Water Quality Index of River Cauvery in Tiruchirappalli district, Tamilnadu

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Abstract

The water quality of river Cauvery in Tiruchirappalli district was monitored for a period of 3 months (January - March, 2009). Water samples were assessed by analyzing the various physico-chemical parameters, such as pH, total dissolved solids, total hardness, total alkalinity, dissolved oxygen, biological oxygen demand, chloride, sulphate, nitrate and calcium. These 10 parameters were considered to compute the Water Quality Index (WQI). The WQI reveals the water of river Cauvery to be polluted moderately in the upstream of the city and unfit for human consumption towards the downstream. It needs sufficient treatment and management.

Keywords: River Cauvery, Water Quality Parameters, Water Quality Index, Urbanization and Sewage Discharge

1. Introduction

The river Cauvery, one of the sacred rivers of southern India, is the source of water for an extensive irrigation system and hydroelectric power. It has supported irrigated agriculture for centuries and served as the lifeblood of the ancient kingdoms and modern cities in the states of Karnataka and Tamilnadu. This river is the very life-guard of central Tamilnadu's agriculture. The five districts (Karur, Namakkal, Tiruchirappalli, Thanjavur and Nagapattinam) which depend on the Cauvery for irrigation produce over 40% of the food crops of Tamilnadu [1]. In addition to the bumper cropped agriculture and dense vegetation of the easternghats, the rapid industrialization and urbanization along the river bank are the supporting pillars of the economic development of this part of the nation. On the other hand environmental degradation is felt intensely in this area [2]. For a sustainable progress, it is necessary to strike a balance between the two. To manage the environmental degradation, it is mandatory to assess the quality of the chief fresh water source, river Cauvery.

Water Quality Index (WQI) may be defined as the rating that reflects the composite influence of a number of water quality factors on the overall quality of water. It reduces the large amount of water quality data to a single numerical value. It is one of the most effective ways to communicate information on water quality trends to policy makers, to shape sound public policy and implement the water quality improvement programmes efficiently [3-5].

The chief objective of this study is to link the quality of water in river Cauvery through WQI and the distance from Tiruchirappalli city. This shall be helpful for the efficient improvement in water quality management and policy making.

2. Materials and Methods

2.1. Sampling Stations

For the present study, roughly about 28 km of the river in the Tiruchirappalli district has been selected. Four sampling stations were opted for specific reasons:

Station 1: Pettavaithai

The Uyyakondan canal confluences and increases the quantum of water into the river. One water pumping station is located here and distributes water to the local villages. Under the social forestry scheme monoculture of Eucalyptus was nurtured by the forest department.

Station 2: Upper Anicut

Upper anicut (Mukkombu) is the water reservoir and a beautiful picnic spot located in the outskirts of Tiruchirappalli at a distance of 13 km from the city, upstream. Mukkombu has various tourist attractions such as amusement park for children, sports facilities, fishing, etc.

The purpose of the dam is to divert the water of the river via irrigation canals across the fertile delta regions. Also the Coleroon river and branches off here for flood control.

Station 3: Kambarasampettai

The Kambarasampettai is located 3 km upstream from the Tiruchirappalli city. The Head Water Works (HWW) located in the river basin pumps 14,000 lpm of water to 3 reservoirs and the water is distributed throughout the city. The Kudamurutti River is a tributary of the river Cauvery, downstream of the Kambarasampettai. This river is polluted due to city sewage discharges and human activities. Since it traverses the city it is polluting the main river Cauvery.

Station 4: By-pass Bridge

It is located outside the Tiruchirappalli city at a distance of 3 km down stream. This bridge is a continuation of the National Highways (NH45) which connects Chennai (towards north) and Dindigul (towards south). Two sewage discharging points, one to the west (2 km upstream) and one to the east of the bridge are located on the southern bank of the river.

2.2. Water Sampling and Analyses

Water samples were collected on the second week of every month (Jan, Feb, and Mar- 2009), from all the four stations, by spot sampling [6]. It was done at about 0.5m depth from the water surface, in pre-cleaned 2L plastic containers, after rinsing sufficiently in the same water.

pH and dissolved oxygen (DO) were measured in-situ through portable hand pH meter (HI96107 - Hanna Instruments) and by the modified Winkler's method respectively. The collected samples were immediately transferred and the other water quality parameters (TDS, total hardness, total alkalinity, BOD, chloride, sulphate, nitrate & calcium) were analyzed in the Water Analyses Laboratory, Department of Environmental Sciences, Bishop Heber College, Tiruchirappalli. All water quality analyses were carried out as per APHA [7]. To find out the significance of the results, one way ANOVA (SPSS 14 Evaluation) was applied.

2.2. Water Quality Index

In order to calculate the Water Quality Index, all the 10 physico-chemical parameters have been utilized [8-12].

Table 1. The permissible values of various pollutants for drinking water (expressed in mg/l except pH) recommended by the CPCB and Indian Standards have been quoted

Sl. No.	Parameters	CPCB	IS (10500)
1	pH	6.5 - 8.5	6.5 - 8.5
2	TDS	500	500
3	Total Hardness	300	300
4	Total Alkalinity	200	200
5	DO	6.0	-
6	BOD	2.0	-
7	Chloride	250	250
8	Sulphate	200	200
9	Nitrate	20	45
10	Calcium	75	75

Weighting: The word weighting implies relative significance of each of the factor in the overall water quality and it depends on the permissible level in drinking water, as suggested by CPCB (Central Pollution Control Board) [13] and Bureau of Indian Standards (BIS: 10500) [14]. Factors which have higher permissible limits are less harmful and have low weightings. Therefore, $Wi = K/S_n$

Where,

W_i - Unit weight of chemical factor, K - constant of proportionality and is given as:

$$K = \frac{1}{1/Vs_1 + 1/Vs_2 + \ldots\ldots\ldots\ldots + 1/Vs_n}$$

S_n - standard value of i^{th} parameter

Rating scale: Each chemical factor has been assigned a water quality rating to calculate WQI.

$Qi = 100\ [(V_a-V_i)/(V_s-V_i)]$

Where,

V_a - average of measured values in the water sample for three months at one place

V_s - standard value of i^{th} parameter

V_i - ideal value for pure water (0 for all parameters except pH and DO)

The above equation becomes: $Q_i = 100\ (V_a/V_s)$

For dissolved oxygen (DO): The ideal value = 14.6 mg/l; permissible value = 6 mg/l, $QDO = 100\ [(V_a-14.6)/(6-14.6)]$.

For pH: The ideal value = 7.0; Max. Permissible value = 8.5, $QpH = 100\ [(V_a-7.0)/(8.5-7.0)]$

Water Quality Index (WQI) = $[\sum(Q_iW_i)/\sum W_i]$

Where,

$\sum(Q_iW_i)$ - Q_i (pH) X W_i (pH) + Q_i (DO) X W_i (DO) + ……+ Q_i (Ca) X W_i (C_a).

$\sum W_i$ - total unit weight of all chemical factors.

Using the water quality index, all the samples were categorized into the following five classes: excellent (0 - 25), good (26 - 50), moderately polluted (51 - 75), severely polluted (76 - 100) and unfit for human consumption (above 100) based on their suitability [15]. According to Padmanabha and Belagali [5], 0 < WQI < 100 indicates that the water is fit for human use and 0 > WQI > 100 reflects its unsuitability for use.

Table 2. Physico-chemical parameters and WQI at Pettavaithalai (S1)

Sl. No.	Parameters (mg/l except pH)	Jan	Feb	Mar	V_a	W_i	Q_i	Q_iW_i
1	pH	8.4	8.8	8.6	8.6	0.136	106.7	14.51
2	TDS	410	500	500	470	0.002	94.0	0.19
3	Total Hardness	169	162	160	163.67	0.004	54.56	0.22
4	Total Alkalinity	200	210	190	200	0.006	100	0.6
5	DO	7.7	8.0	7.8	7.83	0.192	78.72	15.11
6	BOD	1.9	1.6	0.9	1.47	0.577	73.5	42.41
7	Chloride	51	86	94	77	0.005	30.8	0.15
8	Sulphate	13.2	24.6	28.6	22.13	0.006	11.07	0.07
9	Nitrate	0.01	0.15	0.1	0.087	0.058	0.435	0.03
10	Calcium	40.1	32.5	38.5	37.03	0.015	49.37	0.74

$\sum W_i = 1.001$; $\sum Q_iW_i = 74.03$; WQI = 73.96

Table 3. Physico-chemical parameters and WQI at Upper anicut (S2)

Sl. No.	Parameters (mg/l except pH)	Jan	Feb	Mar	V_a	W_i	Q_i	Q_iW_i
1	pH	8.4	8.7	8.6	8.57	0.136	104.67	14.24
2	TDS	480	500	520	500	0.002	100	0.2
3	Total Hardness	154	171	180	168.33	0.004	56.11	0.22
4	Total Alkalinity	210	220	210	213.33	0.006	106.67	0.64
5	DO	7.9	7.8	7.7	7.8	0.192	79.07	15.18
6	BOD	0.7	2.3	1.5	1.5	0.577	75	43.28
7	Chloride	60	83	100	81	0.005	32.4	0.16
8	Sulphate	18.1	26.8	28.6	24.5	0.006	12.25	0.07
9	Nitrate	0.014	0.1	0.1	0.071	0.058	0.36	0.02
10	Calcium	36.1	33.2	43.3	37.53	0.015	50.04	0.75

$\sum W_i = 1.001$; $\sum Q_iW_i = 74.76$; WQI = 74.69

Table 4. Physico-chemical parameters and WQI at Kambarasampettai (S3)

Sl. No.	Parameters (mg/l except pH)	Jan	Feb	Mar	V_a	W_i	Q_i	Q_iW_i
1	pH	8.4	8.7	8.6	8.57	0.136	104.67	14.24
2	TDS	480	500	520	500	0.002	100	0.2
3	Total Hardness	154	171	180	168.33	0.004	56.11	0.22
4	Total Alkalinity	210	220	210	213.33	0.006	106.67	0.64
5	DO	7.9	7.8	7.7	7.8	0.192	79.07	15.18
6	BOD	0.7	2.3	1.5	1.5	0.577	75	43.28
7	Chloride	60	83	100	81	0.005	32.4	0.16
8	Sulphate	18.1	26.8	28.6	24.5	0.006	12.25	0.07
9	Nitrate	0.014	0.1	0.1	0.071	0.058	0.36	0.02
10	Calcium	36.1	33.2	43.3	37.53	0.015	50.04	0.75

$\sum W_i = 1.001$; $\sum Q_iW_i = 85.29$; WQI = 85

3. Results and Discussions

The physico-chemical characteristics of all samples are shown in the Tables 2 - 5 (Stations 1 - 4). It has been found that some of the parameters exceeded the limit of the CPCB and BIS standards (Table 1). Out of the 10 water quality parameters, pH, total alkalinity and dissolved oxygen are not significantly different and other parameters are significantly differing, during the study period (Table 6).

Among all stations on all sampling days, there is no significant variation in the pH values (8.0 - 8.8). In general the pH values are alkaline in all stations and are close to the permissible limits. The pH changes may be due to the variation in photosynthetic activities of aquatic plants, which increases due to consumption of dissolved carbon dioxide in the process [16].

Table 5. Physico-chemical parameters and WQI at By-pass Bridge (S4)

Sl. No.	Parameters (mg/l except pH)	Jan	Feb	Mar	V_a	W_i	Q_i	Q_iW_i
1	pH	8.5	8.2	8.0	8.23	0.136	82.0	11.15
2	TDS	460	610	670	580	0.002	116	0.23
3	Total Hardness	154	194	214	187.33	0.004	62.44	0.25
4	Total Alkalinity	200	250	260	236.67	0.006	118.34	0.71
5	DO	7.8	6.3	5.6	6.57	0.192	93.37	17.93
6	BOD	1.3	4.2	6.0	3.83	0.577	191.5	110.5
7	Chloride	46	108	121	91.67	0.005	36.67	0.18
8	Sulphate	16.9	30.1	31.1	26.03	0.006	13.02	0.08
9	Nitrate	0.006	0.41	0.25	0.222	0.058	1.11	0.06
10	Calcium	39.3	46.2	54.5	46.67	0.015	62.23	0.93

$\sum Wi = 1.001$; $\sum QiWi = 142.02$; WQI = 141.88

Table 6. The mean values of physico-chemical parameters

Sl. No.	Variables	Mean of Stations				Statistical Inference
		Jan	Feb	Mar	Mean	
1	pH	8.5	8.6	8.5	8.5	Not significant
2	TDS (mg/l)	407.5	550.0	605.0	520.8	Significant
3	Total Hardness (mg/l)	165.1	184.0	202.5	183.9	Significant
4	Total Alkalinity (mg/l)	205.0	235.0	240.0	226.7	Not significant
5	DO (mg/l)	7.8	7.3	7.2	7.4	Not significant
6	BOD (mg/l)	1.0	3.1	4.3	2.8	Significant
7	Chloride (mg/l)	48.9	96.6	114.9	86.8	Significant
8	Sulphate (mg/l)	12.05	28.18	30.13	23.45	Significant
9	Nitrate (mg/l)	0.01	0.25	0.23	0.16	Significant
10	Calcium (mg/l)	40.10	38.25	49.50	42.62	Significant

Not only pH but also dissolved oxygen is directly related to photosynthesis. During the night, when there is no photosynthesis, the loss of oxygen through respiration is high since there is no counterbalance of oxygen and hence the DO may steadily decline. It is lowest just before dawn, when photosynthesis resumes [17]. The values of DO in the sampling stations are 5.6 - 8.0 mg/l during three months of study. The lowest amount of DO (5.6 mg/l) was estimated in the month of March at the By-pass Bridge (S4). This could be because of the heavy oxygen demand due to organic pollutants closer to the city. The heavy biological oxygen demand at S4 (Table 5) supports this.

High values of biological oxygen demand (0.6 - 6.0 mg/l) were observed in the down stream station (S4) of river Cauvery (Tables 2 - 5). A similar observation has been made previously by Tiwary et al [18] in the river Ganga. They reported a daily discharge of 8.2 million gallons of sewage and sullage in to the Ganga. Apart from sewage, the presence of organic pollution can be attributed to the non-point sources of agriculture run-off scattered over the entire study area.

The range of total dissolved solids (TDS) is 410 - 670 mg/l during the study period. In the months of February & March, the values at station 4 are well above the permissible limits. Water sample from this spot consists of high amounts of minerals, both anions & cations. According to Martin and Haniffa [19], the increase in total dissolved solids is due to urban anthropogenic impact which can be often complicated by intense local agricultural activity leading to local, spatial and temporal variability in the run-off.

The determined total hardness in all stations is 154 - 214 mg/l (Tables 2 - 5). The hardness is well within permissible limits. The variations of total hardness every month in all stations are due to the fluctuations in the quantity of water and waste disposals in the river. The hardness in the water is due to the dissolved minerals from sedimentary rocks, seepage and run-off [17]. Detergents and soaps also aggravate the situations [20].

The ranges of total alkalinity in all the sampling stations are 190 - 260 mg/l during the three months. These values exceed the permissible limit (200 mg/l), except S1 & S3 in the month of January. The hydroxides, carbonates and bicarbonates probably released from limestone, sedimentary rocks, carbonate-rich soils, cleaning agents, food residue, discharge of city sewage and domestic solid wastes contribute to the alkalinity [21].

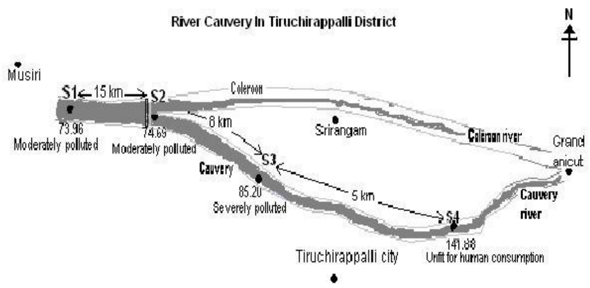
The range of chloride value is 46.1 - 121 mg/l in all stations on the sampling days. The chloride reaches the river from different anthropogenic activities like septic tank effluents, animal feeds, use of bleaching agents by launderer and washing of cloths. In the present study, the determined sulphate values in all sampling stations are 13.2 - 31.1 mg/l. The domestic waste and untreated sewage are responsible for the higher level of sulphate in the Umkhrah water [21].

The values of nitrate in the study stations are well below the permissible limits (0.006 to 0.41 mg/l). The most important source of nitrate is the biological oxidation of organic nitrogenous substances. Also nitrate in river Cauvery may result from point and non-point sources such as sewage disposal systems, faulty septic tanks, soil erosion, livestock wading, parks and gardens of the picnic spot, bathing, and washing cloths in river banks.

The disposal of sewage tends to increase the calcium content in water [21]. But the calcium content in all sampling stations (32.5 to 54.5 mg/l) is sufficiently well within recommended standard values.

The values of WQI at locations 1, 2, 3, & 4 are 73.96, 74.69, 85.20, and 141.88 respectively. Stations 1 & 2 are moderately polluted, station 3 is severely polluted in quality and station 4 is unfit for human consumption. It is due to the anthropogenic activities such as bathing, cleaning, fishing, open defecation and leachates from solid wastes like the paper, polythene bags, plastic cups, sachets, straws, cloths and leaves in addition to municipal sewage, which are non-point sources of pollution in the study area. The progressive increase in the WQI from the upstream towards the downstream of the river is due to the cumulative effect of the pollutants (Fig. 1). The closer the sampling station to the city, the more it is polluted (S4) and farther the station, the least it is polluted (S1).

Figure 1. Sampling stations in river Cauvery and its WQI values



Station 1 is a rural settlement (28 kms from Tiruchirappalli city) and station 2 though rural is a picnic spot (13 kms from Tiruchirappalli city). Station 3 is a sub-urban location, upstream of river (2 kms from Tiruchirappalli city) and station 4 is an urban area, downstream of the river (2 kms after the Tiruchirappalli city). The impact of urban discharges of sewage and solid wastes are the heaviest at station 4 since it is downstream to the city. There are two major sewage discharge canals between station 3 & 4 polluting the river considerably. Patil et al [12] during the study in the waters of Kundalika river have found out that the merging of wastewater considerably increases the WQI.

Moreover, the width of the river also progressively decreases (Fig. 1) from Stations 1 - 4 due to diversion of the river into number of distributaries for irrigation through the Upper anicut (station 2). Thus urbanization seems to be the chief reason for river pollution in this study area.

The variations of WQI values every month in all stations are due to the fluctuations in the quantity of water and wastes disposals in the river (sewage and solid wastes). Decreased water flow and rate of evaporation are the causes for the severe pollution in the month of March. Similar result was recorded by Jameel and Hussain [4] in the Water Quality Index of Uyyakondan channel of river Cauvery at Tiruchirappalli.

4. Conclusions

Closeness of the sampling stations to the Tiruchirappalli city has resulted in the deterioration of the quality of river Cauvery water. This confirms urbanization along the river banks to be the cause for the river water pollution. Immediate management to protect the river Cauvery water and hence the public health are mandatory for a sustainable development of Tiruchirappalli district.

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