

Chapter 20

Assessment of Water Quality Index of Tapi River: A Case Study of Surat City



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Abstract Deteriorating the water quality of river is a major concern in India. This is especially true for river being used as drinking water sources. The water quality of river changes with time and development in the surrounding and upstream area. Therefore, it is necessary to determine the various water quality parameters of river as its presence and amount reflect in water treatment plants and in the surrounding areas which are dependent on river water only. One such river considered in the study is the Tapi river near Surat, Gujarat. The aim of the study is to determine the status of water quality in the Tapi river throughout the year. Surat city is dependent on the Tapi river for its drinking water needs. There are several intake structures constructed to take-off the raw river water. Our study area contains five intake structures from Valak to Rander on Tapi river from where water samples were collected. For assessment of WQI of Tapi river twelve physico-chemical parameters of river water were used. WQI is determined for monsoon, post-monsoon and pre-monsoon from the assessed water quality parameters of the Tapi river. The overall trend of results shows that the river water quality is very poor at stations Valak, Mota Varachha and Rander, while the water quality is poor at stations Sarthana and Katargam. The study indicates that water quality is continuously degrading from monsoon to post-monsoon and from post-monsoon to pre-monsoon which makes it unsuitable for drinking and fish culture.

Keywords Water quality index · Physico-chemical parameters · Drinking water · Surat city · Tapi river

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20.1 Introduction

Urbanization, industrial development, various agriculture and other activities of humans have increased the pollution of surface water & groundwater. In India, 70% of water quality has been infected due to contaminants. As safe & potable drinking water is needed, various treatment methods are adopted to raise the quality of drinking water. It ought to be free from different contamination viz. pollutants, dense metals and pesticides etc. And also, the entirety of its parameters like pH, electrical conductivity, calcium, magnesium, total dissolved solids, alkalinity water, sodium, potassium, nitrate, BOD and sulphate do ought to be within the allowable limit. The water quality of river changes with time and development in the surrounding and upstream area. Therefore, it is necessary to determine the various water quality parameters of river as its presence and amount reflect in treatment plants and in the surrounding areas which are dependent on river water only. Due to pollution in the air, water and land, less amount of rainfall is observed in the last few years. In May 2015, water level in the Ukai dam was 95 m & in May 2016, it degraded to 90 m while in 2017 it is observed at 88.26 m. In 2018 March it is lowest at 85 m. Only 12% of water is there in the Ukai dam to total water storage capacity. So due to less amount of water we should worry about existing water quality. If the quality of raw water is degraded it affects human health. Surat is the eighth largest and fourth cleanest city of India. Water source of Surat city is the Tapi river. Most people use water from Tapi river only. The study objective is to determine the WQI by assessing various physio-chemical parameters of Tapi river water in Surat city.

20.2 Study Area

Tapti river is a river in central India between the Godavari and Narmada rivers. Tapi covers a zone of approximately (79% Maharashtra, 15% Madhya Pradesh and 6% Gujarat) states having tributaries on both the banks. Tapi river is divided into fourteen major tributaries. Four on the right bank namely Vanki, Gomai, Arunavati and aner and ten on the left bank. The Tapi basin extends to a total area of 65, 145 sq. km, which is approximately 2.0% of the total geographical area of India. The main tributaries of the Tapi river are Purna and the Girna as shown in Fig. 20.1 respectively.

Second largest stream flows westward over a length of 724 km before draining through the Gulf of Khambhat into the Arabian sea. Large area covers the state of Maharashtra. The river starts from the Betul district of Madhya Pradesh in the Saputara range at an elevation of 752 m above sea level. The Tapi basin is the basin of the Deccan hill and is located amongst 200 n to 220 n approximately. On the west part, the basin finds its channel in the Arabian sea. It is surrounded on all three sides by hill ranges. The Tapi river drains an area of 65,145 sq. Out of which nearly 80 percentile in Maharashtra.



Fig. 20.1 Tapi river path in Surat. Source www.mapofindia.com

The city Surat is located in the southern part of Gujarat $21^{\circ}10''$ and latitude and $72^{\circ}50'$ longitude on the southern bank of river Tapi presently spread over 334.23 km areas Surat head population of 5,877,241 as per census 2010 Surat has been blessed with a flow of river Tapi which fulfils most its water requirement. It flows through the city and the Arabian sea at about 16 km from Surat. Big water resources projects like Ukai dam, Kakrapar weir Mindhola in the south of it. As mentioned earlier Surat has been blessed by the flow of Tapi however, it has also suffered a lot because of floods in the Tapi since historic times.

Surat city is located on the banks of river Tapi. Obstructing of Tapi made the original port facilities to close the nearest port and is presently in the region of Hazira and Magdala. 13 m is the average elevation of Surat city. The climate is tropical and monsoon rainfall is abundant (about 2500 mm per year).

In the present study 5 stations are selected as these are the location of river water intake for Surat city. The sampling locations are Valak, Mota Varachha, Sarthana, Katargam, and Rander as shown in Fig. 20.2 respectively.

20.3 Methodology & Data Collection

The river water was collected near the location of river intake from Valak, Mota Varachha, Sarthana, Katargam & Rander. The overall analysis is done for the year 2017–18 and water samples are taken considering the monsoon, post-monsoon and pre-monsoon. For monsoon season samples were collected in August and September, for post-monsoon season the samples were collected in the month of December and January. While the water samples were collected in March for pre-monsoon analysis. The water samples were taken by bottle sampler and kept in glass bottles away from sunlight to reduce the chances of the change in water quality. The taken

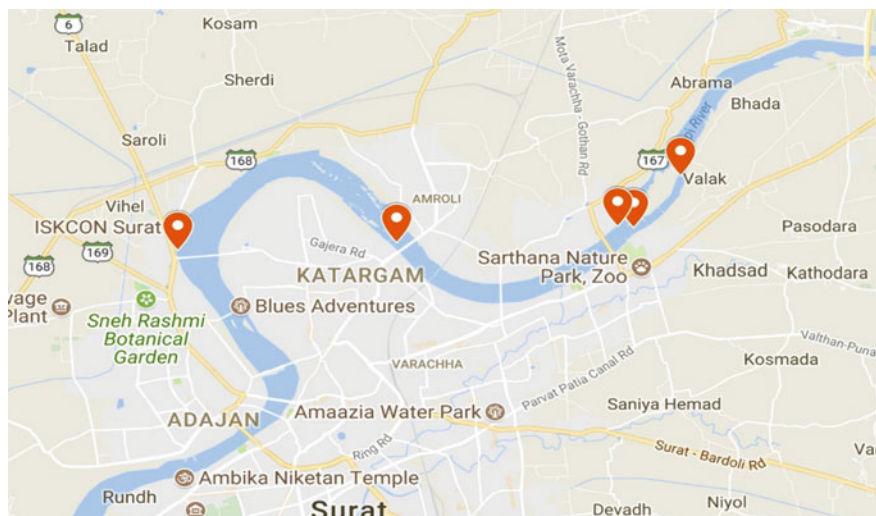


Fig. 20.2 Location of sample station

water samples were then tested for 12 different physico-chemical parameters with the methods which are shown in Table 20.1.

Thus, tested parameters were then used to determine the water quality index of the Tapi river.

WQI is a tremendous organization and general managerial tool in imparting water quality information. In order to calculate the water quality index, the list of data has been verified and useful from a number of different geographical areas all over the

Table 20.1 Test methods for Physio-chemical parameters

Sr. No	Parameters	Test name/equipment	Unit
1	pH	Electro metric method	-
2	Conductivity	Multi-meter	Mohs/cm
3	TDS	Multi-meter	Mg/l
4	Do	Wrinkler method and azide modification	Mg/l
5	BOD	Titrimetric & respirometric method	Mg/l
6	Alkalinity	Standard process	Mg/l
7	Hardness	IS: 3025(p-21): 2009	Mg/l
8	Chloride (Cl^-)	IS: 3025(p-32): 1988	Mg/l
9	Nitrate (NO_3^-)	Apha & awwa.22 nd ed.4500 - NO_3^- -b (4-122)	Mg/l
10	Sulphate (SO_4^-)	Apha & awwa.22 nd ed.4500 SO_4^- -e (4-190)	Mg/l
11	Magnesium (Mg^+)	Apha & awwa.22 nd ed.3500 mg-b (3-84)	Mg/l
12	Calcium (Ca^{+2})	Apha & awwa.22 nd ed.3500 ca-b (3-67)	Mg/l

world of various water bodies critical pollution parameters were considered. Using Delphi techniques or the weighted arithmetic index method WQI has been calculated. With the help of five water quality, the quality rating scale for each parameter [qi] would be calculated.

There are mainly four types of water quality index:

- (a) Nsf-WQI (National sanitation foundation water quality index)
- (b) CCME WQI (Canadian council of ministry of environment water quality index)
- (c) OWQI (organ water quality index)
- (d) WaWQI (weighted arithmetic water quality index).

Using the WaWQI method, the current study deals with the determination of quality using because it has an edge over further approaches for example: in this method numerous water quality parameters are combined into a scientific equation that rates the health of water body through a number called water quality index as well as it describes the suitability of surface and groundwater quality source for human consumption.

Methodology to Calculate Water Quality Index:

Various physio-chemical data with water quality parameters then calculate proportionality constant k value using Eq. 20.1.

$$K = 1 / (1 / \int si) \tag{20.1}$$

where, si = standard permissible for parameter.

For calculating quantity rating for a parameter using Eq. 20.2.

$$Qn = 100((vn - vio)/(sn - vio)) \tag{20.2}$$

where, vn = estimated value of the nth parameter in pure water.

sn = standard permissible value of the n parameter.

The value of sn is taken from the various agencies for given physio-chemical parameters are shown in below mentioned Table 20.2.

Using Eq. 20.3, Calculate the unit weight for nth parameters:

$$Wn = (k/sn) \tag{20.3}$$

Using Eq. 20.4, now Calculate the WQI

$$WQI = ((\int wnqn) / \int wn) \tag{20.4}$$

Thus, the calculated water quality index represents the corresponding grade of quality and status of water quality (Brown et al. 1972) as shown in Table 20.3.

Table 20.2 Recommended standard from various agencies

Sr. No	Parameters	Recommended standard (sn)	Agencies
1	pH	7.5	Icmr/bis
2	Electrical conductivity	300 mohs/cm	Icmr
3	TDS	500 mg/l	Icmr/bis
4	Do	5 mg/l	Who
5	BOD	5 mg/l	Icmr/bis
6	Alkalinity	120 mg/l	Icmr
7	Hardness	300 mg/l	Icmr
8	Chloride (cl^-)	250 mg/l	Icmr
9	Nitrate (no_3^-)	45 mg/l	Icmr/bis
10	Sulphate (so_4^{-2})	150 mg/l	Icmr/bis
11	Magnesium (mg^{+2})	30 mg/l	Icmr/bis
12	Calcium (ca^{+2})	75 mg/l	Icmr/bis

Table 20.3 Water quality index, status & grading of water quality

WQI level	Water quality status	Grading
0–25	Excellent water quality	A
26–50	Good water quality	B
51–75	Poor water quality	C
76–100	Very poor quality	D
100	Unsuitable for drinking and fish culture	E

20.4 Result & Result Analysis

The water samples taken from different locations of Tapi river in Surat city were tested in the laboratory to evaluate 12 physio-chemical parameters. These results were compared with the standard values given by various agencies for assessing the quality index of the Tapi river.

20.4.1 For Monsoon Season

Various samples were collected in August & September month for the monsoon season. The results for 12 physio-chemical parameters as shown in Table 20.4 for August and in Table 20.5 for September.

Table 20.4 Results for August month

Sr. No	Parameters	Unit	Valak	Mota Varachha	Sarhana	Katargam	Rander
1	pH	—	7.53	7.52	7.65	7.57	7.65
2	Electrical conductivity	Mohs/cm	0.627	0.581	0.617	0.573	0.621
3	TDS	Mg/l	0.409	0.389	0.406	0.362	0.423
4	Do	Mg/l	7.5	4.1	7.6	4.8	7.9
5	BOD	Mg/l	4.1	2.6	2.3	1.2	2.7
6	Alkalinity	Mg/l	8.8	8.8	8.7	8.9	11.6
7	Hardness	Mg/l	150.6	152.6	156.62	160.64	204.81
8	Chloride (cl ⁻)	Mg/l	30.49	27.99	29.49	29.49	38.98
9	Nitrate (no ₃ ⁻²)	Mg/l	0	0.97	0.86	0.98	0.57
10	Sulphate (so ₄ ⁻²)	Mg/l	19.65	17.24	23.26	21.12	17.37
11	Magnesium (mg ⁺²)	Mg/l	15.61	15.61	16.58	17.07	25.86
12	Calcium (ca ⁺²)	Mg/l	34.46	35.27	35.27	36.07	39.27

Table 20.5 Results for September month

Sr. No	Parameters	Unit	Valak	Mota Varachha	Sarhana	Katargam	Rander
1	pH	—	7.5	7.54	7.55	7.5	7.43
2	Electrical conductivity	Mohs/cm	0.58	0.5893	0.621	0.672	0.603
3	TDS	Mg/l	0.396	0.385	0.41	0.446	0.398
4	Do	Mg/l	5.8	5.1	6	2.5	4.1
5	BOD	Mg/l	4.9	3	3.3	0.9	3.2
6	Alkalinity	Mg/l	7.6	15.5	6.6	6.8	8.3
7	Hardness	Mg/l	149.1	147.1	143.1	155.2	145.1
8	Chloride (cl ⁻)	Mg/l	35.15	73.87	32.77	32.26	56.2
9	Nitrate (no ₃ ⁻)	Mg/l	1.35	0.31	0.71	0	0.38
10	Sulphate (so ₄ ⁻²)	Mg/l	6.41	13.36	8.55	15.5	8.82
11	Magnesium (mg ⁺²)	Mg/l	18.1	13.7	12.72	14.68	14.68
12	Calcium (ca ⁺²)	Mg/l	29.84	36.36	36.36	37.97	33.93

Table 20.6 Water quality index for Valak station for August month

Sr. No	Parameters	Observed values	Qn	Standard values (sn)	(1/sn)	Wn	Qnwn	WQI
1	pH	7.53	106.00	7.5	0.1333	0.2117	22.438	76.26
2	Electrical conductivity	0.627	0.21	300	0.0033	0.0053	0.001	
3	TDS	0.409	0.08	500	0.0020	0.0032	0.000	
4	Do	7.5	73.96	5	0.2000	0.3175	23.483	
5	BOD	4.1	82.00	5	0.2000	0.3175	26.037	
6	Alkalinity	8.8	7.33	120	0.0083	0.0132	0.097	
7	Hardness	150.6	50.20	300	0.0033	0.0053	0.266	
8	Chloride (cl ⁻)	30.49	12.20	250	0.0040	0.0064	0.077	
9	Nitrate (no ₃ ⁻)	0	0.00	45	0.0222	0.0353	0.000	
10	Sulphate (so ₄ ⁻²)	19.65	13.10	150	0.0067	0.0106	0.139	
11	Magnesium (mg ⁺²)	15.61	52.03	30	0.0333	0.0529	2.754	
12	Calcium (ca ⁺²)	34.46	45.95	75	0.0133	0.0212	0.973	
					0.6299	1.0000	76.264	
				K = (1/(e(1/sn)))	1.5876			

The water quality index is determined from the above results for the monsoon season for each station and the average value of the water quality index represents the quality of river water of Tapi. The water quality index calculated by WaWQI for the Valak station is shown in Table 20.6.

The water quality index is calculated for each station for samples taken in August and September month, the results of the water quality index for the monsoon season are shown in below mentioned Table 20.7.

The result shows that water quality index is higher in September compared to August while the station wise comparison shows that the station on the upstream (u/s) side gives a higher value of WQI and the values are decreasing for the locations in the downstream (d/s) side area.

Table 20.7 Water quality index for Monsoon season

Station	August	September	Average	Grade
Valak	76.26	86.01	81.14	D
Mota Varachha	77.64	77.51	77.58	D
Sarthana	69.88	76.48	73.18	C
Katargam	68.88	71.11	69.99	C
Rander	73.25	77.38	75.32	C
Average	73.18	77.70		
Grade	C	D		

20.4.2 For Post-Monsoon Season

Similarly, various samples were collected in December & January months for post-monsoon season. The result for 12 physio-chemical parameters as shown in Table 20.8 for December and in Table 20.9 for January.

The water quality index is determined from the above results for post-monsoon season for each station and the average value of the water quality index represents the quality of river water of Tapi. The water quality index calculated by WaWQI for the Valak station is shown in Table 20.10.

Table 20.8 Results for December month

Sr. No	Parameters	Unit	Valak	Mota Varachha	Sarthana	Katargam	Rander
1	pH	—	7.6	7.8	7.65	7.51	7.5
2	Electrical conductivity	Mohs/cm	0.58	0.5893	0.621	0.672	0.603
3	TDS	Mg/l	0.396	0.385	0.41	0.446	0.398
4	Do	Mg/l	5.8	5.1	6	2.5	4.1
5	BOD	Mg/l	4.9	3	3.3	0.9	3.2
6	Alkalinity	Mg/l	7.6	15.5	6.6	6.8	8.3
7	Hardness	Mg/l	149.1	147.1	143.1	155.2	145.1
8	Chloride (cl ⁻)	Mg/l	35.15	73.87	32.77	32.26	56.2
9	Nitrate (no ₃ ⁻)	Mg/l	1.35	0.31	0.71	0	0.38
10	Sulphate (so ₄ ⁻²)	Mg/l	6.41	13.36	8.55	15.5	8.82
11	Magnesium (mg ⁺²)	Mg/l	18.1	13.7	12.72	14.68	14.68
12	Calcium (ca ⁺²)	Mg/l	29.84	36.36	36.36	37.97	33.93

Table 20.9 Results for January month

Sr. No	Parameters	Unit	Valak	Mota Varachha	Sarhana	Katargam	Rander
1	pH	–	8.06	8.35	8.6	7.4	8
2	Electrical conductivity	Mohs/cm	599	641	614	727	761
3	TDS	Mg/l	0	0	0	0	0
4	Do	Mg/l	5	3.8	3.8	0	3.6
5	BOD	Mg/l	4	0	0	0	2.5
6	Alkalinity	Mg/l	4.4	5.5	6.5	7	6
7	Hardness	Mg/l	176	168	160	194	200
8	Chloride (cl ⁻)	Mg/l	40.98	38.98	40.48	48.48	57.48
9	Nitrate (no ₃ ⁻)	Mg/l	0.75	0.58	0.33	0.28	0.39
10	Sulphate (so ₄ ⁻²)	Mg/l	15.5	17.27	15.77	27.13	27.67
11	Magnesium (mg ⁺²)	Mg/l	23.32	19.92	18.46	23.81	25.27
12	Calcium (ca ⁺²)	Mg/l	32.06	34.46	33.66	38.47	38.47

The water quality index is calculated for each station for samples taken in December and January and the results of the water quality index for post-monsoon season are shown in below mentioned Table 20.11.

The result shows that the water quality index is higher in January compared to December while the station wise comparison shows that the station on the upstream (u/s) side gives a higher value of WQI and the values are decreasing for the locations in the downstream (d/s) side area. As the monsoon recedes the water quality in the river starts degrading.

20.4.3 For Pre-Monsoon

Similarly, the samples were collected in March month for Pre-monsoon season. The result for 12 physio-chemical parameters is shown in Table 20.12.

The water quality index is determined from the above results for Pre-monsoon season for each station and the average value of water quality index represents the quality of river water of Tapi. The water quality index calculated by WaWQI for the Valak station is shown in Table 20.13.

The water quality index is calculated for each station for samples taken in March. The results of the water quality index for Pre-monsoon season are shown in below mentioned Table 20.14.

Table 20.10 Water quality index for Valak station for December month

Sr. No	Parameters	Observed values	Qn	Standard values (sn)	(1/sn)	Wn	Qnwn	WQI
1	pH	7.6	120.00	7.5	0.1333	0.2110	25.322	90.24
2	Electrical conductivity	0.58	0.19	300	0.0033	0.0053	0.001	
3	TDS	0.396	0.08	500	0.0020	0.0032	0.000	
4	Do	5.8	91.67	5	0.2000	0.3165	29.014	
5	BOD	4.9	98.00	5	0.2000	0.3165	31.019	
6	Alkalinity	7.6	6.33	120	0.0083	0.0132	0.084	
7	Hardness	149.1	49.70	300	0.0033	0.0053	0.262	
8	Chloride (cl ⁻)	35.15	14.06	250	0.0040	0.0063	0.089	
9	Nitrate (no ₃ ⁻)	1.35	3.00	45	0.0222	0.0352	0.106	
10	Sulphate (so ₄ ⁻²)	6.41	4.27	150	0.0067	0.0106	0.045	
11	Magnesium (mg ⁺²)	18.1	60.33	30	0.0333	0.0528	3.183	
12	Calcium (ca ⁺²)	29.84	39.79	75	0.0133	0.0211	0.840	
					0.6299	0.9969	89.964	
				K = (1/(e(1/sn)))	1.5876			

Table 20.11 Water quality index for Post-Monsoon season

Station	December	January	Average	Grade
Valak	90.25	108.73	99.49	D
Mota Varachha	88.52	99.11	93.82	D
Sarthana	80.71	109.34	95.03	D
Katargam	71.53	72.54	72.04	C
Rander	80.34	102.27	91.31	D
Average	82.27	98.40		
Grade	D	D		

The result shows that the water quality index is higher in March compared to other seasons while the station wise comparison shows that in Pre-monsoon all stations had a higher value of water quality index but the overall trend of variation in value remain same.

Table 20.12 Results for March month

Sr. No	Parameters	Unit	Valak	Mota Varachha	Sarthana	Katargam	Rander
1	pH	–	8.7	8.06	8.35	8.6	7.4
2	Electrical conductivity	Mohs/cm	4.83	599	641	614	727
3	TDS	Mg/l	0	0	0	0	0
4	Do	Mg/l	10.1	5	3.8	3.8	0
5	BOD	Mg/l	8	4	0	0	0
6	Alkalinity	Mg/l	6.5	4.4	5.5	6.5	7
7	Hardness	Mg/l	214	176	168	160	194
8	Chloride (Cl ⁻)	Mg/l	29.49	40.98	38.98	40.48	48.48
9	Nitrate (NO ₃ ⁻)	Mg/l	0.18	0.75	0.58	0.33	0.28
10	Sulphate (SO ₄ ⁻²)	Mg/l	14.7	15.5	17.27	15.77	27.13
11	Magnesium (Mg ⁺²)	Mg/l	32.56	23.32	19.92	18.46	23.81
12	Calcium (Ca ⁺²)	Mg/l	32.06	32.06	34.46	33.66	38.47

20.4.4 Comparison of Water Quality Index (WQI)

By comparing the values of the WQI for the year 2017–18, it is observed that the quality of water is fairly good in the monsoon season but as the monsoon recedes the quality also gradually starts decreasing and in Pre-monsoon season it is not suitable for human consumption without treatment. The overall comparison of WQI is shown in below mentioned Table 20.15.

The WQI in the Tapi river shows the same trend for all the seasons in which WQI is higher in station Valak and Mota Varachha, while it decreases at Sarthana and gives the minimum value at Katargam & again increases at Rander. The graphical representation for the same WQI for the Tapi river for the years 2017–18 is shown in Fig. 20.3.

20.5 Conclusion

- Water quality index of Tapi river from Valak to Rander during monsoon is 75.44 (grade c) which falls under the poor river water quality.
- Water quality index of Tapi river from Valak to Rander during post-monsoon is 85.11 (grade d) which falls under the very poor river water quality.

Table 20.13 Water quality index for Valak station for March month

Sr. No	Parameters	Observed values	Qn	Standard values (sn)	(1/sn)	Wn	Qnwn	WQI
1	Ph	8.29	258.00	7.5	0.1333	0.2110	54.441	95.74
2	Electrical conductivity	0.00499	0.00	300	0.0033	0.0053	0.000	
3	TDS	290	58.00	500	0.0020	0.0032	0.184	
4	Do	6.75	81.77	5	0.2000	0.3165	25.882	
5	BOD	1	20.00	5	0.2000	0.3165	6.330	
6	Alkalinity	157.5	131.25	120	0.0083	0.0132	1.731	
7	Hardness	165.3 31.81	55.10	300	0.0033	0.0053	0.291	
8	Chloride (cl ⁻)		12.72	250	0.0040	0.0063	0.081	
9	Nitrate (no ₃ ⁻)	0.01	0.02	45	0.0222	0.0352	0.001	
10	Sulphate (so ₄ ⁻²)	33.65	22.43	150	0.0067	0.0106	0.237	
11	Magnesium (mg ⁺²)	30.7	102.33	30	0.0333	0.0528	5.398	
12	Calcium (ca ⁺²)	30.7	40.93	75	0.0133	0.0211	0.864	
					0.6299	0.9969	95.439	
				K = (1/(e(1/sn)))	1.5876			

Table 20.14 Water quality index for monsoon season

Station	March	Grade
Valak	162.89	D
Mota Varachha	153.57	D
Sarthana	145.97	D
Katargam	124.01	D
Rander	149.69	D
Average	147.23	
Grade	D	

- The overall trend of results shows that the river water quality is very poor at stations Valak, Mota Varachha and Rander, while the very quality is poor at stations Sarthana and Katargam.
- Decrease in BOD, do, nitrate, sulphate and magnesium content in water evident to aquatic plant growth in water.

Table 20.15 Comparison of WQI of Tapi river for year 2017–18

Station	August	September	December	January	March	Average	Grade
Valak	76.26	86.01	90.25	108.73	162.89	81.14	D
Mota Varachha	77.64	77.51	88.52	99.11	153.56	77.58	D
Sarthana	69.88	76.48	80.71	109.34	145.97	73.18	C
Katargam	68.88	71.11	71.53	72.54	124.01	69.99	C
Rander	73.25	77.38	80.34	102.27	149.69	75.32	C
Average	75.44		85.11				
Grade	C		D				

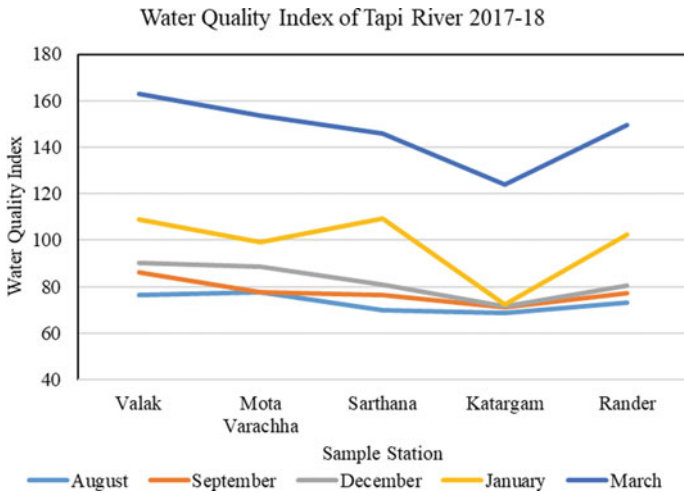


Fig. 20.3 WQI of Tapi river for the year 2017

- Unknown sources of untreated water released in the river water may lead to an increase in the water quality index between Valak, Sarthana and Mota Varachha at which the WQI score is above 100 (grade e).
- Water quality is continuously degrading from monsoon to post-monsoon season which makes it unsuitable for drinking and fish culture.

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