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RESEARCH ARTICLE

WATER QUALITY INDEX FOR SURFACE WATER QUALITY ASSESSMENT: TAPI RIVER, GUJARAT, INDIA

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Abstract

Tapi river is one of large rivers of India which water quality is affected by natural and anthropogenic influences. Present study provides understanding of the water quality of the river based on water quality index (WQI). From March-2015 to Feb-2016, water samples were monthly collected from three different sites along the river. Ten parameters viz., pH, Temperature(Temp), Dissolved Oxygen (DO), Nitrate (NO₂), Nitrite (NO₃), Ammonia(NH₄), Phosphate (PO₄), Total Coliform (TC), Fecal Coliform (FC) and Fecal Streptococci (FS) were measured to calculate the WQI. The average WQI value at upstream reference site was fell under category of good water quality. Spatial variations in water quality were observed with WQI>100 which indicates poor water quality with suggested disinfection treatments when water abstracted for drinking and domestic use. Present study gives a simple interpretation of the recorded data to help local people understanding the status of River water quality.

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Introduction:-

Water, an essential source for existence of mankind, is one of the most abused and exploited resource. Surface water, the flowing water in form of streams and rivers is the second largest source of freshwater on the earth. Due to industrialization and with the growth of population urban rivers many have been associated with poor water quality and there has been a serious concern of discharging untreated domestic and industrial waste into the water course. Pollutants, when discharged into a river system, change their physical, chemical, and biological characteristics—depleting the dissolved oxygen (DO) and augmenting the organics like carbon, nitrogen, etc. This speeds up the biological activities in in the river (Van der Velde et al., 2006; Kannel et al., 2010; Rusjan et al., 2008). In order to maintain the water quality, it is important to know the levels and characteristics of the pollutant a river can assimilate without impacting its self-purification capacity (Glavan and Pintar, 2010).

The present study intends to assess the water quality in terms of water quality index. WQI is a single number that expresses water quality by aggregating the measurements of water quality parameters such as DO, pH, nitrate etc. It reduces large informational data from the many water quality parameters into a single value and expresses the data in a simplified and logical form (Semiromi et al., 2011). Assessment of water quality could provide us the overall information on the quality of the water bodies and its potential threat to various uses. The application of WQI is a useful method in assessing the water quality of the river. It helps to understand the overall water quality status of individual sampling stations at a time (Yogendra and Puttaiah, 2008) and its suitability for various beneficial uses.

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Water quality is assessed by the following categories of indicators: hydromorphological (water depth, flow, width and level); physical (water temperature, pH, electrical conductivity, transparency, turbidity, temporary, permanent and total hardness); chemical (dissolved oxygen, COD-Mn, COD-Cr, BOD) (Teodosiu et al., 2015), nutrients (nitrogen and phosphorus compounds), metals (Cd, Hg, Zn, Cr, Cu, Ni, As, Ag, Mo, Se, Co), organic and inorganic micropollutants (detergents, pesticides, phenols, cyanides, hydrocarbons); biological (plankton, benthic algae and macrozoobentos); and microbiological (coliforms and streptococci).

Tapi River is the most peculiar and passes through Surat-the Diamond city of Country, famous for world class industries on diamonds, textiles, and chemicals. The stagnant part of the water body is now within the reach of human habitat and accumulates waste load (organic pollutant and nutrients) turning it to be eutrophic. Rivers is exploited to meet people's needs at remote places beyond the river basin. The activities that fall under this unorganized exploitation include washing clothes, cattle farming, religious activities, cremation, recreation, fishing and agriculture. The aim of this research is to develop a water quality index (WQI) for Tapi River based on physicochemical and microbial water quality parameters, to help understand the overall condition of river and impact of such anthropogenic activities in it.

Study Area:

Three sampling stations were selected along the stretch of Tapi river for the collection of surface water samples (Fig.1). Among the sampling stations, Galteshwar was selected as reference site with no urban developments in surrounding. Utran was selected considering disposal of domestic sewage, anthropogenic pollution and thermal power station waste effluent discharge in water channel. Ashwanikumar was the site where river receives domestic sewage as well as cremation ground drainage discharge and ritual activities carry out on the bank. Utran and Ashwanikumar are the sites in the urban city area.

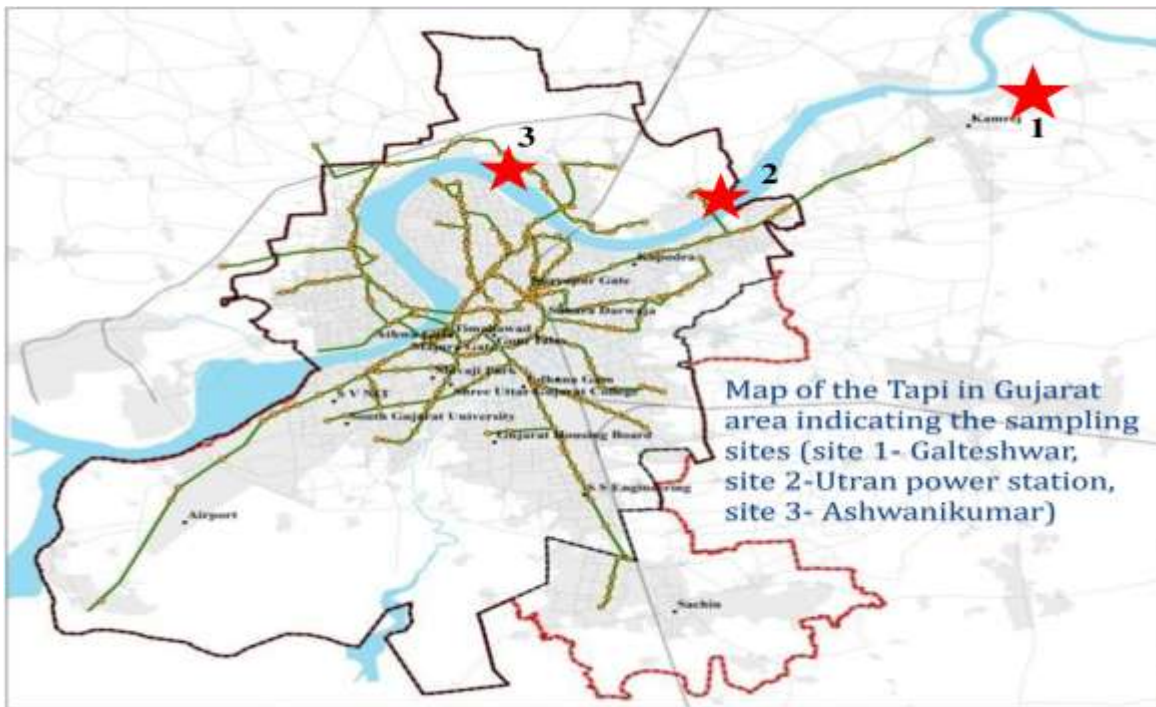


Fig 1:- Map of Tapi River indicating Sampling Sites.

Methodology:-

Surface water samples were collected from three sampling sites along the stretch of Tapi River. Sample collection was done during last week of every month from March-2015 to Feb-2016 for duration of one year. The collected river water and sediment samples were brought to laboratory to carry out the physico-chemical analysis of the constituents.

In this study, ten physico-chemical and microbiological parameters were selected, namely pH, Temperature(Temp), Dissolved Oxygen (DO), Nitrate (NO₂), Nitrite (NO₃), Ammonia(NH₄), Phosphate (PO₄), Total Coliform (TC), Fecal Coliform (FC) and Fecal Streptococci (FS) for generating the overall Water Quality Index (WQI) of Tapi river. . Analysis and collection of samples has been done according to standard methods prescribed by American Public Health Association (1995) and Trivedi and Goel (1986).

Water Quality Index (WQI) was used for evaluating the composite influence of individual water quality parameter on on the overall quality of water. The weighted arithmetic index method ((Ramakrishnaiah et al., 2009, Bhaven et al., 2011 and Srinivasa et al., 2012) was used to calculate the Water Quality Index (WQI).

$$WQI = \frac{\sum QiWi}{\sum Wi} \quad (1)$$

The quality Rating (Qi) scale for each parameter qi was calculated by using the formula as follow

$$Qi = 100[(Vn - Vi)/(Vs - Vi)] \quad (2)$$

Where, Vn is estimated value of parameter in sample, Vi is ideal value in pure water and Vs is recommended standard value of parameter.

The unit weight (Wi) for each water quality parameter is calculated by using the following equation

$$Wi = K/Si \quad (3)$$

Where, K = proportionality constant and can be calculated by using the following equation:

$$K = \frac{1}{\sum 1/Si} \quad (4)$$

The rating of water quality according to this WQI is given in Table 2.

Table 1:- WQI value based water quality classification (Ramakrishnaiah et al., 2009).

Class	WQI value	Water Quality Status
I	<50	Excellent
II	50-100	Good Water
III	100-200	Poor Water
IV	200-300	Very poor water
V	>300	Water unsuitable for drinking

Generally water quality index is discussed for a specific intended use of water. In present study, the WQI for drinking water abstraction from surface water was considered and standard values used in calculation are BIS standards for surface water, and EPA standards (USEPA, 2012) for surface water. The descriptive statistical analyses was carried out using Microsoft office excel 2010. Correlation test was performed by using SPSS-16.0 to estimate the strength of the linear relationship between variables.

Results and Discussion:-

The water quality parameters recorded during study period are depicted in Table-1. pH was recorded neutral to slightly alkaline at all the three sampling sites which are well within the permissible limits given by WHO and BIS. pH in proper range supports the efficiency of chlorine disinfection processes when abstracted for drinking purpose. Temperature of river water was ranged between 17.7°C to 29°C because of seasonal variations with slight variations at different sites. Concentration of Dissolved Oxygen ranged from 6.08 to 12.36 with an average of 7.551 mg/L at Galteshwar, 5.74 to 8.71 with an average of 6.829 mg/L at Utran and 5.47 to 8.31 with an average of 6.520 mg/L at Ashwanikumar. Slow Depletion in DO at downstream sites was observed. The DO level indicates the degree of pollution in the water bodies (Gopalkrushna, 2011).

Nitrate is an undesirable ion in water with detrimental health effects. Values of Nitrate ranged from 0.548 mg/l to 2.766 mg/l with 1.865 mg/l annual average at Galteshwar, 1.612 mg/l to 9.907 mg/l with 4.457 mg/l annual average at Utran and 2.178 mg/l to 7.187 mg/l with 1.865 mg/l annual average at Ashwanikumar. In urban areas sewage water rich in nitrates contaminate surface water thus increases the nitrate amount. Annual average concentration of ammonia was 0.295 mg/l, 0.442 mg/l and 0.532 mg/l at Galteshwar, Utran and Ashwanikumar respectively. Ammonia is very toxic to the biological flora of river even at very low concentrations (Debels et al., 2005). Nitrite content of waters were 0.015 mg/l to 0.042 mg/l, 0.014 mg/l to 0.088 mg/l and 0.022 mg/l to 0.098 mg/l at Galteshwar, Utran and Ashwanikumar with average values 0.024 mg/l, 0.054 mg/l and 0.052 mg/l respectively. Phosphates are not harmful to living organisms until they are present in very high concentration. Phosphate content in the samples was noted in range of 0.005 mg/l to 0.684 mg/l with average 0.170 mg/l at Galteshwar, 0.037 mg/l to 1.680 mg/l with average 0.442 mg/l at Utran and 0.006 mg/l to 1.39 mg/l with average 0.482 mg/l at Ashwanikumar.

During the analysis period, numbers of Total Coliform was recorded in range of 16×10^2 to 43×10^2 CFU/100 ml, 28×10^2 to 63×10^2 CFU/100 ml and 31×10^2 to 76×10^2 CFU/100 ml at Galteshwar, Utran and Ashwanikumar respectively with average values 29.58×10^2 , 50.25×10^2 and 55.08×10^2 CFU/100 ml. Fecal Coliform was recorded in range of 0.7×10^2 to 4.5×10^2 CFU/100 ml, 1.7×10^2 to 5.8×10^2 CFU/100 ml and 1.5×10^2 to 6.1×10^2 CFU/100 ml at Galteshwar, Utran and Ashwanikumar respectively with average values 2.64×10^2 , 4.00×10^2 and 4.26×10^2 CFU/100 ml during investigation. During the study period, Fecal Streptococci was recorded in range of 2.3×10^2 to 5.4×10^2 CFU/100 ml, 0.5×10^2 to 2.8×10^2 CFU/100 ml and 1×10^2 to 4×10^2 CFU/100 ml at Galteshwar, Utran and Ashwanikumar respectively with average values 3.56×10^2 , 1.81×10^2 and 2.2×10^2 CFU/100 ml. Multiple studies have shown that E.coli and Enterococci correlate better with disease outbreak than other classical indicators (Byappanahalli et al., 2012) and regarded as the best candidates to primary and mandatory fecal indicators in river water. (Rodrigues, 2017; Wu et al., 2011; USEPA 2012; Directive 2006/7/EC of 15.02).

Table 2:- Descriptive statistics of water quality parameters.

Parameters	G	U	AK
temp (°C)	17.70 - 28.8 (24.350 ± 0.970)	18.1 - 28.8 (24.733 ± 0.969)	18.2 - 29 (24.783 ± 0.967)
pH	7.20 - 8.43 (7.616 ± 0.125)	7.39 - 8.64 (7.920 ± 0.104)	7.16 - 8.78 (7.907 ± 0.130)
DO (mg/l)	6.08 - 12.36 (7.551 ± 0.473)	5.74 - 8.71 (6.829 ± 0.249)	5.47 - 8.31 (6.520 ± 0.267)
NO3 (mg/l)	0.548 - 2.766 (1.865 ± 0.203)	1.612 - 9.907 (4.457 ± 0.698)	2.178 - 7.187 (5.313 ± 0.573)
NO2 (mg/l)	0.015 - 0.042 (0.024 ± 0.003)	0.014 - 0.088 (0.054 ± 0.007)	0.022 - 0.098 (0.052 ± 0.006)
NH4 (mg/l)	0.009 - 1.302 (0.295 ± 0.111)	0.113 - 1.263 (0.456 ± 0.120)	0.102 - 2.724 (0.532 ± 0.213)
PO4 (mg/l)	0.005 - 0.684 (0.170 ± 0.061)	0.037 - 1.680 (0.442 ± 0.131)	0.006 - 1.39 (0.480 ± 0.148)
TC (CFU/100ml)	1600 - 4300 (2958.333 ± 217.583)	2800 - 6300 (5025.000 ± 350.135)	3100 - 7600 (5508.333 ± 407.591)
FC (CFU/100ml)	70 - 450 (264.167 ± 31.442)	170 - 580 (400.000 ± 38.019)	150 - 610 (426.667 ± 39.530)
FS (CFU/100ml)	230 - 540 (356.667 ± 30.633)	50 - 280 (181.667 ± 18.823)	100 - 400 (220.833 ± 25.863)

G-Galteshwar, U-Utran, AK-Ashwanikumar

Table 3:- Correlation matrix for water quality parameters.

Parameters	Temp	pH	DO	Nitrate	Nitrite	Ammonia	Phosphate	TC	FC	FS
Temp	1									
pH	.170	1								
DO	-.009	-.093	1							
Nitrate	-.010	.451**	-.267	1						
Nitrite	.302	.265	-.178	.516**	1					
Ammonia	-.200	-.179	-.149	.105	.023	1				
Phosphate	.357*	.305	-.343*	.241	.494**	-.124	1			
TC	.443**	.000	-.286	.351*	.616**	.256	.414*	1		
FC	.184	-.311	-.399*	.216	.199	.161	.227	.672**	1	
FS	-.060	-.511**	.057	-.427**	-.409*	.161	-.178	-.222	.093	1

□ p < 0.05, □□ p < 0.01

Correlation:

Pearson linear correlation matrix was generated using water quality analysis results with 10 parameters viz, Temperature, pH, Dissolved Oxygen (DO), Nitrate (NO₂), Nitrite (NO₃), Ammonia (NH₄), Phosphate (PO₄), Total Coliform (TC), Fecal Coliform (FC) and Fecal Streptococci (FS) and values are furnished in Table 3. The obtained results show strong positive correlation of TC with Nitrite and FC, moderate positive correlation of PO₄ with pH, NO₂, NO₃ and TC, TC with Temp and NO₃ as well as pH with NO₃. Moderate negative correlation was observed between DO with PO₄ and FC, FS with pH, NO₂ and NO₃. All other parameters show weak correlation among them.

Water Quality Index:

Water Quality Index allows for a general analysis of water quality on many levels that affect a stream's ability to host life and whether the overall quality of water bodies poses a potential threat to various uses of water (Akkaraboyina and Raju, 2012). From Table: 4, the WQI of G, U and AK were 89.271, 145.616 and 167.524 respectively. Comparing these values to WQI based classification, it is noted that water at G was of good quality whereas at U and AK the water quality was deteriorated and laid under class III that shows poor water quality. G is the location with least human interference and as river flows down through the urban areas, water quality deteriorates and pollution increases at U and AK.

WQI values at Utran and Ashwanikumar show poor water quality, and this may be due to various natural phenomena and anthropogenic activities occurring along the river. Such observation was also made by Bora and Goswami (2017) in their studies of water quality assessment of Kolong River, Assam, where the water samples showed a decreasing pollution trend further downstream. Ewaid (2017) have observed better water quality status in upstream than downstream due to a decrease in water and accumulation of contaminants along the downstream of the river. Other researchers like Othman et al. (2012) and Naubi et al. (2016) have shown differing results in the improvement of water quality at downstream because of proper management policy and remedial measures. The WQI values obtained suggests that untreated water from the river is of low quality and must be treated well before use to minimize water-related illnesses (Ewaid and Abed, 2017). Furthermore, proper management plans can lower the deterioration and help improving overall water quality.

Table 4:- Water quality parameters and Water Quality Index at three different sites along the stretch of Tapi.

Parameters	Annual Average (Vi)			ideal value	Std. value	Wi	Qi			Wi* Qi			
	G	U	AK				Vo	Si	G	U	AK	G	U
Temp	24.35	24.73	224.78	0.0	30.0	0.0333	0.00356	81.167	82.444	82.611	0.289	0.294	0.295
pH	7.616	7.920	7.907	7.0	8.5	0.1176	0.01258	41.056	61.333	60.444	0.517	0.772	0.761
DO	7.551	6.829	6.520	14.6	5.0	0.2000	0.02140	73.432	80.944	84.167	1.571	1.732	1.801
NO ₃	1.865	4.457	5.313	0.0	50.0	0.0200	0.00214	3.729	8.914	10.625	0.008	0.019	0.023
NO ₂	0.024	0.054	0.052	0.0	0.5	2.0000	0.21400	4.767	10.867	10.483	1.020	2.325	2.243
NH ₄	0.295	0.456	0.532	0.0	0.2	5.0000	0.53500	147.250	228.042	266.083	78.779	122.002	142.355
PO ₄	0.170	0.442	0.480	0.0	0.5	2.0000	0.21400	34.050	88.333	95.900	7.287	18.903	20.523
TC	2958.3	5025.0	5508.3	0.0	5000	0.0002	0.00002	59.167	100.500	110.167	0.001	0.002	0.002
FC	264.1	400.0	426.6	0.0	1000	0.0010	0.00010	26.417	40.000	42.667	0.003	0.004	0.005
FS	356.6	181.6	220.8	0.0	200	0.0050	0.00053	178.333	90.833	110.417	0.095	0.049	0.059
K							9.3438	WQI			89.571	145.975	167.937
0.107							1.003				89.271	145.616	167.524

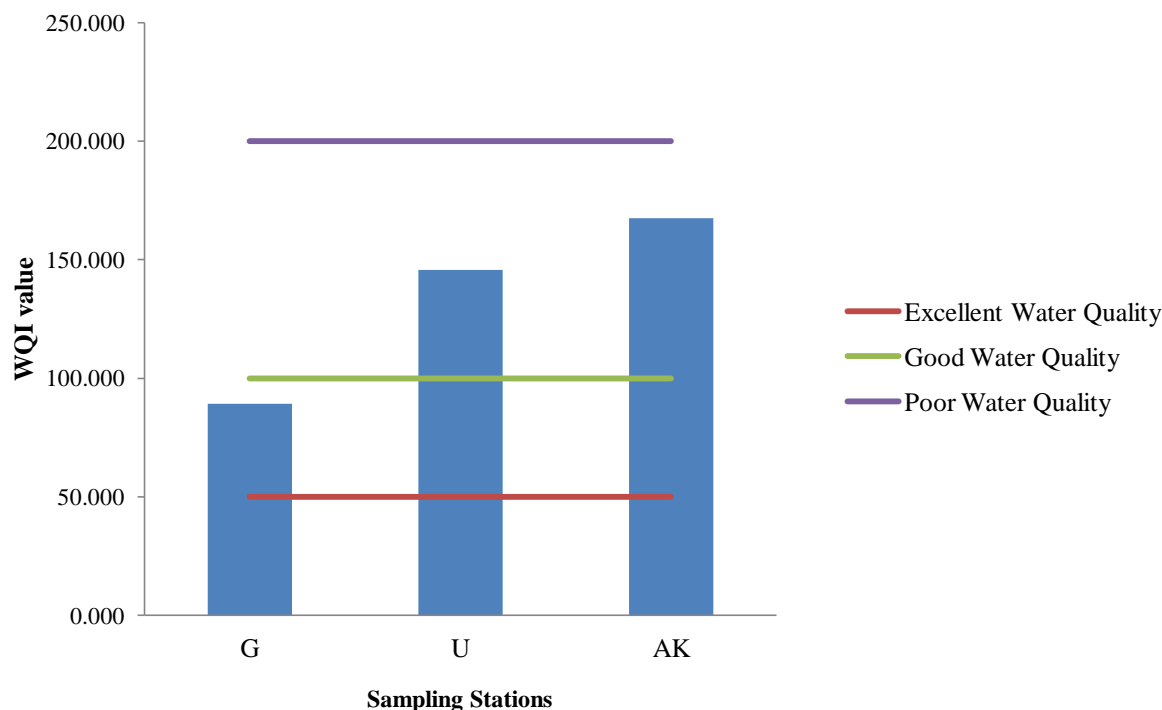


Fig 2:- Graphical representation of variation in WQI at different Sites along the stretch of Tapi

Conclusion:-

In the present study, WQI method was applied to assess the water quality in the river. The results showed that the water quality was good at upstream according to the WQI based classification. Spatial variations were observed as the river flows down with poor water quality at both the downstream due to anthropogenic influences. Additionally, annual variations of nutrients' concentration were observed in river water. The results obtained in this study are acceptable and comparable to those of previous studies Carried out in Tapi River and this consistence suggests the suitability and applicability of WQI for assessment of water quality.

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