 1813-1819.

Bell, T. and J. Kalff (2001). The contribution of picophytoplankton in marine and freshwater systems of different trophic status and depth. *Limnology and Oceanography*, **46(5):** 1243-1248.

Bolgrien, D.W., Scharold, J.V., Angradi, T.R., Corry, T.D., Schwieger, E.W. and J. Kelly (2009). Trophic status of three large Missouri River reservoirs. *Lake and Reservoir Management*, **25(2):** 176-190.

Bucci, M.M.H.S., Delgado, F.E.D.F. and L.F.C. de Oliveira (2015). Water quality and trophic state of a tropical urban reservoir for drinking water supply (Juiz de Fora, Brazil). *Lake and Reservoir Management*, **31(2):** 134-144.

Bulut, V.N., Bayram, A., Gundogdu, A., Soylak, M. and M. Tufekci (2010). Assessment of water quality parameters in the stream Galyan, Trabzon, Turkey. *Environmental Monitoring and Assessment*, **165(1):** 1-13.

Carlson, R.E. (1977). A trophic state index for lakes 1. *Limnology and Oceanography*, **22(2):** 361-369.

Carlson, R.E. and K.E. Havens (2005). Simple graphical methods for the interpretation of relationships between trophic state variables. *Lake and Reservoir Management*, **21(1):** 107- 118.

Chaurasia, S. and R. Gupta (2016). Study on trophic state index of river Mandakini at Chitrakoot, India. *International Journal of Advanced Research in Engineering and Applied Sciences*, **5(8):** 34-43.

Chaurasia, S. and R. Karan (2014). Assessment of water quality index and trophic state index of river Mandakini, India. *International J. of Plant, Animal, and Environmental Sciences*, **4(1):** 343- 347

Dodds, W.K. (2006). Eutrophication and trophic state in rivers and streams. *Limnology and Oceanography*, **51(1part2):** 671-680.

Dodds, W.K. (2007). Trophic state, eutrophication and nutrient criteria in streams. *Trends in Ecology & Evolution*, 22(12): 669-676.

Duan, H., Zhang, Y., Zhang, B., Song, K. and Z. Wang (2007). Assessment of chlorophyll-a concentration and trophic state for lake Chagan using Landsat TM and field spectral data. *Environmental Monitoring Assessment*, **129:** 295-308.

EPA, U. (2000). Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria for Lakes and Reservoirs in Nutrient Ecoregion IX. edited by United States Environmental Protection Agency. *Washington, DC: Office of Water*.

Essien-Ibok, M.A. and I.A. Umoh (2013). Seasonal association of physico-chemical parameters and phytoplankton density in Mbo River, Akwa Ibom State, Nigeria. *International Journal of Engineering and Technology*, **5(1):** 146.

Fruh, E.G., Stewart, K.M., Lee, G.F. and G.A. Rohlich (1966). Measurements of eutrophication and trends. *Journal (Water Pollution Control Federation)*, **38(8):** 1237-1258.

Gulati, R.D. (1983). Zooplankton and its grazing as indicators of trophic status in Dutch lakes. *Environmental Monitoring and Assessment*, **3(3):** 343-354.

Hatvani, I.G., de Barros, V.D., Tanos, P., Kovács, J., Kovács, I.S. and A. Clement (2020). Spatiotemporal changes and drivers of trophic status over three decades in the largest shallow lake in Central Europe, Lake Balaton. *Ecological Engineering*, **151:** 105861.

Hou, D., He, J., Lü, C., Sun, Y., Zhang, F. and K. Otgonbayar (2013). Effects of environmental factors on nutrients release at sediment-water interface and assessment of trophic status for a typical shallow lake, Northwest China. *The Scientific World Journal*, **2013:** 716342.

Hsieh, C.H., Sakai, Y., Ban, S., Ishikawa, K., Ishikawa, T., Ichise, S. and M. Kumagai (2011). Eutrophication and warming effects on long-term variation of zooplankton in Lake Biwa. *Biogeosciences*, **8(5):** 1383-1399.

Lind, O.T. (1979). *Handbook of common methods in limnology*. The CV Mosley Company.

Mahesh, S., Srikantha, H., Mohan, K.S. and S. Vathsala (2014). Eutrophication assessment for the Dantaramakki lake of Chikmagalur city using GIS technique. *International J. Chem Tech Research.*, **6(1):** 440-449.

Molin, P.G., Couto, H.T.Z. and D.F. Silva Filho (2007**).** Uso de videografia multispectral aérea para quantificar o uso de solo em uma microbacia hidrográfica urbana. *In:* SIMPÓSIO INTERNACIONAL DE INICIAÇÃO CIENTIFICA DA USP, 15., Pirassununga. Anais**...** São Paulo: USP, pp. 4603-4603.

Nalamutt, T.D. and S. Karmakar (2014). Modeling impreciseness of trophic state levels for eutrophication assessment. *Journal of Clean Energy Technologies*, **2(2):** 140-144.

Pimenta, A.M., Albertoni, E.F. and C. Palma Silva (2012). Characterization of water quality in a small hydropower plant reservoir in southern Brazil. *Lakes & Reservoirs: Research & Management*, **17(4):** 243-251.

Rodrigues, L.D.A., Torres, N.H., Tornisielo, V.L., Ferreira, L.F.R. and L.A. Maranho (2015). Determination of toxicity assays, trophic state index, and physicochemical parameters on Piracicaba River and Itapeva Stream. *Revista Ambiente & Água*, **10:** 310-317.

Santos, J.C.N., Andrade, E.M., Neto, J.R.A., Meireles, A.C.M. and H.A.Q. Palacio (2014). Land use and trophic state dynamics in a tropical semi-arid reservoir. *Revista Ciencia Agrondmica*, **45(1):** 35-44.

Sharma, D. and Shardendu (2012). Determination of Carlson's trophic state index of Kabar wetland of Bihar. *Proc. Indian National Science Academy*, **78(2):** 189-196.

Shi, K., Zhang, Y., Song, K., Liu, M., Zhou, Y., Zhang, Y. and B. Qin (2019). A semi- analytical approach for remote sensing of trophic state in inland waters: Bio-optical mechanism and application. *Remote Sensing of Environment*, **232:** 111349.

Sutcliffe, D.W. and J.G. Jones (1992). Eutrophication: Research and application to water supply. Freshwater Biological Association, & International Water Supply Association.

Walsh, J.R., Carpenter, S.R. and M.J. Vander Zanden (2016). Invasive species triggers a massive loss of ecosystem services through a trophic cascade. *Proceedings of the National Academy of Sciences*, **113(15):** 4081-4085.

Wojtkowska, M. and D. Bojanowski (2018). Influence of catchment use on the degree of river water pollution by forms of phosphorus. *Rocznik Ochrona Środowiska*, **20:** 887-904.

Xie, P. (2006). Biological mechanisms driving the seasonal changes in the internal loadingof phosphorus in shallow lakes. *Science in China Series D*, **49(1):** 14-27.

Zbierska, J., Ławniczak, A.E. and A. Zbierska (2015). Changes in the trophic status of lake Niepruszewskie (Poland). *Journal of Ecological Engineering*, **16(4):** 65-73.

Zuoyong, L. and Z. Huijun (1993**.** Trophic state index and its correlation with lake parameters. *Acta Scientiae Circumstantiae*, **4**.