International Journal of Advanced Research in Engineering and Applied Sciences

ISSN: 2278-6252
Impact Factor: 6.655

STUDY ON TROPHIC STATE INDEX OF RIVER MANDAKINI AT CHITRAKOOT, INDIA

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Abstract: *"Trophic state" is used to classify aquatic ecosystems according to biotic productivity. A trophic state index incorporates a scale of 0 to 100. Each major division (10, 20, 30 etc.) represents a doubling in algal biomass. The index number can be calculated from any of several parameters, including secchi disc transparency, chlorophyll and total phosphorus. This index can be used as a predictive tool in lake management. In the present study the selected reach of River Mandakini was found in different trophic level. It was fond Oligotrophic at S1 site and Mesotrophic at S2, S3, S4& S5 sites respectively. It is indicating that site S2, S3, S4 and S5 needs conservation from being Eutrophic.*

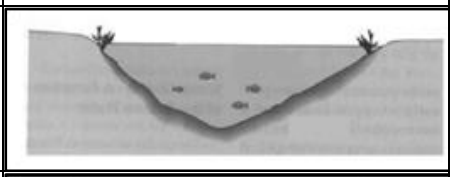
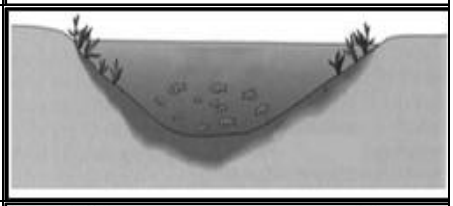
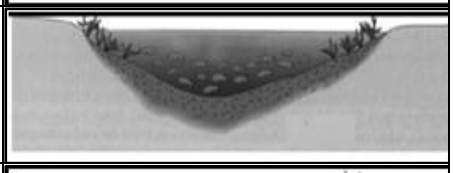
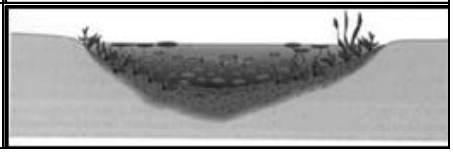
Keywords: *Trophic State, Trophic State Index, Transparency (SDT), Chlorophyll, Phosphate.*

INTRODUCTION

It is well known that clean water is absolutely essential for several purposes for healthy living (Mandalam et al., 2009). Rivers are the most important natural resource for the survival of all living organisms and human development, but it is being polluted by indiscriminate disposal of sewage, industrial waste and plethora of human activities, which affects its physico-chemical and microbiological quality. Due to increasing problem of deterioration of river water quality, it is necessary to monitoring the water quality to evaluate the production capacity (Mishra et al., 2009).

Trophic state is defined as the total weight of the biomass in a water body at a specific location and time. Trophic state is the biological response for nutrient additions to the water bodies. Carlson's trophic state index mainly uses to calculate trophic index with the help of three variables namely Chlorophyll-a(Chl-a), Transparency and Total phosphate (TP).Based on the values of CTSI the river are classified as Oligotrophic, Mesotrophic, Eutrophic and Hypereutrophic. The detail of various trophic states is given in Table-1.

Table 1 Various trophic state and their characteristics

S. No.	Trophic State	Level of productivity	Range of Chl-a	Range of TP	Range of SDT	Figure of various trophic State
1.	Oligotrophic	Low productive	>3 µg/l	>15 µg/l	< 13 feet	
2.	Mesotrophic	Moderately productive	3 - 7 µg/l	15 - 25 µg/l	8-13 feet	
3.	Eutrophic	Highly productive	7 - 40 µg/l	25- 100 µg/l	3 - 8 feet	
4.	Hypereutrophic	Very highly productive	<40 µg/l	<100 µg/l	>3 feet	

TSI is a standard measure or means for calculating the trophic status or productivity of a River. More specifically, it is the total weight of living algae (algae biomass) in a water body at a specific location and time. Three variables, chlorophyll-a, secchi depth, and total phosphorus, independently estimate algal biomass. These three water quality measurements are related. When phosphorus increases, that means there is more food available for algae, so algal concentrations increase. When algal concentrations increase, the water becomes less transparent and the Secchi depth decreases.

The overall Trophic state index (TSI) of a River is the average of the TSI for phosphorus, the TSI for chlorophyll-a and the TSI for secchi disc transparency. Therefore, it can be thought of as the river condition taking into account phosphorus, chlorophyll-a and secchi disc transparency. Trophic State Index is not necessarily interchangeable with water quality. Water quality is subjective and depends on how you intend to use the water body.

STUDY AREA

Chitrakoot Dham is an important place of pilgrimage to millions of Hindus. It is the place where lord Rama along with his wife Sita and brother Lakshman spent eleven and half years when he was in exile-at-forest (Banabasa). The place is situated on the northern spur of

Vindhya Mountain, amidst lush green forest & sparkling river. The holy river Mandakini flows through the place adding serene beauty.

Chitrakoot is a town and nagar panchayat and located at Latitude - 25.1788^{o} N, Longitude - 80.8655^{o} E in Satna district of Madhya Pradesh, India. The Climate of Chitrakoot is tropical with extremes of weather – in summer the temperature can soar to 49^{0}C while in winter it can plummet to 5^{0}C. Average rainfall in Chitrakoot is 900mm. The relative humidity was highest in August about 85% and lowest in April about 12%.

Fig.1 Map of M.P. showing location of Chitrakoot

It is a town of religious, cultural, historical and archaeological importance, situated in the Bundelkh and region. It borders the Chitrakoot district in Uttar Pradesh, whose headquarters Chitrakoot Dham (Karwi) is located nearby. The town lies in the historical Chitrakoot region, which is divided between the present-day Indian states of Madhya Pradesh and Uttar Pradesh. It is known for a number of temples and sites mentioned in Hindu scriptures.

The River Mandakini originates from the hills of khillora near Pindra village, Majhgawan block (25° 09' 24.8"N, 80° 52' 55.3"E), Satna district, M.P. at an elevation of 156 meter above mean sea level in the state of Madhya Pradesh of northern India. Whole watershed area is 1956.3 Sq. km. The River passes through two states especially between M.P. and U.P. states. Sati Anusuiya is a perennial reach of Mandakini River where a large number of small springs feed to the river. Afterwards it passes through various religious and non-religious points.

The number of drains carrying wastewater of town joining the river at various points increasing the pollution load of the river and altering its water quality. The Mandakini is a sacred river and only water source for local people. Therefore present study was under taken to know the trophic state index of river Mandakini at various reach at Chitrakoot.

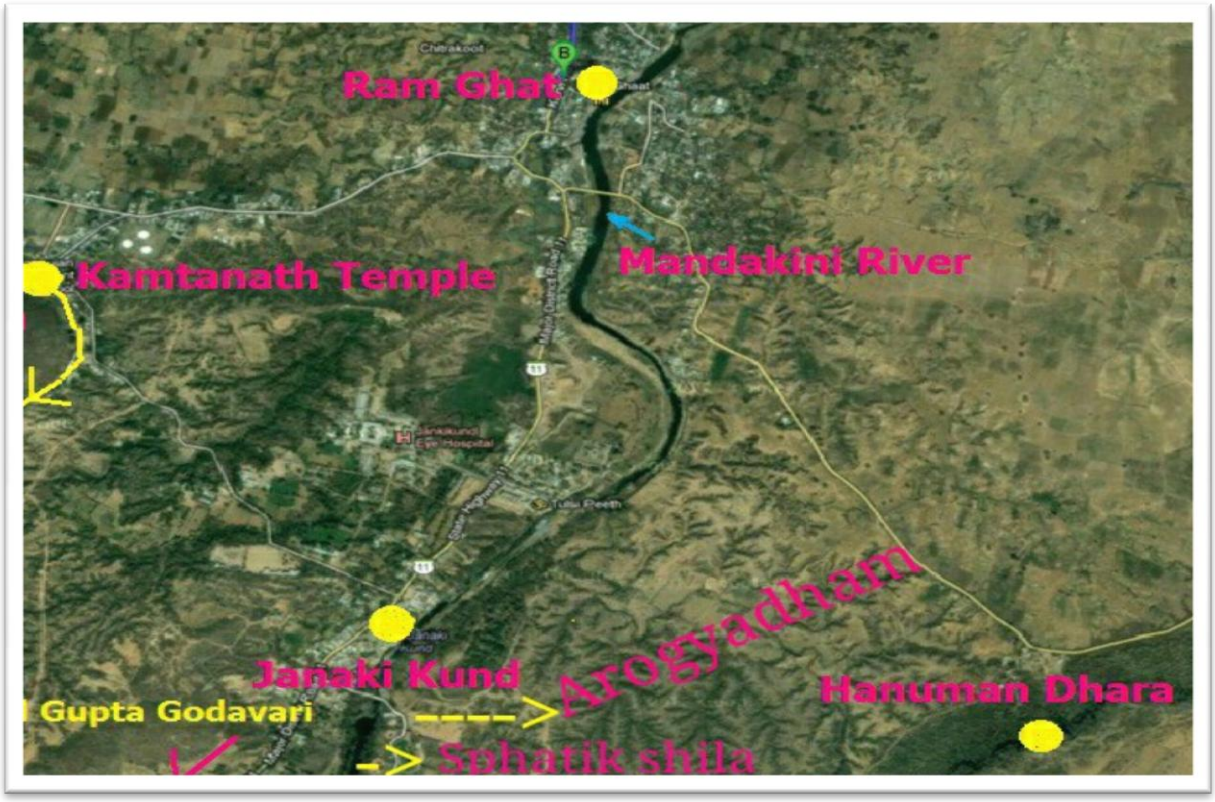


Fig.2 Showing location of River Mandakini at Chitrakoot

MATERIALS AND METHOD

On the stretch of river(8.5 km approximate)five sampling station were selected namely Sphatikshila, Arogyadham, Jankikund, Pramodvan and Ramghat (Table-2). To determine the water quality and trophic state of river Secchi disc transparency(SDT), DO, BOD, COD, Total Phosphate (TP) and Chl-a were monitored on weakly basis for three months (March, April& May).

The water samples were collected in a 2 L capacity bottles (plastic water sample containers) brought to the laboratory for analysis. Care was taken to guard the samples against shaking and exposure to the atmosphere during transport. The methods for analysis were followed as per APHA AWWA WPCF (2005).

Table-2: Details of Sampling Stations

S. No.	Sampling station code	Sampling station detail	Latitude and Longitude
1.	S_1	This sampling station is known as **Sphatikshila**. It is an upstream station, 3 Km in the south of Chitrakoot.	25^0 8'46.5" N and 80^0 51' 25.1" E
2.	S_2	This sampling station is known as **Arogyadham**. 2.0 Km downstream from Sphatikshila.	25^0 9' 25.9" N and 80^0 51' 46.7" E
3.	S_3	This sampling station is known as **Jankikund**. 1.0 Km downstream from Arogyadham.	25^0 9'31.6" N and 80^0 51' 51.4" E
4.	S_4	This sampling station is known as **Pramodvan**. 1.0 Km. downstream from Jankikund.	25^0 10'15.2" N and 80^0 52' 1.1" E
5.	S_5	This sampling station is known as **Ramghat**. 1.5 Km downstream from Pramodvan.	25^0 10'40.8" N and 80^0 52' 15.9" E

Calculation of Trophic State Index (TSI)

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

$$\text{TSI for Secchi Disc Transparensy (SDT) } TSI = 10[\,6 - \frac{\ln SD}{\ln 2}\,]$$

$$\text{TSI for Chlorophyll} - a\ (Chl - a)\ TSI\ = 10[\,6 - \frac{2.04 - 0.68 \ln (Chl - a)}{\ln 2}\,]$$

$$\text{TSI for Total Phosphate (TP) } TSI\ = 10[\,6 - \frac{\ln \frac{48}{TP}}{\ln 2}\,]$$

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

RESULTS AND DISCUSSION

Experimental results of the samples analyzed in all the 5 selected stations were tabulated parameter wise, location wise in Table-3.The trophic state index calculated for selected stations were given inTable-5.

Transparency (SDT): - Water clarity refers to the clearness or **transparency** of water. Several factors can affect water clarity such as free floating algae, dissolved organic compounds and suspended solids. It is responsible for self-purification of water quality. The maximum value was recorded 81.72 cm at **S_1** site and minimum 41.02 cm at **S_5** site (Table-3&Fig-4).

Dissolved Oxygen (DO):-DO is the amount of oxygen that is dissolved in water. Its correlation with the water body gives direct and indirect information about bacterial activity, photosynthesis, etc., (Premlata and Vikal, 2009). The lower values may be due to increase in temperature and higher rate of decomposition of organic matter and limited flow of water. The DO values were observed 7.24 mg/l, 5.08 mg/l, 5.16 mg/l, 5.20 mg/l and 4.99mg/l at site S_1, S_2, S_3, S_4 and site S_5 respectively (Fig-3). The maximum values were recorded **7.24 mg/**l at site **S_1** and minimum value **4.99 mg/l** at **S_5** site where domestic sewage drainage entering into the river.

Chemical Oxygen Demand (COD):-COD is the amount of dissolved oxygen required to cause chemical oxidation of the organic material in water. It is commonly used to indirectly measure the amount of organic compounds in water. COD values are greater than BOD values. A higher value of the ratio indicates the waste water is difficult to biodegradable. For non-biodegradable wastewater the ratio exceeds 10. The limiting value of COD of wastewater generally specified by the authorities is 250 mg/l.COD value range was observed from **79.48** to **149.68mg/l**. The maximum Values were recorded at S_5 site and minimum value at S_1 site which were within the permissible limit (Fig-4).

Bio-chemical Oxygen Demand (BOD):-BOD values range between **2.28** to **8.64 mg/l**. The maximum values were recorded at **S_5** site and minimum values at **S_1** site (Fig-3). High concentration of BOD due to organic matter and domestic sewage are directly discharged into river Mandakini. It is an important parameter for oxygen required to degrade organic matter.

Phosphate (PO_4^-):- Phosphorus is a nutrient necessary for the growth of algae and aquatic plants. Phosphorus can enter the river through runoff from agriculture, fertilized lawns, erosion, manure, improperly maintained septic systems, and many other sources. When this nutrient is in low supply (and all other factors necessary for plant and algae growth are present in sufficient amounts), low biological productivity can be expected. On the other end of the trophic state scale, highly productive water bodies usually have an abundance of Phosphorus. Phosphates are not toxic to people or animals unless they are present in very high levels. Digestive problem could occur from extremely high level of phosphate. The major sources of phosphate are domestic sewage, detergents, agricultural and runoff with

fertilizers. The value of Phosphate was found in range of **1.49** to **4.08 mg/l**. The minimum value was found 1.49mg/l at S_1site, while maximum was found 4.08 mg/l at S_5site (Fig-3).

Chlorophyll-a (Chl-a):-Chlorophyll-a is the pigment that makes plants and algae green. Chlorophyll-a is measured to determine algal concentration. A high measurement of chlorophyll-a means, that there is a large amount of algae in the river. In general, when total chlorophyll is high the water body will be more biologically productive. The Chl-a value was found in range of **1.35** to **5.08µg/l**. The minimum value was found 1.35µg/l at S_1while maximum was 5.08µg/l at S_5site (Fig-3) indicating that site S5 is more productive due to mixing of sewage.

Carlson's Trophic State Index: -With the help of SDT, Total phosphate and Chl-a CTSI value was calculated at the results were given in Table-5**.**The minimum CTSI value was observed 35.32 at Sphatikshila (S_1) while maximum value was 47.90 at Ramghat (S_5). The value <40 indicates that Sphatikshila (S_1)is Oligotrophic state and value ≥40 indicates that Arogyadham (S_2), Jankikund (S_3), Pramodvan (S_4) and Ramghat (S_5) are Mesotrophic state. The progression of river from oligotrophic to eutrophic state is a gradual process due to ingress of sewage. The conversion from one life stage to another is based on the changes in the degree of nutrient inflow and the productivity of the river.

Table 3 Average Physico-chemical parameters of River Mandakini at Various stations (2016)

S. No.	Parameter		Sampling Stations				
			S_1	S_2	S_3	S_4	S_5
1.	Secchi Disc Transparency (cm)	Mean	81.72	66.74	46.90	42.66	41.02
		±SD	± 0.66	± 0.40	± 0.41	±0.41	±0.58
2.	Dissolved Oxygen (mg/l)	Mean	7.24	5.08	5.16	5.20	4.99
		±SD	± 0.26	±0.11	±0.23	±0.19	±0.25
3.	Bio-chemical Oxygen Demand (mg/l)	Mean	2.28	2.64	2.42	3.62	8.64
		±SD	± 0.22	±0.18	±0.27	±0.19	±0.11
4.	Chemical Oxygen Demand (mg/l)	Mean	79.48	79.86	80.02	100.24	149.68
		±SD	±1.12	± 0.88	±0.63	±0.48	±0.78
5.	Total Phosphate (mg/l)	Mean	1.49	3.09	1.89	3.11	4.08
		±SD	±0.010	±0.015	±0.020	±0.015	±0.011
6.	Chlorophyll-a (µg/l)	Mean	1.35	2.18	2.20	2.26	5.08
		±SD	±0.013	± 0.016	±0.023	±0.021	±0.044

Table 4 Carlson's Trophic State Index Value, Trophic condition and Attributes

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.

Source: Robert E. Carlson's (1977).

Table 5 Carlson's Trophic State Index value of River Mandakini (2016)

S. No.	Sampling Station	TSI of SDT	TSI of Chl-a	TSI of TP	CTSI (average)	Trophic Level
1.	Sphatikshila	62.89	33.39	09.68	35.32	Oligotrophic
2.	Arogyadham	65.59	47.28	20.28	44.38	Mesotrophic
3.	Jankikund	70.49	47.43	13.12	43.83	Mesotrophic
4.	Pramodvan	72.23	47.68	20.34	46.75	Mesotrophic
5.	Ramghat	72.92	46.52	24.27	47.90	Mesotrophic

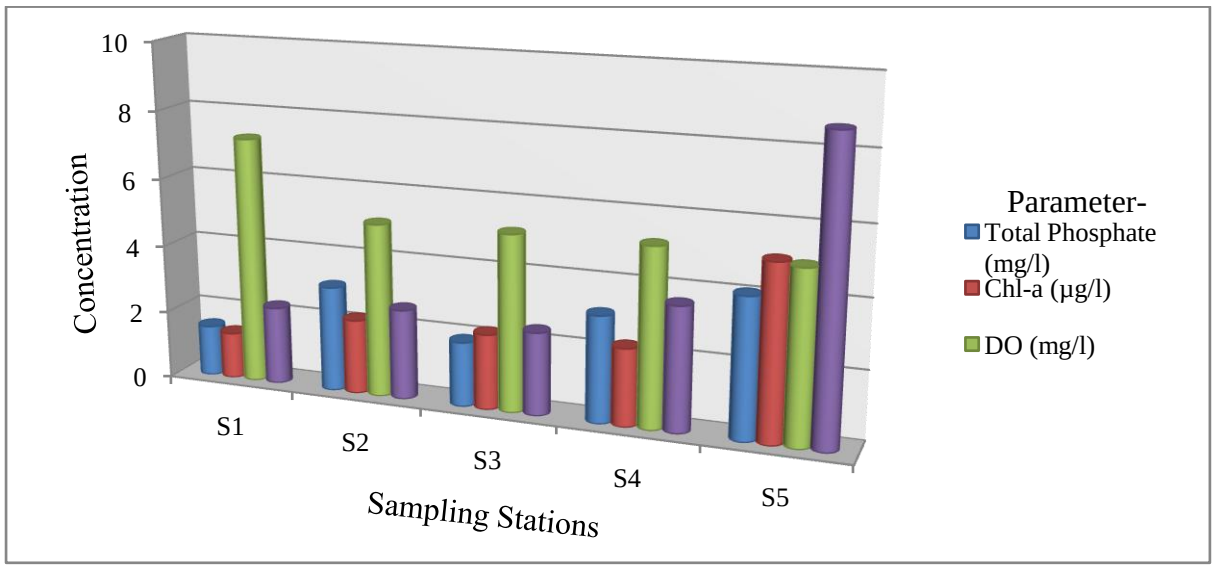


Fig. 3 Showing concentration of Phosphate, Chl-a (Chlorophyll-a), DO&BOD at various sampling stations

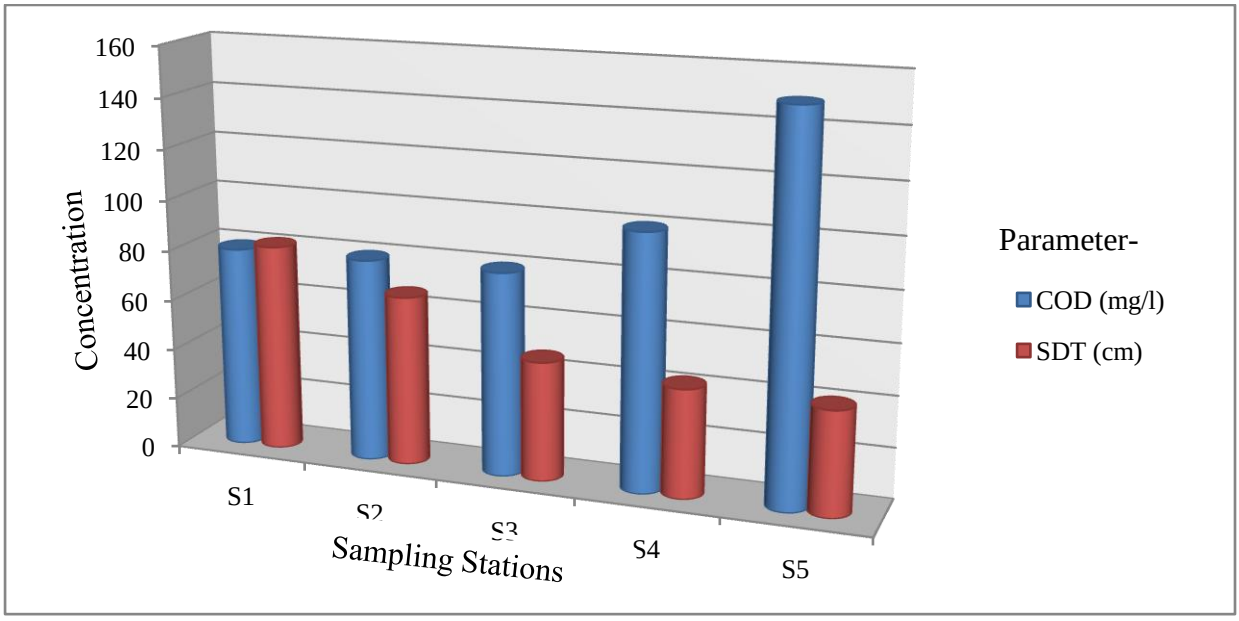


Fig. 4 Showing concentration of COD&SDT (Secchi Disc Transparency) at various sampling stations

CONCLUSION

Trophic state index of River Mandakini was monitored with the help of various physico-chemical parameters from March, April and May (2016) at various selected sites. It was observed that site S_1 was found in **Oligotrophic** condition and site S_2, S_3, S_4 &S_5 in **Mesotrophic** condition.

BOD was found highest only at S_5(8.64 mg/l). The permissible limit for BOD is 5 mg/.l Remaining four sites were within the permissible limit in term of BOD. Total phosphorus values were higher at all the sampling sites. It was observed that site S_5 was most polluted site& S_1 was least polluted. It may be due to flood plane agriculture and entry of sewage into the river. COD values were observed within the permissible limit at all the sampling site prescribed by various agencies.

Over all study reveals the site S_5 is most polluted & in mesotrophic condition. It is a serious concern for river health. This may create serious problem to river and local people also.

The TSI can be a valuable tool for River management and it is also a valid scientific tool for investigations where an objective standard of trophic state is necessary. This index can serve as a standard of trophic measurement against which comparisons can be made between the many chemical and biological components of river that are related to trophic status. The

result could give more complete and dynamic picture of how these components are related to one another and with trophic status.

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