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Water Quality Index of Surface Water Bodies of Gujarat, India

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Abstract: Present communication deals with a study of Physico-chemical parameters such as pH, Temperature, Total Suspended Solids, Turbidity, Dissolved Oxygen, Biochemical Oxygen Demand, Nitrate, Phosphate and Fecal coliform in water samples of rivers, lake and canal in Gujarat state of India. The water quality of the samples was compared with standard values given by World Health Organization (WHO) and United State Salinity Laboratory for drinking and irrigation purposes. Water Quality Index (WQI) was also calculated to know the overall quality of water samples. The results show that the water quality index is observed in the range of 44-61 and expected in the range of 45-64 which shows marginally water quality for drinking purposes. The water quality index is calculated by indicator (100-point scale) shows that this water can be used for drinking purpose after purification treatment. Results show that quality for irrigation purpose is quite good.

Key words: Water Quality Index, Rivers, Lake, Canal, Surface water

Introduction

The term "water quality" includes the water column and the physical channel required to sustain aquatic life. The goal of the federal Clean Water Act, "To protect and maintain the chemical, physical and biological integrity of the nation's waters," establishes the importance of assessing both water quality and the habitat required for maintaining other aquatic organisms. Water, the precious gift of nature to human being, is going to be polluted day-by-day with increasing urbanization. Although three-fourth part of earth is being surrounded by water but a little portion of it can be used for drinking purpose. In spite of the fact that the municipal water supply in most of the cities is through treated surface water, due to over contamination, more stringent treatments would-be required to make the surface water potable. The prominent source of surface water pollution is domestic sewage, industrial wastewater and agricultural run-off. So, we must turn to surface water quality studies in details. Application of fertilizers, pesticides, manure, and lime refuse dumps etc. is the main source of surface water and ground water pollution. Surface water is generally using for drinking and irrigation purposes in India. Therefore, we carried out studies of physico-chemical parameters of surface water in Gujarat state whether it is fit for drinking or some other purposes of various western areas in Gujarat (Pandit and Oza 2004, Joshi *et al.,* 2004, Bhoi *et al.,* 2005). Rivers, lake and canal water is generally using in coastal region for drinking and irrigation purposes. Investigations in hygiene, sanitation and water supplies proved to control these diseases. Universal access to safe drinking water and sanitation has been promoted as an essential step in reducing the preventable diseases (WHO, 1994; 2001). The major hazard in drinking water supplies is microbial contamination, which is due to agricultural land wash, domestic sewage, industrial effluents, improper storage and handling (WHO, 2006; Saha *et al.,* 2006).

Primary contamination in drinking water is improper storage of water supply, water storage and leakage of pipes and secondary contamination due to manmade such as improper handling, storage, distribution and serving methods (Tambekar *et al*., 2005). Shah *et al*. (2006, 2008) suggested that the water quality of bore wells of Gandhinagar taluka (Gujarat) is poor for drining purpose as per water quality index

A water quality index is a means to summarize large amounts of water quality data into simple terms for reporting to management and the public in a consistent manner. Similar to the UV index or an air quality index, it can tell us whether the overall quality of water bodies possess a potential threat to various uses of water, such as habitat for aquatic life, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. Water quality index (WQI) is a single value indicator to the water quality. It integrates the data pool generated after collecting due weights to the different parameters. The present study is based on the analyses of water samples collected from various locations along the coastal region of Jamnagar, Gujarat. The advantages of an index include its ability to

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represent measurements of a variety of variables in a single number, its ability to combine various measurements in a variety of different measurement units in a single metric and its effectiveness as a communication tool. When the same objectives and variables are used, the index can be used to convey relative differences in water quality between sites over time. Water intended for human consumption should be both safe and wholesome. It should also be easily accessible, adequate in quantity, free from contamination and readily available (CCME WQI, 2005).

Materials and Methods

Surface Water samples were collected from various sampling locations of rivers, canal and lake of Gujarat (Table 1). Samples were collected in polythene bottles and analyzed for various water quality parameters as per standard procedures given in APHA, Standard Methods, 1992. The observed values were compared with standard values recommended by World Health Organization (WHO, 2002) for drinking water purposes. The calculation of Water Quality Index (WQI) carried out using software of world sanitation website weighted arithmetic index method i.e. Keith Alcock's. WQI is subsequently formulated using Keith Alcock's JavaScript webmaster process (2008) and the results obtained for each sample tested is reported. Water quality index is calculated to determine the suitability of water for drinking purposes (Srivastava and Sinha, 1994; Das *et al*., 2001; Joshi *et al.,*2004; Bhoi *et al*.,2005).

Table 1: Surface Water Sampling Locations in Gujarat

Sr. No.	Sampling Locations
River	**Coastal Gujarat**
1	Sinhan River, Jamnagar
2	Fulzer River, Jamnagar
3	Asi River, Wankhaner
Lake and Canal	**Central Gujarat**
4	Gangasagar Lake, Viramgam
5	Sardar Sarover Canal, Viramgam
Rivers	**North Gujarat (Rivers)**
6	Rupen River, Patan
7	Banas River, Banaskhantha

The statistical analysis such as mean, standard deviation (SD) and coefficient of variance (% CV) were also determined using Biostatics (Mungikar, 1997). The water quality of Gujarat is also classified into five classes i.e. Excellent, Good, Fair, Marginal and Poor according to the classification made by United State Salinity Laboratory. Locations of surface water quality of Gujarat, India are given in Table 1.

Various physical and chemical parameters were analysed for the surface water samples from different locations in Gujarat state. The wide ranges of variations in the values of those parameters are reported. The present study reveals how these wide variations in different parameters can be boiled down to a single number when reported with the help of WQI, thereby making it quite convenient to comment on the overall quality of the water sample from its pollution points of view.

Results and Discussion

Physico-chemical characteristics of Surface water quality of rivers (Fulzer, Sinhan and Asi) of costal region of Jamnagar, lake and canal near Viramgam, Ahmedabad at Central Gujarat and rivers (Banas and Rupen) of north Gujarat is shown in Table 2. It should be recognized that, like dissolved oxygen, pH also varies in streams naturally throughout the day due to the photosynthesis and respiration cycles in the presence of algae in water bodies. The pH is measure of the intensity of acidity or alkalinity and the concentration of hydrogen ion concentration. pH has no direct adverse effects on health; however, higher values of pH hasten the scale formation in water heating apparatus and also reduce germicidal potential of chloride. High pH induces the formation of tri halo methane which is toxic. pH below 6.5 starts corrosion in pipes, thereby releasing toxic metals such as Zn, Pb, Cd and Cu etc. (Trivedy and Goel, 1986). The pH values of water samples of present study ranged from 7.5 to 9.0 for Rivers, Lake and canal water in Gujarat. These values are within the prescribed limit of standards (WHO 2001; 2002). The percent coefficient of variance values of coastal rivers water i.e. Fulzer, Sinhan rivers in Jamnagar and Asi river in Wankhaner in Gujarat is 5.92; for Gangasagar lake and Sardarsarovar Cannel at Viramgam is 14.76 and for Rupen and Banas rivers in north Gujarat is 23.23. It shows that the % Coefficient of Varience of pH in surface water is increasing from costal region to North region of Gujatat. The analyses of the parameters, their range, mean, percent coefficient Variance (% CV), compared with WHO standards are given in Tables 3 to 6.

Table 2: Physico-chemical characteristics of Surface water quality of rivers, lake and canals

Sr. No.	Parameters	Rivers			Lake and Canal		Rivers	
		Coastal region			Central Gujarat		North region	
		Fulzer	Sinhan	Asi	Ganga Sagar	Sardar-sarovar	Banas	Rupen
Physical								
1	pH	8.0	7.5	8.7	9.0	8.6	8.1	8.2
2	Temperature (^{0}C)	18	28	40	38	37	40	35
3	Turbidity (NTU)	2	13	8	54	2	12	12
4	T.S.S.	2	41	11	32	4	15	12
5	T.D.S.	1180	341	1600	950	140	1040	6250
6	Conductivity (mS/cm)	1970	568	2400	1440	240	1600	11200
Inorganic								
7	Alkalinity	304	179	136	297	92	93	279
8	Total hardness	680	171	519	109	77	371	1350
9	Calcium hardness	340	83	176	79	44	238	289
10	Chloride	400	83	640	302	8	372	3952
11	Sulphate	83	23	177	46	10	88	315
12	Sodium	187	73	326	305	15	172	2219
13	Potassium	3	3	6	9	5	8	16
14	Nitrate (NO_3)	29	21	3.0	2.0	5.0	0.4	0.4
Nutrient / Organic								
15	Phosphate (PO_4)	0.1		0.30	0.43	1.64	0.05	0.02
16	DO	10	6.7	8	7.1	7.3	6.7	6.9
17	COD	15	40	13	56	<10	35	40
18	BOD	<5	17	<5	24	<3	13	17
Heavy Metals								
19	Nickel (Ni)	-	ND	-	ND	ND	ND	0.01
20	Cadmium (Cd)	-	0.01	-	ND	ND	ND	0.01
21	Chromium (Cr)	0.04	ND	0.02	ND	ND	ND	ND
22	Copper (Cu)	-	ND	-	ND	0.01	0.01	0.01
23	Lead (Pb)	-	0.05	-	0.01	0.05	0.04	0.01
24	Ferrous (Fe)	0.17	0.46	0.17	1.62	2.97	0.43	0.70
25	Mangnese (Mn)	-	0.40	0.15	0.20	0.32	0.65	0.023
26	Zinc (Zn)	-	ND	-	ND	0.02	6.41	6.08
27	Cobalt (Co)	-	ND	-	ND	ND	ND	ND
Biological								
28	Total coliform (CFU)	2400	225	180	400	445	410	660
29	Fecal coliform (CFU)	210	19	20	70	80	100	110
30	Phytoplankton	7493	168	9971	240	168	246	246
31	Zooplankton (No/m^3)	-	5000	-	6857	3120	3333	1714
32	PPI	19	10	6	-	-	-	5
33	SWDI	-	2.232	-	2.250	1.929	0.500	0.919

All values are given in mg/l except pH, Temp., Turbidity, conductivity and biological parameters

Table 3: Surface water quality parameters correlates with WHO Standards with the values for water samples of (Fulzer, Sinhan and Asi) Rivers Jamnagar/Wankhaner

Water quality parameters	WHO Standard value	Range	Mean	SD	%CV	Comparison with WHO standard
Temperature (^{0}C)	40±5	24-30	28	1.97	6.97	Within
pH	5.5-9.0	7.5-8.9	8.0	0.48	5.92	Within
D.O. (mg/l)	>5	3.8-9.6	7.0	1.99	26.64	Within
Turbidity (NTU)	10	2-14	9	4.62	54.31	within
Fecal Coliform (CFU)	0	15-218	98	88.58	90.47	Exceed
BOD (mg/l)	5	3-18	7	5.10	74.58	Within
Total Phosphate (mg/l)	5	0.1-0.29	2	0.07	3.40	Within
Nitrate (mg/l)	20	0.7-30	19	12.66	4.14	Within
TSS (mg/l)	0	4-33	17.1	0.71	68.20	Exceed

Table 4: Surface water quality parameters correlates with water WHO Standards with the values for water samples of Gangasagar Lake Viramgam, Ahmedabad

Water quality Parameters	WHO Standard value	Range	Mean	SD	%CV	Comparison with WHO standard
Temperature (^{0}C)	40±5	29-30	29.5	0.5	0.0	Within
pH	5.5-9.0	9-9.2	9.1	0.07	14.76	Within
D.O. (mg/l)	>5	7.1-7.5	7.25	0.17	3.01	Within
Turbidity (NTU)	10	52-54	52.75	0.83	23.32	Exceed
Fecal Coliform (CFU)	0	69-75	71.25	2.28	1.19	Exceed
BOD (mg/l)	5	20-24	23.25	1.48	2.72	Exceed
Total Phosphate (mg/l)	5	0.41-0.45	0.42	0.01	1.94	Within
Nitrate (mg/l)	20	2-2.8	2.45	0.29	11.8	Within
TSS (mg/l)	0	32-33	32.5	0.50	1.54	Exceed

Table 5: Surface water quality parameters correlates with WHO Standards with the values for water samples of Sardar Sarovar Canal Viramgam, Ahmedabad ,Gujarat

Water quality parameters	WHO Standard value	Range	Mean	SD	%CV	Comparison with WHO standard
Temperature (^{0}C)	40±5	30-30	30	0	0	Within
pH	5.5-9.0	6.4-8.6	7.05	1.04	14.76	Within
D.O. (mg/l)	>5	7.1-7.6	7.3	0.22	3.01	Within
Turbidity (NTU)	10	2-3.1	2.5	0.58	23.32	Within
Fecal Coliform (CFU)	0	80-82	80.75	0.96	1.19	Exceed
BOD (mg/l)	5	2.9-3.1	3.0	0.08	2.72	Within
Total Phosphate (mg/l)	5	1.16-1.67	1.63	0.03	1.94	Within
Nitrate (mg/l)	20	5-5.4	5.2	0.18	3.51	Within
TSS (mg/l)	0	3-9	5.75	2.75	47.89	Exceed

Table 6: Surface water quality parameters correlates with WHO Standards with the values of North Gujarat water samples Rupen and Banas rivers Patan / Banaskhantha district

Water quality parameters	WHO Standards	Range	Mean	SD	%CV	Comparison with WHO standard
Temperature (^{0}C)	40±5	28-30	29	0.74	2.53	Within
pH	5.5-9.0	5.1-8.2	6.64	1.54	23.23	Within ,
D.O. (mg/l)	>5	3.9-6.9	5.31	1.3	24.39	Within
Turbidity (NTU)	10	11-18	15	3.25	21.68	Exceed
Fecal Coliform (CFU)	0	12-117	83.38	44.12	52.92	Exceed
BOD (mg/l)	5	4-18	11	5.11	45.94	Within
Total Phosphate (mg/l)	5	0.01-0.06	0.03	0.02	66.63	Within
Nitrate (mg/l)	20	0.3-0.9	0.6	0.24	38.01	Within
TSS (mg/l)	0	12-23	16.63	4.24	25.51	Exceed

Electrical conductivity (EC) value of water samples of costal region of rivers (Fulzer, Sinhan and Asi) ranged from 568 mS/cm to 2400 mS/cm, 1400 mS/cm in Gangasagar lake, 240 mS/cm in Sardarsarovar Canal and 1600 to 11200 mS/cm in Banas and Rupen river in north Gujarat. The results show that EC values of river water are increasing from costal region towards north region of Gujarat. Prescribed standard values by WHO for EC is 1400 mS/cm. The value of EC is very low (240 mS/cm) in the water of Sardar Sarover as the source is of Mahi river near Baroda, Gujarat.

Total suspended solids (TSS) are found in natural surface water. TSS values of water samples ranged from 2 to 41mg/l. The sequence of % CV values of TSS for water samples of rivers of costal Gujarat, Gangasagar lake and Sardar Sarovar canal 68.20, 1.54 and 47.89 respectively. In rivers waters of north Gujarat the TSS value of % CV are 25.51. Percent coefficient variance values are observed higher side in coastal region than north regions of Gujarat.

Dissolved oxygen concentration of river water samples of Jamnagar and Wankhaner of costal Gujarat region ranged from 6.7 mg/l to 10. mg/l; 7.1mg/l in Gangasagar Lake while in Sardar Sarovar 7.3 mg/l; 6.7 mg/l and 6.9 mg/l in Banas and Rupen rivers respectively of North Gujarat. All water samples of Gujarat region were found within the permissible limit given by WHO 2001, 2002. The % CV values of DO in water samples is for Fulzer, Sinhan and Asi rivers computed as (% CV=26.64) for costal region, Gangasagar lake and Sardar Sarovar canal (% CV=3.01) each, Rupen and Banas rivers of North Gujarat computed as (% CV=24.39). The % CV of DO is almost same from costal region to North region of Gujarat except in water of Sardarsarovar canal indicates low % CV as this water source is from Mahi River near Baroda.

The scope of parameters is limited to evaluation indicators or criteria that are representative of the type of pollution. For example, although there are many forms of phosphorus that can be measured, we use total phosphorus as an indicator for phosphorus enrichment. Total phosphate content of river water samples of Jamnagar and Wankhaner costal region of Gujarat ranged from 0.1 mg/l to 0.3 mg/l, 0.43mg/l in Gangasagar lake and 1.64 mg/l in Sardarsarovar canal; 0.05 mg/l, 0.02 mg/l in Banas and Rupen rivers respectively of Notrh Gujarat. All water samples of Gujarat region for phosphate were found within the permissible limit given by (WHO standard value 5.0 mg/l). The value of % CV of total phosphate of water samples is for fulzer, Sinhan and Asi rivers computed as (3.40) for costal region, Gangasagar lake and Sardarsarovar canal is 1.94 each, Rupen and Banas rivers of North Gujarat computed as (66.63). High % CV observed in the water of Banas and Rupen rivers of Gujarat.

Nitrate content in river water samples of Jamnagar and Wankaner costal region of Gujarat region ranged from 3.0 mg/l to 29.0 mg/l, 2.0 mg/l in Gangasagar lake and 5.0mg/l in Sardar Sarovar canal, 0.4 mg/l each in Banas and Rupen rivers of North Gujarat region. All water samples of Gujarat and region were found within the permissible limit given by WHO standards (20 mg/l) except Fulzer and Sinhan rivers in Jamnagar district which is very near to the source of GSFC fertilizer plant ESSAR and RIL refineries. The value of % CV of Nitrate of water samples is for Fulzer, Sinhan and Asi rivers computed as (4.14) for costal region, Gangasagar lake (11.8) and Sardar Sarovar canal is 3.51, Rupen and Banas rivers of north Gujarat computed as (38.01).

BOD content of river water samples of Jamnagar and Wankaner costal region of Gujart ranged from <5.0 mg/l to 17.0 mg/l, 24 mg/l in Gangasagar lake and <3mg/l in Sardar Sarovar canal, 13mg/l in Banas River and 17mg/l in Rupen rivers of North Gujarat region. All water samples of Gujarat region was found within the permissible limit given by WHO; BOD 30 mg/l (5 days at 20^0 C). The value of % CV of BOD of water samples is for Fulzer, Sinhan and Asi rivers computed as (74.58) for costal region, Gangasagar lake and Sardar Sarovar canal is 2.72 each, Rupen and Banas rivers of North Gujarat computed as (45.94). The % CV of BOD observed higher in costal region of Gujarat and decreasing towards north Gujarat.

Turbidity content of river water samples of Jamnagar and Wankaner costal rivers in Gujart region ranged from 2.0 NTU to 13.0 NTU, 2.0 NTU in Gangasagar Lake 54.0 NTU in Sardarsarovar canal 2.0 NTU and 12 NTU in Banas and Rupen rivers respectively of North Gujarat region. All water samples of Gujarat region was found within the permissible limit given by WHO 10 NTU except Banas, Rupen, Sinhan rivers and Gangasagar Lake in Gujarat. The value of % CV of Turbidity of water samples is for Fulzer, Sinhan and Asi rivers computed as (54.31) for costal region, Gangasagar lake and Sardar Sarovar canal % CV=23.32 each, Rupen and Banas rivers of North Gujarat computed as (% CV=21.68). The %CV ranges from (21.68 to 54.31) coastal region of Gujarat.

Faecal coliform content of river water samples of Jamnagar and Wankaner costal Gujart region ranged from 19 CFU to 210 CFU, 70 CFU in Gangasagar lake and 80 CFU in Sardar Sarovar canal, 100 CFU and 110 CFU in Banas and Rupen rivers respectively of Notrh Gujarat region whereas. The permissible limit of faecal coliform given by WHO is zero CFU. All water samples of Gujarat region were exceed the permissible limit given by (WHO 2001, 2002). The value of % CV of faecal coliform of water samples is for Fulzer, Sinhan and Asi rivers computed as (% CV=90.47) for costal region, % CV= 1.19 each for Gangasagar lake and Sardar Sarovar canal, Rupen and Banas rivers of North Gujarat computed as (% CV=52.92). This indicates that the river water shows high values of % CV; lake and canal indicate low value of % CV. For temperature all water samples of Gujarat region ranges from 18^0C-40^0C were found within the permissible limit given by WHO 40±5.

Since no prescribed standards are suggested by WHO for potassium content for drinking purpose. So, no comparison can be made from observed values. Water quality index is 100 point scale that summarizes results form and total of nine different parameters, nine factors were chosen and same were judged more important than others so, a weighted mean is used tom combine the values; so that the measurement could be converted to index values and the level of water quality (0 through 100) corresponding to the measurement. The curves were then averaged and are thought to represent the best possible judgement. Water quality index (WQI) of surface water in Costal Gujarat, Central Gujarar and North Gujarat shown in Table 7 to Table 13. Water quality index of Fulzer, Sinhan and Asi rivers of coastal region of Gujarat are compute as 55, 56 and 59 respectively. Water quality index of Gangasagar lake and Sardar Sarovar Canal of Central region of (Viramgam, Ahmedabad) is computed as 44 and 58 respectively. Water quality index of Rupen and Banas River of north Gujarat Patan Banaskanta districts is 61 and 59 respectively. Total WQI is computed for all sampling locations comes in the range between 44-61 which shows quality of water is poor (marginal) which is frequently threatened or impaired; conditions often depart from natural or desirable levels and it is calculated by indicator (100-point scale). It indicates that the quality of costal Gujarat is poor for drinking purpose.

Table 7: Physico-chemical characteristics of surface water of Fulzer River, Jamnagar

Parameters	Upstream	Downstream	Left bank	Right bank	Mean	WQI
Temperature (^{0}C)	28	29	25	24	26.5	14
pH	8.0	7.9	8.1	8.0	8.0	83
D.O. (mg/l)	10	9.1	9.5	9.6	9.5	7
Turbidity (NTU)	2	3	3	3	3	91
Fecal Coliform (CFU)	210	200	215	218	210	37
BOD(mg/l)	<5	<3	<4	<3	<4	63
Phosphate (mg/l)	0.1	0.11	0.11	0.1	0.1	96
Nitrate (mg/l)	29	28	30	30	29	28
TSS (mg/l)	2	3	4	3	3	80
						Avg. WQI =55

Table 8: Physico-chemical characteristics of surface water of Sinhan River

Parameters	Upstream	Downstream	Left bank	Right bank	Mean	WQI
Temperature(^{0}C)	28	29	30	30	29	11
pH	7.5	7.5	7.9	7.8	7.7	91
D.O.(mg/l)	8.0	7.5	7.3	7.1	7.4	6
Turbidity (NTU)	13	12	14	11	13	71
Fecal Coliform(CFU)	20	15	25	30	23	62
BOD.(mg/l)	<5	<5	<5	<5	<5	56
Phosphate (mg/l)	0.17	0.18	0.25	0.21	0.20	91
Nitrate (mg/l)	21	22	30	25	25	33
TSS (mg/l)	41	40	45	49	44	86
						Avg. WQI =56

Table 9: Physico-chemical characteristics of surface water of samples of Asi River

Parameters	Upstream	Downstream	Left bank	Right bank	Mean	WQI
Temperature (^{0}C)	29	28	30	30	29	42
pH	8.7	8.5	8.8	8.9	8.72	58
D.O. (mg/l)	6.7	7.1	4.1	3.8	5.42	5
Turbidity (NTU)	8	8.1	12	13	10.27	75
Fecal Coliform(CFU)	19	20	101	102	60.5	50
BOD.(mg/l)	17	18	7	5	11.75	28
Phosphate (mg/l)	0.30	0.29	0.11	0.13	0.20	92
Nitrate (mg/l)	3.0	3.1	0.9	0.7	1.92	95
TDS(mg/l)	11	10	29	21	17.75	84
						Avg. WQI =59

Table 10: Physico-chemical characteristics of surface water of o Gangasagar Lake

Parameters	North region	South region	East region	West region	Mean	WQI
Temperature (^{0}C)	30	30	29	29	30	43
pH	9.0	9.1	9.2	9.1	9.1	46
D.O. (mg/l)	7.1	7.1	7.5	7.3	7.25	6
Turbidity (NTU)	54	52	52	53	52.75	37
Fecal Coliform	70	71	69	75	71.25	48
BOD.(mg/l)	24	23	20	22	22.25	9
Phosphate (mg/l)	0.42	0.41	0.43	0.45	0.42	69
Nitrate (mg/l)	2.0	2.5	2.8	2.4	2.42	93
TSS (mg/l)	32	33	32	32	32.25	85
						Avg. WQI =44

Table 11: Physico-chemical characteristics of surface water of Sardar Sarovor canal

Parameters	North region	South region	East region	West region	Mean	WQI
Temperature (^{0}C)	30	30	30	30	30	45
pH	8.6	6.5	6.4	6.7	7.05	89
D.O. (mg/l)	7.3	7.1	7.5	7.6	7.37	6
Turbidity (NTU)	2	2.9	3.1	2.0	2.5	92
Fecal Coliform(CFU)	80	81	82	80	80.75	47
BOD.(mg/l)	<3	2.9	3.1	3	3	67
Phosphate (mg/l)	1.64	1.67	1.60	1.61	1.63	30
Nitrate (mg/l)	5.0	5.1	5.3	5.4	5.2	64
TSS .(mg/l)	4	7	9	3	4.95	80
						Avg. WQI =58

Table 12: Physico-chemical characteristics of surface water of samples Banas River

Parameters	Upstream	Downstream	Left bank	Right bank	Mean	WQI
Temperature (^{0}C)	30	29	30	30	30	44
pH	8.1	7.9	5.4	5.1	6.62	76
D.O. (mg/l)	6.7	6.2	4.2	3.9	5.25	5
Turbidity (NTU)	12	11	16	17	14	69
Fecal Coliform(CFU)	100	101	117	109	106.75	43
BOD(mg/l)	13	14	7	9	10.75	31
Phosphate (mg/l)	0.05	0.06	0.03	0.02	0.04	98
Nitrate (mg/l)	0.4	0.6	0.8	0.9	0.67	96
TSS (mg/l)	15	12	18	19	16	83
						Avg. WQI =61

Table 13: Physico-chemical characteristics of surface water of samples Rupen River

Parameters	Upstream	Downstream	Left bank	Right bank	Mean	WQI
Temperature (^{0}C)	29	28	30	29	29	40
pH	8.2	8.1	5.1	5.2	6.6	75
D.O. (mg/l)	6.9	6.2	4.1	4.3	5.37	5
Turbidity	12	14	18	20	16	66
Fecal Coliform(CFU)	12	13	112	103	60	50
BOD.(mg/l)	17	18	7	4	11.5	29
Phosphate (mg/l)	0.02	0.01	0.02	0.01	0.01	100
Nitrate (mg/l)	0.4	0.3	0.7	0.9	0.57	96
TSS (mg/l)	12	13	23	21	17.25	83
						Avg. WQI =59

Evaluation of results and grading: For each indicator, the grading scale followed the "ranking" scale recommended by the CCME (2001). That also used five categories or levels that correspond to specific levels of water quality impairment.

Water quality index (WQI) of Surface water of various sampling locations of Gujarat ranged from 44-61 indicates the poor quality of water. WQI was calculated to find the suitability of water for drinking purposes. An appropriate method for improving the surface water quality in the affected areas is considered for suitable treatment.

WQI values ranges from 100 (excellent) to 0 (very poor). WQI scores were grouped into one of five categorized that serves to summarizes the overall state of water quality. The categories and category description are as follows:

Table 14: Water Quality Index (WQI) of Surface Water at Various Sampling Locations

Gujarat Regions	**WQI**	**WQI Range**	**Water Quality Indicators (Status) (CCME, 2005)**	
Fulzer River (Jamnagar)	55	**44-61 (poor to marginal water quality)**	95-100	**Excellen**t: Water quality is protected with virtual absence of threat or impairment; conditions very close to natural or desirable levels
Sinhan River (Jamnagar)	56		80-94	**Good**: Water quality is protected with only minor degree of threat or impairment; conditions depart from natural or desirable levels
Asi River (Jamnagar)	59		60-79	**Fair**: Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels
Gangasagar Lake (Ahmedabad)	44		45-59	**Poor (Marginal)**: Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels
Sardarsarovar Canal (Ahmedabad)	58		0-44	**Very Poor**: Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels (unsuitable for drinking)
Rupen River (Patan)	61			
Banas River (Banas)	59			

According to National Academy of Science (1977), the higher cases of sodium can be related to cardiovascular diseases and in women toxemia associated with pregnancy. The sodium content of water samples ranged from 73 mg/l to 236 mg/l in the rivers (Fulzer, Sinhan and Asi) of costal Gujarat, 305 mg/l in Gangasagar lake, 15mg/l in Sardarsarovar canal, 172 mg/l in Banas rive and, 2219 mg/l in Rupen river of Gujarat. Water samples of Fulzer, Sinhan, Banas rivers were found within permissible limits given by WHO (200 mg/l). The sodium content are exceeded the prescribed limits for Asi river, Gangasagar lake, Rupen river.

The classification of water quality of sampling locations for irrigation purpose is presented in Table 15. It suggests that water samples of Viramgam, Wankaner, Jamnagar talukas of Gujarat state were quite good (fair) for irrigation purpose due to high salinity of water.

Salinity and electric conductivity are directly related to each others but it inversely proportional to the quality of water (Shah *et al.,* 2006;2008). Electrical conductivity of (Fulzer, Sinhan, Asi) rivers of coastal region of Gujarat are ranged between 568 µS/cm and 2400 µS/cm (Avg. 1646 µS/cm) shows medium quality of water. Electrical conductivity of Gangasagar lake and Sardar Sarovar Canal in Central region (Viramgam, Ahmedabad), Gujarat renged from 240 µS/cm and 1400 µS/cm (Avg. 840 µS/cm), shows water good quality for drinking after suitable treatment followed by disinfection. Electrical conductivity of Rupen and Banas River of north Gujarat Patan / Banaskanta districts are very high ranged from1600 µS/cm and 11200µS/cm (Avg. 6400 µS/cm), shows poor quality of water according to the classification made by United State Salinity Laboratory.

Table 15 : Classification of water quality of Gujarat for irrigation

Sr. No.	Electrical conductivity (µS/cm)	Category of water Salinity	Name of sampling locations region wise
1	240 to 1400 (Avg.840)	Low salinity (Excellent)	Central region (lake and canal), Gujarat
2	568 to 2400 (Avg.1646)	Medium (Good)	Coastal region, rivers Gujarat
3	1600 to 11200 (Avg. 6400)	Very High (Poor quality)	North Gujarat

Conclusion

- Water quality index (WQI) of Surface water of various Sampling locations of Gujarat ranged between 44-61 indicates the poor quality of water
- The high value of WQI at some of the stations has been found to be higher values of fecal Coliform , nitrate , total suspended solids, BOD in the surface water
- WQI can play a big role in mitigating the pollution problems after encountered in different surface water bodies
- The analysis reveals that surface water from coastal south region to north region of Gujarat is poor for drinking purpose as per the water quality index. However, this water can be used for drinking purpose after purification treatment followed by disinfection before consumption and it also need to be protected from the perils and contaminations and quite good for irrigation purpose.

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