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Water Quality Assessment of River Kuwano, Basti (U.P.), using WQI and Pollution Indices

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ABSTRACT

The samples were analysed for physico-chemical and microbiological quality in order to ascertain the quality of river water for public use. There are several ways to access the suitability of water for drinking, irrigation and industrial use. The Water quality Index (WQI) along with Organic Pollution Index (OPI) and Comprehensive Pollution Index(CPI) provide a complete picture of water quality in term of index number. In the study WQI, OPI and CPI was determined on the basis of several physico-chemical parameters i.e., pH, TDS, EC, DO, BOD, COD, Total Hardness, Ammonia, Nitrate, Nitrite, Phosphate, Ca, Mg, Fe, *E. coli*, Fecal Coliform and Total Coliform.

Key words *: River Kuwano, Water quality Index (WQI), Organic Pollution Index (OPI), Comprehensive Pollution Index (CPI).*

Introduction

Water is the most valuable, natural asset, significant for human endurance. Because of its free occurrence in nature, is often taken for granted and abused, especially in third world nations where information is neither readily accessible, nor disseminated to society (Longe and Balogun, 2010). The total water on earth is assessed to be 1.4 x 109 km^3 of which 97. 4% is ocean water and 2.6 % is fresh water. Of the fresh water 4/5 is in ice covers and ice sheets and around 1/5 is somewhat ground water. Under 1% of fresh water (0. 014% of total) is found in lakes, soils, streams, biota and the environment. Water is mostly utilized for drinking, irrigation, and transportation, washing and garbage removal form production houses and utilized as a coolant for nuclear energy stations (Singh and Shrivastava, 2015).

Ground and surface water quality can be affected by three different forms of pollution all over the world viz. chemical, biological and physical pollution. These polluting factors can influence natural environment and human health (Ersoy *et al*., 2007). Globally, contaminated drinking water is the chief source of chronic human intoxication (Gebel, 2000; Smith *et al*., 2000). The WHO reports that approximately 36% of urban and 65% of rural Indian's were without access to safe drinking water (WHO, 2009) and has estimated that up to 80% of all sickness and disease in the world is caused by inadequate sanitation; pollution or unavailability of water(WHO, 1997).

Rivers are the most important water resources. They have been misused since long time for releasing the litters. Pollution in river system imposes environmental threat and degradation such as decreased quality of fish harvest and degraded water quality for aquaculture ponds (Pleto *et al*., 2020). Anthropogenic activities along with Agro-industrial wastes boost the pollution level of river waters

(Yadav, 2014). Contamination primarily influences physico-chemical quality of the stream and finally the sensitive food wab. Therefore, it has become essential to assess the changes in water quality of a water body to identify the pollutants and to maintain the ecological health and restore the carrying capacity of the water body (Al-Saboonchi *et al*., 2016)).

River Kuwano, is the life line of Basti District (U.P.). There are dozens of small-scale industries including the manufacturing units of brassware, iron and carpentry goods, agricultural implements, bricks, agro-products, foot-wear, soaps, candles, industries are situated in vicinity of river. These industries along with three sugar mills discharge their waste directly or indirectly in the river every day. Effluents discharged from Sugar factories contains a number of chemical pollutants, such a carbonate, bicarbonate, nitrite, phosphate, oil and grease in addition to total suspended solids volatile solids and score of other toxicants (Deshmukh, 2014). These pollutants could modify the basic properties of water like temperature, humidity, oxygen supply, hardness, etc., and leads to a partial or complete alteration in the physical, chemical and physiological spheres of the biota (Verma and Shukla, 1969). When the untreated effluents are discharged into the environment, they deteriorate the water quality and disrupt the ecosystem (Behera and Mishra, 1985). Therefore, it is imperative to find out some pollution monitoring tools for water body (Chougule *et al*., 2009; Paralkar *et al.*, 2021).

In the last few decades, various methodological research papers ware published in order to assess the water quality of water bodylike NSF WQI (Kumar *et al.*, 2014; Shivalli and Giriyappanavar, 2015; Bharti and Gupta, 2019), Water Quality Index of Central Pollution Control Board (Sarkar and Abbasi, 2006; Sivaranjani *et al*., 2015), comprehensive pollution index (CPI) (Guo, 2006; Imneisi and Aydin, 2018: Matta *et al*. 2018), Overall Index of Pollution (Sargaonkar and Deshpande, 2003; Ismail, 2014), Eutrophication index (EI) (Karydis *et al*., 1983; Liu *et al*., 2011), organic pollution index (OPI) (Quan *et al*., 2005; Al-Saboonchi *et al*., 2016; Azhar and Makia, 2020), etc. based on the water quality parameters. The water quality index (WQI) has been used by many scholars for quality assessment of waters (Hameed *et al.*, 2010; Parmar and Parmar, 2010; Umamaheswari, 2016; Tripsthi and Singal, 2019; Deoli and Naun, 2021; Pali and Chandrakar, 2021).

The present study primarily aimed to establish the river water quality, with the application of WQI, and pollution Indices and ascertain best use of river water for various purposes. The study also aimed to find out suitability of use of WQI, and pollution Index together to monitor pollution in waters.

Materials and Methods

The study Area

The river Kuwano begins from Bahriach District of U.P. It passes through Gonda and Siddharth Nagar district before entering in Basti District near Chandhokha village of Ramnager block. In the district, Kuwano flows through north-west to south-east and is fed by its tributaries Bisuni, Manvar and Kathinaya. Before draining through, near Banpur in Kudaraha block, it travels over a length of approx. 55 kms within district boundaries (Fig. 1). In Gorakhpur district it merges in Ghaghara near Shahpur village.

Study method

The water samples from the selected locations: Upstream Bandhuwa village (26º 812 N and 82º 692 E), Midstream in Amhut (26º 772 N and 82º 712 E) and Downstream in Lalganj (26º 652 N and 82º 822 E) were collected (Fig. 1) in replicate. The sample ware collected in the Monsoon (September) and summer (May). The river water samples from different sampling stations were collected in duplicate in two litre capacity polythene containers pre-washed with dilute Hydrochloric acid, detergent, tap water & distilled water. Sampling was carried out manually

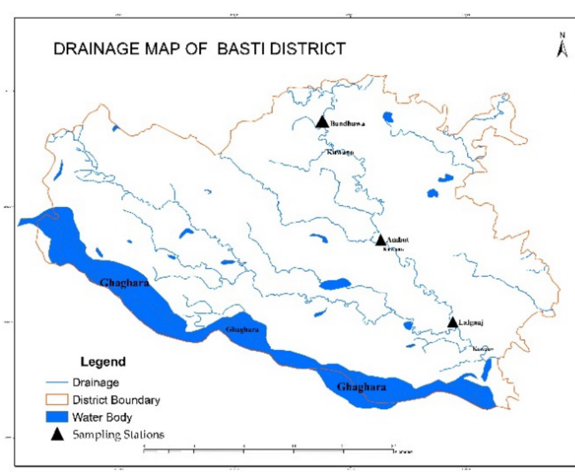

Fig. 1. Sampling location map of the study area.

without adding any preservative, after flushing out at least 2 to 3 minutes. Samples were brought immediately to the laboratory and kept in the refrigerator for further analysis.

The collected water samples were used for analysis of seventeen important parameters. The parameters studied were, pH, TDS, EC, DO, BOD, COD, Total Hardness, Ammonia, Nitrate, Nitrite, Phosphate total, Ca, Mg, Fe, E. Coli, Fecal Coliform and Total Coliform (Table 1 and 2). The pH, Temperature, TDS and EC were analysed on the spot by Digital portable meters, the remaining parameters were analysed in the laboratory within twenty-four hours of sample collection.

Water quality index (WQI)

Water quality index was calculated from mean values of parameters for Monsoon and Summer. The WQI has been calculated by using the standards of water quality recommended by the Central Pollution Control Board (1979) and Bureau of Indian

Table 2. Means of selected physico-chemical and bacteriological parameters in dry and rainy season.

S. No.	Variable	Rainy Season (September 2020) (Mean±SD)	Dry Season (May 2021) (Mean±SD)
1.	pH	7.7±0.04	6.5±0.30
2.	TDS	98.3±12.34	60.3±5.51
3.	EC	176.0±8.66	110.0±2.00
4.	DO	4.0±0.20	3.4±0.49
5.	BOD	1.1±0.23	1.7±0.12
6.	COD	3.3±0.23	2.8±0.35
7.	Total Hardness	87.0±2.65	77.0±1.00
8.	Ammonia	0.04±0.01	0.3±0.05
9.	Nitrate	0.4±0.21	0.6±0.13
10.	Nitrite	0.3±0.21	0.5±0.16
11.	Phosphate total	0.3±0.03	0.3±0.02
12.	Ca	12.7±0.12	16.7±0.56
13.	Mg	18.1±0.62	14.7±0.12
14.	Fe	1.5±0.24	0.3±0.09
15.	*E. Coli*	135.0±86.13	111.3±36.02
16.	Fecal Coliform	335.3±113.55	278.0±40.84
17.	Total Coliform	397.3±65.03	341.3±72.34

Table 1. River water parameters used in the study

S.No	Parameters	Symbols	Unit	Analytical Method	Instrument/ Apparatus
1.	pH	pH	-	-	IonixpH meter
2.	Toral Dissolved Solid	TDS	mg/l	-	Ionix TDS meter
3.	Electrical Conductivity	EC	ìS/cm	- Conductivity Tester	HM Digital AP-2
4.	Dissolved Oxygen	DO	mg/l	Azide Modification*	-
5.	Biochemical Oxygen Demand	BOD	mg/l	5-Day BOD Test*	-
6.	Chemical Oxygen Demand	COD	mg/l	Closed Reflux, Colorimetric Method*	Aimil Spectrochem NV-201 (Model No 022000 SPL)
7.	Total Hardness	-	mg/l	EDTA Titrimetric Method*	-
8	Ammonia	NH4z	mg/l	Colorimetric method⁺	Aimil Spectrochem NV-201 (Model No 022000 SPL)
9	Nitrate	$NO3^-$	mg/l	Brucin Method⁺	Aimil Spectrochem NV-201 (Model No 022000 SPL)
10	Nitrite	$NO2^-$	mg/l	Sulphanilic Acid Method⁺	Aimil Spectrochem NV-201 (Model No 022000 SPL)
11	Phosphate (Total)	$PO4^{3-}$	mg/L	Ascorbic acid Method*	Aimil Spectrochem NV-201 (Model No 022000 SPL)
12	Calcium	Ca	mg/l	EDTA Titrimetric Method*	-
13	Magnesium	Mg	mg/l	Calculation Method*	-
14	Iron	Fe	mg/l	Phenanthroline Method*	Aimil Spectrochem NV-201 (Model No 022000 SPL)
15	*E. Coli*	-	MPN/100ml	MPN of coliform⁺	-
16	Fecal Coliform	-	MPN/100ml	MPN method for faecal coliform⁺	-
17	Total Coliform	-	MPN/100ml	MPN of coliform⁺	-

⁺Trivedy & Goel (1984) *APHA. (2005)

Standards (1993 and IS10500:2012). The weighted arithmetic index method (Yogendra and Puttaiah, 2008) has been used for the calculation of WQI of the river water. Further, quality rating or sub index (qn) was calculated using following expression.

$$qn = 100\,\frac{[Vn - Vi0]}{[Sn - Vi0]}$$

(Let there be n quality parameters and quality rating or sub index (qn) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the ground water with respect to its standard permissible value.)

qn = Quality rating for the n^{th} Water quality parameter.

Vn = Estimated value of the n^{th} parameter at a given sampling station.

Sn = Standard permissible value of the n^{th} parameter.

Vio = Ideal value of n^{th} parameter in pure water.

(Vio = 0 for all parameters except the parameter pH and Dissolved Oxygen i.e., 7.0 and 14 mg/L respectively) (Table 3).

Unit weight was calculated by a value inversely proportional to the recommended standard value Sn of the corresponding parameter.

Wn =K / Sn

Wn = unit weight for the n^{th} parameters.

Sn = Standard value for n^{th} parameters.

K = Constant for proportionality.

The overall Water Quality Index was calculated by aggregating the quality rating with the unit weight linearly.

$$WQI = \frac{\sum qn \times Wn}{\sum Wn}$$

Comprehensive pollution index (CPI)

The CPI is used to access the level of pollution in a specic waterbody by using monitoring statistics (Liu and Zhu, 1999). The formula to calculate CPI is presented as follows:

$$CPI = \frac{1}{n}\sum_{i=I}^{n} Pli$$

where CPI = Comprehensive Pollution Index; n = number of monitoring parameters; P*li* = the pollution index number*i*. P*li* is calculated according to the

Table 3. Water standards and unit weight

S. No.	Parameters	Unit	Required/ ideal value	Unit weight	Desirable/ Permissible limit	Standard
1.	pH		7.0	0.07	6.5-8.5	IS 10500 : 2012
2.	TDS	mg/l	0	0.07	500	IS 10500 : 2012
3.	EC	µS/cm	0	0.03	1000	CPCB (1979) and the BIS (1982)
4.	DO	mg/l	6	0.08	Min 5	CPCB (1979) and the BIS (1982)
5.	BOD	mg/l	0	0.07	Max 3	CPCB (1979) and the BIS (1982)
6.	COD	mg/l	0	0.07	Max 250	-
7.	Total Hardness	mg/l	0	0.03	200-600	IS 10500 : 2012
8	Ammonia	mg/l	0	0.03	0.5	IS 10500 : 2012
9	Nitrate	mg/l	0	0.03	20	CPCB (1979) and the BIS (1982)
10	Nitrite	mg/l	0	0.07	1.0	IS 10500 : 1991
11	Phosphate total	mg/l	0	0.07	10-50	IS 10500 : 1991
12	Ca	mg/l	0	0.03	75-200	IS 10500 : 2012
13	Mg	mg/l	0	0.03	30-100	BIS 10500: 1993
14	Fe	mg/l	0	0.07	0.3	IS 10500 : 2012
15	*E. Coli*		not detectable/ 100 ml sample	0.08	50	CPCB (1979) and the BIS (1982)
16	Fecal Coliform		not detectable/ 100 ml sample	0.08	50	CPCB (1979) and the BIS (1982)
17	Total Coliform		not detectable/ 100 ml sample	0.08	500	CPCB (1979) and the BIS, (1982)

Table 4. Water quality index

Season	Upstream	Mid-stream	Down stream	(Mean ± SD)
Dry Season	204.07	231.7	224.14	219.97±11.65
Rainy Season	254.85	304.78	274.64	278.11±20.52

following equation:

$$Pli = \frac{Ci}{Si}$$

where Ci = measured concentration of parameter number in water; Si= permitted limitation of parameter number according to environmental standard. In the study, 17 water parameters: pH, TDS, EC, DO, BOD, COD, Total Hardness, Ammonia, Nitrate, Nitrite, Phosphate total, Ca, Mg, Fe, E. Coli, Fecal Coliform and Total Coliform was used to calculate CPI.

Organic pollution index (OPI)

OPI is used to evaluate the pollution level of a waterbody (Liu and Zhu, 1999) based on four parameters: Chemical Oxygen Demond (COD), Dissolved Oxygen (DO), concentration of dissolved inorganic nitrogen (DIN), and dissolved total phosphate (DTP). The organic pollution index (OPI) is calculated by the following equation:

$$OPI = \frac{COD}{CODs} + \frac{DIN}{DINs} + \frac{DTP}{DTPs} + \frac{DO}{DOs}$$

where, according to the environmental standard, CODs, DOs, DINs and DTPs are the limited concentrations of COD and DO; DINs is total limited concentration of nitrate, nitrite and ammonium; and DIPs is the limited concentration of phosphate.

OPI is classied into four categories: excellent (OPI <0); good (OPI 0–1); polluted (1–4), extremely polluted (4–5).

Results

In general, mean values of various parameters studied were found under permissible limit (Table 2), except dissolved oxygen and microbiological one. The amount of oxygen in water, shows its overall health. That is, higher oxygen levels suppose that pollution levels in the water are low. The presence of coliforms in water is an indicator of contamination by human or from animal excrement.

WQI depicts the composite influence of different water quality parameters and communicates water quality information to the public and legislative decision makers (Tyagi and Sharma, 2013). The water quality Index of river Kuwano varied from 204.07 to 231.7 from upstream to downstream with a mean of 219.97±11.65 in dry season, while in rainy season the variation was 254.85 to 304.78 with an average of 278.11±20.52. It is observed that WQI was higher than the safe value at all the three sampling stations in both seasons (Table 4 and 5).

Comprehensive pollution index, is a tool for evaluating surface water quality based on single factor water quality identification index (Qun *et al.*,

Table 5. Water quality index (WQI) and status of water quality (Chaterjee and Raziuddin, 2002; Ramakrishnaiah *et al.*, 2009).

S. No.	Water quality Index Level	Water Quality Status	
1	0 – 25	Excellent water quality	Water quality is protected with virtual absence of threat or impairment; conditions very close to natural or desirable levels
2	26 – 50	Good water quality	Water quality is protected with only minor degree of threat or impairment; conditions depart from natural or desirable levels
3	51 – 75	Poor water quality	Water quality is usually protected but occasionally threat ened or impaired; conditions sometimes depart from natural or desirable levels
4	76 -100	Very Poor water quality	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
5	100 - 150	Unsuitable For drinking	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels, only used for irrigation
6	151 - 300	Slightly polluted	Can be used for Irrigation and Recreational Purpose
7	301 - 450	Moderately Polluted	Can be used for Irrigation with some treatment
8	> 450	Severely Polluted	Not Suitable

Table 6. Organic pollution index (OPI) and comprehensive pollution index (CPI).

	Rainy Season (September 2020)	Dry Season (May 2021)	(Mean ± SD)
Organic Pollution Index (OPI)	4.01	3.89	3.95±0.06
Comprehensive Pollution Index (CPI)	0.50	0.48	0.49±0.01

Table 7. Comprehensive pollution index (CPI) and status of water quality (Liu and Zhu, 1999).

S. No.	Category	CPI score	Water Quality Status
1	Category 1	0 – 0.20	clean
2	Category2	0.21– 0.40	subclean
3	Category3	0.41 – 1.00	slightly polluted
4	Category4	1.01 – 2.00	medium polluted
5	Category5	≤ 2,01	heavily polluted

2009). The comprehensive Pollution Index (CPI) value of River Kuwano was found around 0.49 with a negligible seasonal variation of 0.01. The OPI value in rainy season found high i.e., 4.01 than the summer season i.e., 3.89 (Table 6) with a mean of 3.95±0.06.

Discussion

Lower dissolved oxygen is generally associated with heavy contamination by organic matter. In the present study values of DO fluctuates between 3.4 to 4.0 mg/l. The fluctuation may be due to oxygen demanding wastes (Sharma and Ravichandran, 2021). The presence of fecal coliforms in water indicates a potential public health problem because faecal matter is a source of pathogenic bacteria and viruses (Hosetti and Kumar, 2002). The indiscriminate disposal of domestic waste, improper disposal of solid waste, leaching of wastewater from landfill areas, further aggravate the chances of bacterial contamination of river water.

The result of present investigation clearly indicate that Kuwano river water is not suitable for domestic usage, bathing and recreational purpose according to WQI's classification (Table 5). Midstream higher value of WQI indicating higher input of sewage from nearby municipal area (City) and accumulation of pollutants (Suthar *et al*., 2009; Pleto *et al*., 2020). The seasonal variation in WQI reflects that quality of water was comparatively better in summer season to the rainy season. The results confirm that the WQI could be used effectively for quality assessment of water (Budhlani, 2015).

The mean value of OPI for river water was recorded (3.95) and classified as organically polluted. This may be due to direct sewage discharge in to river without proper treatment (Azhar and Makia, 2020). The CPI can indicate whether a water is heavily polluted or not, but it cannot identify the specific pollutant that is mostly affecting the body of water (Imneisi and Aydin, 2018). In the study comprehensive pollution index (CPI) score (0.49±0.01) corresponds to pollution level 1-4 of the OPI classification (Table 7). Which categorized river water as slightly polluted.

The river water quality is severely threatened. The water quality of river fails to meet standard for domestic use (CPCB 1979, BIS 1993 and IS10500:2012), and qualifies the standards to use water only for irrigation purpose. The WQI, CPI and OPI were successfully applied (Son *et al.*, 2020) to assess the overall water quality assessment of Kuwano river. Gupta *et al.* (2003) had compared various water quality indices for costal water. Deteriorating quality of the river systems is directly linked to the inadequacy of the existing sewage systems in Basti municipal area and untreated wastewater discharged from domestic, agricultural runoff, commercial and industrial sources. The finding will provide baseline data for framing suitable remedial plan by the competent authorities.

References

Al-Saboonchi, A. A., Maki, A. and Hassan, J. K. 2016. Using organic pollution index (OPI) to evaluate the water quality of east hammar marsh, Iraq. *Journal of International Academic Research for Multidisciplinary*. 4(7): 185-191.

APHA, 2005. *Standard Methods for the Examination of Water and Wastewater*, 21st ed.; American Public Health Association: Washington, DC, USA.

Azhar, A. A. and Makia, M. A. 2020. Application of organic pollution index (OPI) to assess the water quality of Al-Chibayish marsh, southern Iraq. *Marsh Bulletin.* 15(1): 57–64.

Behera, B.K. and Mishra, B.N. 1985. The effect on sugar mill effluent on enzyme activities of rice seedlings.

Industrial Research. 37: 390-398.

Bharti, S. and Gupta, A. K. 2019. A Comparative study of water quality of river Yamuna using fuzzy logic and NSF WQI. *International Journal of Engineering Development and Research*. 7(2): 249-252.

Budhlani, G. N. 2015. Determination of water quality index (WQI) and suitability of holy wardha river water (Kaundyanapur) from Amravati District, Maharashtra, India. *Microbiology*. 5(11): 477-479.

Chaterjee, A.A. and Raziuddin, M. 2002. Determination of water quality index (WQI) of a degraded river in Asanol industrial area, Raniganj, Burdwan, West Bangal. *Nature, Envirion. & Pollu. Technology*. 1(2): 181-189.

Chougule, M.B., Wasif, A.I. and Naik V.R. 2009. Assessment of water quality index (WQI) for monitoring pollution of river Panchganga at Ichalkaranji. *Proceedings of International Conference on Energy and Environment*. March 19-21 In Environenergy : 122-127.

Deoli, V. and Naun, S. 2021. Groundwater quality analysis using WQI for Sahibabad (Uttar Pradesh). *Indian Journal of Ecology*. 48(1): 52-54.

Deshmukh, K.K. 2014. Environmental impact of sugar mill effluent on the quality of groundwater from Sangamner, Ahmednagar, Maharashtra, India. *Research Journal of Recent Sciences.* 3: 385-392.

Ersoy, A.F., Ersoy, H. and Gultekin, F. 2007. Nitrate, nitrite and ammonia contamination in ground water: A case study from Gumuphacykoy Plain, Turkey. *Asian J. of Water, Environment & Pollution*. 4: 107-118.

Gebel, T. 2000. Confounding variables in the environmental toxicology of Arsenic. *Toxicology.* 144 : 155-162.

Guo, M.M. 2006. Application of mark index method in water quality assessment of river. *Environmental Science and Management.* 31(7): 175–178.

Gupta, A. K., Gupta, S. K. and Rashim, S. P. 2003. A comparison of water quality indices for coastal water. *J. Environ. Sci. Health, Part A.* 38(11) : 2711-2725.

Hameed, M. A., Alobaidy, J., Abid, H. S. and Maulood, B. K. 2010. Application of water quality index for assessment of Dokan lake ecosystem, Kurdistan region, Iraq. *Journal of Water Resource and Protection*. 2(9): 792-798.

Hosetti, B. B. and Kumar, A. 2002. *A Textbook of Applied Aquatic Biology*. Daya Publishing House, Delhi. pp. 35.

Imneisi, I. and Aydin, M. 2018. Water quality assessment for Elmali stream and Karaçomak stream using the comprehensive pollution index (CPI) in Karaçomak Watershed, Kastamonu, Turkey. *Fresenius Environmental Bulletin.* 27(10): 7031-7038.

Ismail, A. H. 2014. Applicability of overall index of pollution (OIP) for surface water quality in assessment of Tigris riverquality within Baghdad. *Eng. & Tech. Journal*. 32(1): 74-90.

Karydis, M., Ignatiades, L. and Moschopoulou, N. 1983. An index associated with nutrient eutrophication in the marine environment *Estuarine, Coastal and Shelf Science*. 16: 339-344.

Kumar, A., Sharma, M.P. and Yadav, N. S.2014. Assessment of water quality changes at two locations of Chambal River. *J. Mater. Environ. Sci*. 5(6): 1781-1785.

Liu, S. and Zhu, J. P. 1999. Comparison of several methods of environment quality evaluation using complex indices. *Environ. Monit.* 15: 33–37.

Liu, S., Lou, S., Kuang, C., Huang, W., Chen W., Zhang, J. and Zhong, G. 2011. Water quality assessment by pollution-index method in the coastal waters of Hebei Province in western Bohai Sea, China. *Mar. Pollut. Bull.* 62(10): 2220-2229.

Longe, E.O. and Balogun, M.R. 2010. Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. *Res. J. Appl. Sci. Eng. Technol.* 2(1) : 39-44.

Matta, G. 2018. Comparative study on seasonal variation in hydro-chemical parameters of Ganga River water using comprehensive pollution index (CPI) at Rishikesh (Uttarakhand) India. *Desalination and Water Treatment*. 118 : 87–95.

Pali, R. J. and Chandrakar, T. 2021. Assessment of seasonal variation in irrigation water quality of Indravati River in Bastar District of Chhattisgarh. *Int. J. Curr. Microbiol. App. Sci.* 10(02) : 757-762.

Paralkar, S. M. 2021. Surface water quality analysis of Panchaganga river. *International Research Journal of Engineering and Technology (IRJET)*. 8(4) : 2712-2715.

Parmar, K. and Parmar, V. 2010. Evaluation of water quality index for drinking purposes of river Subernarekha in Singhbhum District. *International J. Envi. Sci*. 1(1): 77-81.

Pleto, J. V. R., Migo, V. P. and Arboleda, M. D. M. 2020. Preliminary water and sediment quality assessment of the Meycauayan River Segment of the Marilao-Meycauayan-Obando river system in Bulacan, Philippines. *Journal of Health and Pollution*. 10(26): 1-9.

Quan, W., Shen,M. X. Q., Han, J. D. and Chen, Y. Q. 2005. Analysis and assessment on eutrophication status and developing trend in Changjiang estuary and adjacent East China Sea. *Mar. Environ. Sci.* 24 : 13–16.

Qun, M., Ying, G., Zhiqiang, L. and Xiaohui, T. 2009. Application of comprehensive water quality identification index in water quality assessment of river. *WRI Global Congress on Intelligent Systems*. 166 : 333-337.

Ramakrishnaiah, C.R., Sadashivaiah, C. and Ranganna, G. 2009. Assessment of water quality Index for the ground water in Tamkur Taluk, Karnataka State; India. *E. J. of Chem*. 6(2) : 523-530.

Sargaonkar, A. and Deshpande, V. 2003. Development of an overall index of pollution for surface water based on a general classification scheme in Indian context. *Environ. Monit. Assess*. 89(1) : 43- 67.

Sarkar, C. and Abbasi, S. A. 2006. Qualidex-A new software for generating water quality indices. *Environ. Monit. and Assess*. 119(1): 201-231.

Sharma, R. T. and Ravichandran, C. 2021. Appraisal of seasonal variations in water quality of river Cauvery using multivariate analysis. *Water Science*. 35(1) : 49–62.

Shivalli, P.B. and Giriyappanavar, B.S. 2015. Application of NSF-WQI for the assessment of water quality of two temple tanks of Karnataka, India. *J. Inte. Acad. Res. for Multidisciplinary.* 3(2) : 221-226.

Singh, P. K. and Shrivastava, P. 2015. Analysis of water quality of river Narmada. *Int.J.Curr. Res.* 7(12): 24073-24076.

Sivaranjani, S., Rakshit, A. and Singh, S. 2015. Water quality assessment with water quality indices. *Int. J. Bioresource Sci.* 2(2) : 85-94.

Smith, A. H., Lingas, E.O. and Rahman, M. 2000. Contamination of drinking water by arsenic in Bangladesh: A public health emergency. *Bulletin World Health Org.* 83: 177-186.

Son, C. T. 2020. Assessment of Cauriver water quality assessment using a combination of water quality and pollution indices. *J. Water Supply: Research and Technology-AQUA*. 2 : 160-172.

Suthar, S., Sharma, J., Chabukdhara, M. and Nema, A. K. 2009. Water quality assessment of river Hindon at Ghaziabad, India: Impact of industrial and urban wastewater. *Enviro. Moni. and Assessment.* 165(1-4) : 103-112.

Tripsthi, M. and Singal, S. K. 2019. Use of principal component analysis for parameter selection for development of a novel water quality index: A case study of river Ganga India. *Ecol. Indic.* 96 : 430-443.

Trivedy, R. K. and Goel, P. K. 1984. *Chemical and Biological Methods for Water Pollution Studies*. Environmental Publications, Karad, (India).

Tyagi, S. and Sharma, B. 2013. Water quality assessment in terms of water quality index. *American J. of Water Resources*. 1(3) : 34-38.

Umamaheswari, S. 2016. CCME water quality index in river Cauvery Basin at Talakadu, South India. *Intern. J. of Plant, Animal and Environ. Sci.* 6(1) : 148-151.

Verma, S.R. and Shukla, G.R. 1969. Pollution in a perennial stream 'Khala' the sugar factory effluent near lakes. *Env. Health*. 11 : 145-162.

WHO. 1997. *World Health Forum Bulletin, the ten biggest killers in the world*. World Health Organization. Pp: 18.

WHO. 2009. *World Health Statistics, World Health Organization 2009*, World Health Organization, 20 Avenue Appia, 1211 Geneva 27, Switzerland.

Yadav, N.S., Sharma, M.P. and Kumar, A. 2014. Ecological health assessment of Chambal River using water quality parameters. *J. Integr. Sci. Technol*. 2 : 52-56.

Yogendra, K. and Puttaiah, E.T. 2008. Determination of water quality index and suitability of an urban water body in Shimoga town, Karnataka. *Proceedings of Taal 2007: The 12th World Lake Conference*. 342-346.