e-ISSN:2347-7830
p-ISSN:2347-7822

Research & Reviews : Journal of Ecology and Environmental Sciences

Ecological Health Assessment of Perennial River Tamirabarani, Tamilnadu, India

Mophin-Kani K and Murugesan AG*

*Manonmaniam Sundaranar University, Sri Paramakalyani Centre of Excellence in Environmental Sciences, Alwarkurichi, Tirunelveli - 627 412. Tamil Nadu, India.

Research Article

Received date: 30/5/2015
Accepted date: 20/6/2015
Published date: 28/6/2015

***For Correspondence**

Murugesan AG, Manonmaniam Sundaranar University, Sri Paramakalyani Centre of Excellence in Environmental Sciences, Alwarkurichi, Tirunelveli - 627 412. Tamil Nadu, India.

Email: agmspkce@rediffmail.com; kmophin@gmail.com

Keywords: Water quality, River Tamirabarani, Oxygen demand, Domestic activities, Self-purification, Coliform organisms

ABSTRACT

Water samples were collected from the perennial river Tamirabarani over a distance of 125 km to assess the health status of the flow before it convergence with Bay of Bengal. Twelve sampling points were selected and the water samples were examined with physicochemical along with coliform content. Significant spatial and temporal variations were recorded; which classified the river quality in to 5 classes correspondingly "A" to "E". Overall the quality of the river at downstream areas was poor compared with upstream locations with respect to its direct use value. Highest DO, BOD and COD levels were recorded as 10.47 mg/l, 10.02 mg/l and 17 mg/l respectively. Total and fecal coliform content were high are suburban and urban reaches as 2800 and 340 MPN/ml and 3500 and 2800 MPN/ml respectively during the study period and at different localities.

INTRODUCTION

Water is an integral component of the environment, responsible for various life processes and hence persistence of life on this planet. Rapid urbanization, population explosion, and industrialization have increased the pollution stress and quality deterioration [1]. Almost all Indian rivers act as carrier of raw or semi treated sewage, industrial effluents, domestic debris, and runoff from irrigational and urban areas [2-5]. The surface water pollution has been enlisted as one of the most serious problems in developing countries like India.

Running water is capable of purifying itself with distances through a process known as self purification. It is carried out by physical chemical and biological process which work simultaneously and purify the system as it moves downstream areas.

Rivers remain in the heart of societal development, especially, housing and other infrastructural aspects. All types of sanitization and disposal are randomly made through rivers without any second thought. River streams have been a natural source for water for all human activity. Therefore, it is important to investigate the pollution status of the rivers regularly considering the heavy disposal of garbage and pollutants.

Also, they are important in maintaining the soil fertility, forest and wildlife conservation activities. Therefore, river water quality monitoring program is necessary in order to safeguard public health as well as to safeguard the ecosystem [6]. Water pollution due to anthropogenic activities at river Tamirabarani has been reported in earlier studies [7-15]. However, there is a need

e-ISSN:2347-7830
p-ISSN:2347-7822

to study the self purification status and to classify the river basin, especially from the upstream area up to the convergence point. In that context, present study is planned to assess quality along with the self purification ability of the perennial river Tamirabarani and to classify the suitability of water for different uses.

Description of the Study Area

River Tamirabarani (**Figure 1**) is the only perennial river in southern parts of Tamil Nadu, India; one of the most important river because of its water flow throughout the year in comparison with other rivers (i.e., Chittar river, Vaigai river) in southern parts of Tamil Nadu; it supplies potable water and it is used for domestic, agricultural, industrial, and recreational purposes for two major districts (Tirunelveli and Thoothukkudi) with the population of about 42, 96, 261 (2001 census). The river originates at the eastern slops of Western Ghats at an altitude of 1725m above MSL between latitude 8°30'N and 9°18'N and between longitude 77°07'30"E and 78°15'E. The main river drains huge volume of water with its large network of springs with the catchment area of 4400 sq.km. Since all its main tributaries are arising from the Western Ghats, the river is prone to heavy flood especially during north east monsoon period. The river flows about 125 km through dense populated areas from Pabanasam region (Tirunelveli district) and convergence with the Bay of Bengal at Gulf of Mannar region. River Servalar, Manimuthar, Koraiyar, Gadana, Pachaiyar and Chittar are the principle tributaries of the river. Rapid urbanization, agricultural activities, domestic activities like bathing and washing, huge gathering for taking holy dip, open defecation, direct discharge of sewage and domestic remains increases pollution threat to the river and its tributaries.

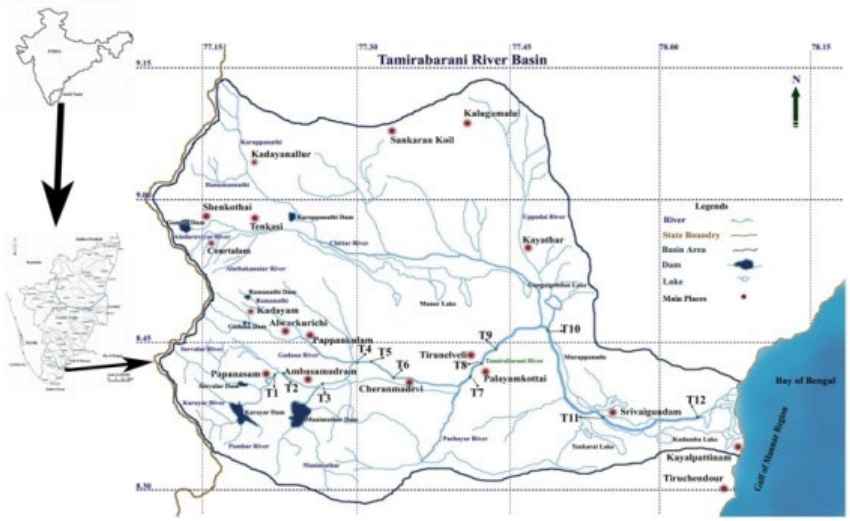

Figure 1. Study Area.

MATERIALS AND METHODS

Sampling

The water samples were collected first week of every month at 12 different locations (T1-T12) of main river flow (**Table 1** and **Figure 1**) during the period of January 2008-March 2009. Sampling, preservation, and transportation of the water samples to the laboratory were carried out as per standard methodologies.

Table 1. Geographical positions of the sampling sites of river Tamirabarani.

Site ID	Locations	Latitude	Longitude
T1	Pabanasam	8°42'39"N	77°22'2"E
T2	V.K.Puram	8°42'25"N	77°22'56"E
T3	Ambasamudram	8°41'38"N	77°27'43"E
T4	Thiruppudaimaruthur	8°43'41"N	77°29'45"E
T5	Mukkudal	8°43'57"N	77°30'48"E
T6	Cheranmahadevi	8°42'4"N	77°33'56"E
T7	Kurukkuthurai	8°42'37"N	77°41'49"E
T8	Tirunelveli - Kokkirakulam	8°43'38"N	77°42'49"E
T9	Tirunelveli - Vannarappettai	8°44'21"N	77°43'6"E
T10	Seevalapperi	8°46'53"N	77°48'36"E
T11	Srivaigundam	8°37'35"N	77°54'44"E
T12	Aattur	8°37'35"N	78° 4'8"E

Analysis

The water temperature (T), pH and electrical conductivity (EC) were measured in situ with portable multi parameter meter

(PCSTester 35 series; Eutech Instruments) and the turbidity was measured with portable turbidometer (TDY) (TN-100; Eutech Instruments). Chemical (dissolved oxygen (DO), suspended solids (SS), total hardness (TH), chemical oxygen demand (COD), biological oxygen demand (BOD), ammoniacal nitrogen (AN), nitrite nitrogen (NO_2), nitrate nitrogen (NO_3), phosphate (PO_4), sulphate (SO_4), calcium (Ca), magnesium (Mg), sodium (Na) and potassium (K)) and biological (total coliforms (TC) and fecal coliforms (FC)) analysis was carried out based on APHA (1999) methods.

According to the studied parameters, the water quality of the river is classified based on the national [16] and international [17] water quality criteria. The results obtained were statistically analyzed using MS excel (Version 2007) and SPSS (Pearson correlation) package (Version 15).

RESULTS and DISCUSSION

Results of the present study are presented in the form of descriptive summary in **Tables 2 and 3** respectively.

Table 2. Descriptive statistics for physicochemical parameters of the river Tamirabarani.

Station		T	pH	EC	DO	TDY	TSS	TH	NH_4N	NO_2	NO_3	PO_4	COD	BOD	SO_4	Ca	Mg	Na	K	TC	FC
T1	Mean	25.193	7.619	56.387	7.676	1.331	2.067	30.111	0.022	0.009	0.229	0.621	5.267	1.351	3.292	4.449	0.283	7.147	0.607	83.533	16.400
	SD	1.650	0.358	16.835	1.041	0.872	1.438	16.076	0.035	0.012	0.171	0.739	2.685	0.690	2.132	2.239	0.140	3.522	0.365	110.670	25.102
	Variance	2.724	0.128	283.408	1.083	0.761	2.067	258.435	0.001	0.000	0.029	0.546	7.210	0.476	4.547	5.013	0.020	12.403	0.134	12247.838	630.114
	Minimum	22.6	7.03	33.47	6.133	0.13	1	12	0	0	0.022	0.157	3	0.456	0.99	2.004	0.122	1	0.2	2	2
	Maximum	28	8.31	93.5	9.86	3.24	6	66	0.112	0.048	0.515	2.913	13	2.6	7.74	8.818	0.656	12.6	1.4	340	90
T2	Mean	25.393	7.764	81.027	7.163	1.386	2.533	35.000	0.037	0.009	0.394	0.713	6.600	2.033	5.256	6.185	0.304	10.493	0.707	79.067	21.733
	SD	1.803	0.343	41.015	1.004	0.552	1.598	16.997	0.035	0.008	0.179	0.490	3.906	1.478	3.394	3.563	0.108	6.191	0.554	90.219	39.458
	Variance	3.249	0.118	1682.197	1.009	0.305	2.552	288.893	0.001	0.000	0.032	0.240	15.257	2.185	11.522	12.697	0.012	38.328	0.306	8139.495	1556.924
	Minimum	22.6	7.35	33.85	4.8	0.6	1	15.5	0	0	0.173	0.184	2	0.61	1.012	2.605	0.134	2.1	0.3	7	2
	Maximum	28.5	8.39	177.8	9.06	2.4	7	66	0.112	0.025	0.84	2.336	15	6.4	12.956	14.429	0.535	22.4	2.4	330	140
T3	Mean	26.227	7.575	107.080	6.723	1.888	3.867	48.311	0.078	0.013	0.472	0.772	7.533	2.562	5.452	10.301	0.349	11.547	1.007	160.467	36.067
	SD	1.716	0.329	49.021	1.126	1.409	2.503	29.653	0.059	0.014	0.202	0.388	3.420	1.134	2.619	6.368	0.203	5.197	0.938	114.438	46.731
	Variance	2.944	0.108	2403.102	1.268	1.985	6.267	879.273	0.003	0.000	0.041	0.150	11.695	1.287	6.858	40.551	0.041	27.010	0.881	13096.124	2183.781
	Minimum	24	6.98	47.13	5.2	0.47	1	16.5	0	0	0.204	0.131	4	0.55	1.16	2.806	0.012	4.3	0.3	17	2
	Maximum	30	8.18	223.53	8.81	4.8	10	120	0.168	0.056	1.015	1.469	14	4.8	10.83	24.048	0.729	22.1	4	340	170
T4	Mean	27.027	7.787	137.689	6.557	3.012	5.800	68.122	0.011	0.013	0.380	0.903	7.467	2.566	4.609	12.547	0.551	14.847	1.153	49.267	7.800
	SD	1.707	0.308	71.910	0.932	3.290	4.296	37.879	0.023	0.008	0.215	0.654	3.502	1.181	2.378	7.593	0.356	10.765	1.023	46.086	5.870
	Variance	2.914	0.095	5171.054	0.868	10.824	18.457	1434.831	0.001	0.000	0.046	0.428	12.267	1.394	5.654	57.647	0.127	115.896	1.047	2123.924	34.457
	Minimum	25	7.41	56.12	5.2	0.7	2	18	0	0	0.099	0	3	0.85	1.19	4.008	0.194	5.2	0.3	11	2
	Maximum	30.3	8.3	285.57	8.333	9.6	15	126	0.056	0.026	0.952	1.826	16	4.88	8.54	30.46	1.31	40.7	4	170	26
T5	Mean	27.280	7.731	140.481	6.613	2.971	6.067	75.244	0.045	0.011	0.390	1.021	7.333	2.351	6.208	14.117	0.608	14.453	1.100	68.933	15.933
	SD	1.949	0.348	68.485	1.231	2.697	3.788	63.724	0.038	0.009	0.250	0.629	4.030	1.607	3.600	9.711	0.484	5.917	0.901	88.248	29.202
	Variance	3.797	0.121	4690.174	1.515	7.273	14.352	4060.789	0.001	0.000	0.063	0.396	16.238	2.582	12.961	94.304	0.234	35.010	0.811	7787.781	852.781
	Minimum	25	7.15	61.78	4	0.47	2	21	0	0	0.031	0.007	2	0.809	1.23	4.008	0.097	6.5	0.4	12	2
	Maximum	30.9	8.3	292.95	8.533	9.3	16	272	0.112	0.029	1.013	1.867	14	6.1	12.36	40.08	2.089	28.9	3.8	340	120
T6	Mean	28.427	7.726	137.356	6.678	5.018	6.800	57.033	0.063	0.016	0.449	1.250	7.133	2.373	6.143	12.424	0.457	15.387	1.213	99.000	26.933
	SD	2.374	0.247	59.479	1.079	5.162	5.894	26.720	0.051	0.014	0.277	0.999	2.825	1.618	3.045	7.743	0.242	5.755	1.000	111.384	46.667
	Variance	5.638	0.061	3537.761	1.164	26.643	34.743	713.981	0.003	0.000	0.077	0.997	7.981	2.619	9.273	59.951	0.059	33.118	1.000	12406.429	2177.781
	Minimum	25	7.36	69.86	4.4	1.11	2	24	0	0	0.013	0.046	3	0.71	2.025	3.407	0.146	7.3	0.4	14	2
	Maximum	32	8.27	298.59	8.467	16.4	22	120	0.168	0.056	1.087	3.281	13	5.06	13.16	30.262	0.851	29.7	4.1	340	170

Table 3. Descriptive statistics for physicochemical parameters of the river Tamirabarani.

Station		T	pH	EC	DO	TDY	TSS	TH	NH_4N	NO_2	NO_3	PO_4	COD	BOD	SO_4	Ca	Mg	Na	K	TC	FC
T7	Mean	28.767	7.729	172.678	6.706	3.387	6.267	67.233	0.090	0.030	0.532	1.460	7.600	2.516	7.675	15.965	0.466	18853	1.473	393.067	95.400
	SD	2.290	0.287	77.978	1.294	2.533	3.807	26.917	0.066	0.029	0.307	1.152	3.269	1.622	3.906	9.131	0.262	8.337	1.137	732.517	124.378
	Variance	5.245	0.082	6080.552	1.676	6.416	14.495	724.531	0.004	0.001	0.094	1.326	10.686	2.631	15.256	83.384	0.069	69.498	1.294	536580.924	15469.829
	Minimum	25	7.3	82.14	4	0.62	2	28	0	0	0.111	0.18374	4	0.2	2.68	5.611	0.024	9.6	0.5	17	7
	Maximum	33	8.34	387.68	8.64	9.7	15	126	0.224	0.112	1.178	3.2642	15	6.8	15.59	39.278	0.972	39.2	4.5	2800	340
T8	Mean	29.247	7.869	178.853	6.839	3.622	7.133	69.789	0.153	0.021	0.545	1.542	9.000	3.829	7.649	15.012	0.560	21447	1.713	820.933	295.667
	SD	2.488	0.291	72.367	1.167	2.227	4.518	27.100	0.100	0.041	0.349	1.323	4.520	1.145	3.668	6.996	0.254	8.785	1.294	1219.595	711.817
	Variance	6.190	0.084	5236.985	1.361	4.961	20.410	734.407	0.010	0.002	0.122	1.751	20.429	1.312	13.456	48.940	0.064	77.180	1.674	1487413.067	506683.667
	Minimum	26	7.33	90.5	4.4	0.8	2	33	0	0	0.091	0.007	3	2.1	2.93	7.014	0.170	10.9	0.6	34	9
	Maximum	33	8.31	362.53	9.32	8.01	17	138	0.28	0.168	1.135	3.4642	16	6.2	16.342	32.064	0.996	41.4	5.4	3500	2800
T9	Mean	29.193	7.741	181.585	6.219	3.443	6.133	71.867	0.086	0.031	0.482	1.532	7.333	3.233	7.362	15.097	0.580	21607	1.807	264.867	75.333
	SD	2.269	0.386	69.570	0.987	2.695	4.190	29.727	0.070	0.022	0.307	1.288	3.811	1.835	3.229	6.508	0.239	8.661	1.246	409.527	76.706
	Variance	5.148	0.149	4839.977	0.975	7.261	17.552	883.695	0.005	0.001	0.094	1.658	14.524	3.366	10.425	42.360	0.057	75.019	1.552	167712.41	5883.810
	Minimum	26.3	7.05	91.08	4	0.96	2	34	0	0	0.091	0.085	3	0.439	3.033	7.4148	0.170	11.9	0.8	33	7

	Maximum	33.5	8.35	348.37	7.43	10.37	15	148	0.224	0.0686	1.178	3.6936	17	7.6	13.05	28.056	0.92	43.5	5.2	1700	260
T10	Mean	29.227	7.836	236.240	6.022	3.335	5.800	97.467	0.049	0.061	0.542	1.516	6.800	3.380	9.544	19.586	0.837	30.060	2.147	88.933	27.200
	SD	2.308	0.355	98.031	1.523	2.490	3.629	47.435	0.042	0.093	0.299	1.280	3.256	2.359	4.589	8.907	0.393	14.236	1.241	82.834	34.520
	Variance	5.328	0.126	9610.169	2.320	6.199	13.171	2250.088	0.002	0.009	0.089	1.638	10.600	5.565	21.062	79.343	0.155	202.671	1.541	6861.495	1191.600
	Minimum	26.3	7.36	110.85	2.8	0.62	2	43.5	0	0	0.073	0.0525	2	1.073	2.36	7.014	0.316	15	0.9	13	4
	Maximum	33.7	8.38	446.74	8.568	8.99	13	218	0.112	0.0284	1.059	3.2658	15	10.2	18.575	36.072	1.555	65.4	5.3	330	140
T11	Mean	29.627	7.871	242.343	6.737	4.499	5.600	100.111	0.071	0.012	0.452	1.245	6.733	2.305	8.306	21.497	0.813	28.353	2.865	127.867	33.067
	SD	2.514	0.204	82.701	1.297	3.188	3.757	29.426	0.058	0.013	0.252	0.957	3.973	1.004	2.541	6.827	0.301	11.667	1.098	147.728	68.762
	Variance	6.321	0.041	6839.413	1.681	10.166	14.114	865.864	0.003	0.000	0.064	0.916	15.781	1.008	6.457	46.612	0.090	136.123	1.205	21823.695	4728.210
	Minimum	26.2	7.5	132.94	5.1	0.3	2	57.5	0	0	0.013	0.085	2	1.093	3.053	10.4208	0.3888	14.4	1.3	17	4
	Maximum	34	8.2	449.92	10.47	9.97	11	174	0.168	0.056	0.812	2.575	16	4.73	11.89	35.2704	1.385	54.6	4.9	500	270
T12	Mean	30.313	8.006	385.791	6.521	5.800	7.600	151.100	0.119	0.017	0.475	1.842	9.533	2.837	14.020	30.300	1.303	49.200	4.740	257.067	54.867
	SD	2.700	0.184	88.508	1.220	3.746	3.621	58.416	0.087	0.028	0.264	1.592	4.015	1.900	4.125	7.644	0.602	16.407	0.890	419.705	85.164
	Variance	7.288	0.034	7833.606	1.488	14.032	13.114	3412.400	0.008	0.001	0.069	2.533	16.124	3.611	17.018	58.438	0.362	269.181	0.793	176151.924	7252.981
	Minimum	26.4	7.74	229.82	4.8	1.67	4	98	0	0.001	0.044	0.0788	3	0.568	7.142	14.028	0.5832	22.6	2.9	26	9
	Maximum	36	8.24	535.36	8.71	13.37	15	344	0.224	0.112	0.949	4.6458	16	6.9	21.892	43.286	2.8674	79.3	6.3	1700	330

(n=15 months)

Temperature of an aquatic system is an important factor and also plays a vital role in the solubility of gases and alters the saturation levels of gases. The minimum T level observed during the study was 22.6ºC (January 2009) at location T1 and the maximum T level was 36ºC (May 2008) at location T12, the overall mean level is 27.9ºC at the river Tamirabarani.

pH is considered as an index for measuring the pollution content for acidic and alkaline wastes. It remains as the critical factor for survival of aquatic plants and planktonic organisms [18]. The minimum pH was measured as 6.98 (February 2009) at location T3, maximum was recorded as 8.39 (January 2008) at location T1 and the mean pH level recorded was 7.77.

Conductivity mostly depends on the nature of various dissolved ionized substances of an aquatic system [18]. Electrical conductivity of the river was observed between 33.47 µS/cm (January 2009) at location T1 and 535.36 µS/cm (March 2008) at location T12, and the mean EC is 171.46 µS/cm. The pH and EC values of all months and at all sampling locations are compatible with the standard levels prescribed by CPCB and WHO.

DO is one of the most valuable indicators in the determination of water quality of a river health; most of the physical, chemical, and biological activities are directly related to the DO content in natural and wastewater [19].

The observed minimum DO level was 2.8 mg/l at location T10 during the month of April in 2008 and the maximum level recorded as 10.47 mg/l in the month of August 2008 at location T11. The overall mean DO level was 6.7 mg/l. Higher DO level at location T11 was due to higher photosynthetic activity at upstream sides of the check-dam and high turbulence activity within the dam premises due to high wind flow. Observation of lowest level of DO may be due to the direct discharge of organic rich sewage from urban discharges at Tirunelveli and Palayamkottai. Similar observation was found by Mohanraj et al. As DO drops below 4 or 5 mg/L, it may be lethal to the life forms. A minimum of about 2.0 mg/L of dissolved oxygen is required to maintain higher life forms.

The observed level of TDY was within the range of 0.13 -16.4 (nephelometric turbidity units) NTU at location T1 in March 2009 and at location T6 in November 2008 respectively. The overall mean TDY level was 3.31 NTU. Turbidity levels during the months of September October and November exceeded the standard value at downstream areas after location T6; due to the higher runoff from the agricultural, suburban and urban areas during the northeast monsoon period.

Suspended solids of the water samples varied between 1 (at locations T1, T2 and T3 during various months) and 22 mg/l (November 2008) at location T6 during the study and the overall mean SS content is 5.47mg/l. The levels showed higher SS content during northeast monsoon period. The TH content of the samples was observed between 12 and 344 mg/l at locations T1 and T12 respectively during the months of September 2008 and May 2008; the overall mean level is 72.62 mg/l.

Ammoniacal nitrogen in samples was observed in the range of 0-0.28 mg/l during the study, higher level was recorded at location T8 during the month of July 2008 whereas absence of a content record at upstream areas especially during the northeast monsoon periods. Nitrite content of the river water was recorded between 0 - 0.03 mg/l during the period of study, the overall mean NO_2 is 0.02 mg/l. highest level was recorded at location T10 during March month of the year 2008. Nitrate is the end product of aerobic decomposition of organic matter and is the most oxidized form of nitrogen commonly present in natural waters [18-19]. Nitrate level of the samples were recorded in the range of 0.013-1.18 mg/l at locations T11 and T7, T9 respectively during the months of February and October 2008, and the overall mean NO_3 level is 0.45 mg/l. Phosphate is an essential plant nutrient and play as an important limiting factor and responsible for the growth of phyto-planktons in aquatic systems [20,21]. Phosphate level of the samples ranged between 0 (June 2008, at location T4) and 4.65 mg/l (November 2008 and January 2009, at location T12), and the overall mean PO_4 content is 1.2 mg/l. Presence of ammonia and other nitrogenous sources may result in eutrophication and anoxic conditions [22]. Nutrient content of the river water during the study was well within the standard levels

prescribed by CPCB and WHO whereas phosphate values in many stretches exceeded the standard limit of (0.1 mg/l) US Public Health Standards [23]. Higher agricultural practices, natural leeching of ore rocks along with higher human disturbances enrich the PO_4 content [24].

The COD is a measure of oxygen equivalent to the organic matter content of the water susceptible to oxidation by a strong chemical oxidant and thus is an index of organic pollution in the aquatic ecosystems [25]. The COD level of the samples was recorded between 2 and 17 mg/l (location T9), and the overall mean COD level is 7.36 mg/l. During summer the COD content of the entire river stretch exceeded the standard level (10 mg/l), and mainly downstream areas after location T2 showed exceeded levels during various months of the study. BOD is an approximate measure of the amount of biochemically degradable organic matter present in the water and it is used mainly to determine degree of pollution in water bodies and their self-purification capacity, pollution stress of wastewaters, and efficiency of waste treatment plants [18-19]. The BOD level of the samples varied between 0.2 (T7) - 10.2 (T10) mg/l during the months of April and June 2008, and the overall mean BOD level is 2.6 mg/l. Unpolluted stretches like T1 and T4 had the BOD content of less than 5 mg/l; similar results were found by Schulze et al.[26].

Calcium and magnesium content of the river water was observed between 2-43.29 mg/l and 0.012-2.87 mg/l respectively, and the overall mean Ca and Mg levels are 14.79 and 0.59 mg/l during the study. Lowest sodium content was recorded as 1 mg/l at location T1 (August 2008), higher level recorded as 79.3 mg/l at location T12 (March 2008), and the overall mean Na is 20.28 mg/l. Potassium level of the water ranged between 0.2-6.3 mg/l at locations T1 (January 2008) and T12 (September 2008) respectively, and the overall mean K level is 1.71 mg/l.

Bacteriological assessment of the river water reveals that the TC content of the river were within 2-3500 MPN count/100 ml, and the overall mean TC level is 207.75 MPN count / 100 ml during the study. The FC content of the samples was recorded between 2-2800 MPN count / 100 ml, with the overall mean FC level of 58.87 MPN count / 100 ml. Higher coliform content of the river is mainly due to the higher human disturbances along the river and bank areas like huge gathering during festive occasions, open defecation, direct discharge of domestic and sewage wastes, discharges from farmhouses and runoff from urban and rural areas. Previous study carried out by Murugesan et al. [8,11,12] also observed similar results.

Correlation matrix observed among the physicochemical variables is given in **Table 4**. Positively strong correlation was observed between most of the variables and significant negative correlation is recorded between pH and total suspended solids (R^2=-0.224); conductivity and dissolved oxygen (R^2=-0.442); dissolved oxygen and biological oxygen demand (R^2=-0.506), total hardness (R^2=-0.379), calcium (R^2=- 0.433), magnesium (R^2=-0.236) and sodium (R^2=-0.406 at the level of p<0.01.

Table 4. Correlation matrix of water quality parameters of river Tamirabarani.

	T	pH	EC	DO	TDY	TSS	TH	NH_4N	NO_2	NO_3	PO_4	COD	BOD	SO_4	Ca	Mg	Na	K	TC	FC
T	1	.185(*)	.445(**)	-.111	.054	.074	.450(**)	.490(**)	.014	-.060	.055	.379(**)	.247(**)	.263(**)	.371(**)	.391(**)	.474(**)	.254(**)	.075	.013
pH	.185(*)	1	.419(**)	-.077	-.140	-.224(**)	.389(**)	.355(**)	.166(*)	-.045	-.029	.049	.116	.167(*)	.369(**)	.207(**)	.420(**)	.091	.057	.023
EC	.445(**)	.419(**)	1	-.442(**)	.227(**)	.149(*)	.828(**)	.386(**)	.266(**)	.101	.097	.078	.346(**)	.621(**)	.905(**)	.655(**)	.949(**)	.591(**)	.006	-.018
DO	-.111	-.077	-.442(**)	1	.014	.077	-.379(**)	-.184(*)	-.189(*)	.058	.050	-.066	-.506(**)	-.032	-.433(**)	-.236(**)	-.406(**)	-.025	.083	.122
TDY	.054	-.140	.227(**)	.014	1	.865(**)	.239(**)	-.102	-.003	.455(**)	.513(**)	.089	.093	.460(**)	.336(**)	.419(**)	.089	.657(**)	.063	.114
TSS	.074	-.224(**)	.149(*)	.077	.865(**)	1	.150(*)	-.078	-.016	.460(**)	.528(**)	.105	.037	.370(**)	.240(**)	.344(**)	.018	.595(**)	.024	.077
TH	.450(**)	.389(**)	.828(**)	-.379(**)	.239(**)	.150(*)	1	.323(**)	.231(**)	.136	.188(*)	.189(*)	.376(**)	.574(**)	.872(**)	.849(**)	.725(**)	.497(**)	-.034	-.036
NH_4N	.490(**)	.355(**)	.386(**)	-.184(*)	-.102	-.078	.323(**)	1	.065	-.105	-.104	.193(**)	.276(**)	.124	.249(**)	.114	.444(**)	.079	.113	-.019
NO_2	.014	.166(*)	.266(**)	-.189(*)	-.003	-.016	.231(**)	.065	1	.018	-.068	-.049	.138	.260(**)	.283(**)	.095	.229(**)	.006	.015	.002
NO_3	-.060	-.045	.101	.058	.455(**)	.460(**)	.136	-.105	.018	1	.578(**)	.038	.118	.347(**)	.181(*)	.195(**)	.010	.328(**)	.070	.173(*)
PO_4	.055	-.029	.097	.050	.513(**)	.528(**)	.188(*)	-.104	-.068	.578(**)	1	.014	-.104	.338(**)	.181(*)	.352(**)	.008	.455(**)	.086	.201(**)
COD	.379(**)	.049	.078	-.066	.089	.105	.189(*)	.193(**)	-.049	.038	.014	1	.390(**)	-.044	.119	.150(*)	.071	.021	.203(**)	.202(**)
BOD	.247(**)	.116	.346(**)	-.506(**)	.093	.037	.376(**)	.276(**)	.138	.118	-.104	.390(**)	1	.108	.381(**)	.179(*)	.320(**)	.057	.083	.084
SO_4	.263(**)	.167(*)	.621(**)	-.032	.460(**)	.370(**)	.574(**)	.124	.260(**)	.347(**)	.338(**)	-.044	.108	1	.647(**)	.598(**)	.519(**)	.694(**)	.088	.041
Ca	.371(**)	.369(**)	.905(**)	-.433(**)	.336(**)	.240(**)	.872(**)	.249(**)	.283(**)	.181(*)	.181(*)	.119	.381(**)	.647(**)	1	.697(**)	.739(**)	.563(**)	.023	.004
Mg	.391(**)	.207(**)	.655(**)	-.236(**)	.419(**)	.344(**)	.849(**)	.114	.095	.195(**)	.352(**)	.150(*)	.179(*)	.598(**)	.697(**)	1	.564(**)	.634(**)	.012	.016
Na	.474(**)	.420(**)	.949(**)	-.406(**)	.089	.018	.725(**)	.444(**)	.229(**)	.010	.008	.071	.320(**)	.519(**)	.739(**)	.564(**)	1	.512(**)	-.007	-.041
K	.254(**)	.091	.591(**)	-.025	.657(**)	.595(**)	.497(**)	.079	.006	.328(**)	.455(**)	.021	.057	.694(**)	.563(**)	.634(**)	.512(**)	1	-.004	-.013
TC	.075	.057	.006	.083	.063	.024	-.034	.113	.015	.070	.086	.203(**)	.083	.088	.023	.012	-.007	-.004	1	.678(**)
FC	.013	.023	-.018	.122	.114	.077	-.036	-.019	.002	.173(*)	.201(**)	.202(**)	.084	.041	.004	.016	-.041	-.013	.678(**)	1

Cells shows the Pearson correlation coefficient (**) at 0.01 level and (*) at 0.05 level (two tailed)

Total hardness showing significant positive correlation with the presence of Ca, Mg and Na, similar report was provided by Mohanraj et al. [20].

The negative correlation between DO and NH_4-N (R^2=- 0.184) and NO_2 (R^2=- 0.189) revealed that enrichment of nutrients lead to the eutrophication in the river system and inversely affects the dissolved oxygen content of water. Bacteriological study also showed significant positive relationship between NO_3, PO_4 and COD.

Parameters such as Ca^+, Mg^+, K^+, Na^+, SO_4,TH, pH, EC appeared to have gain more concentration at downstream probably

from the riparian land use comprising mainly agricultural lands. Hence, purification efforts along the river flow can be directed to the control of these parameters due to the enrichment of organic compounds all along the river flow.

CONCLUSION

Water quality assessment of the Tamirabarani river basin area revealed potential contamination from various anthropogenic activities and results of the study shows that water quality parameters vary in both relative and absolute terms. Physicochemical characters changes according to the flow pattern and seasonality. During the northeast monsoon period most of the physicochemical characters showed significant variation in concentration due to higher water discharge level. Dilution plays a vital role during monsoon periods which reduce the concentration of pollutants, which also increase the load during earlier periods through runoff from bank and neighbouring areas.

Organic enrichment and higher bacteriological content of the river system determines the quality of the river water. During the study the quality of the river was observed between classes "A" and "E" correspondingly for various uses like (A) drinking water source without conventional treatment but after disinfection; (B) outdoor bathing; (C) drinking water source with conventional treatment followed by disinfection; (D) propagation of wildlife, fisheries and (E) irrigation, industrial cooling controlled waste disposal due to higher bacterial population and BOD content. In conclusion, water quality of the upstream areas of the river Tamirabarani was worsening mainly because of higher bacteriological population and COD levels whereas downstream areas worsening mainly due to high BOD, COD, TC and FC content when compared with the quality criteria of CPCB and WHO.

REFERENCES

1. Sumok P. River water quality monitoring: Sharing Sarawak experience. In Proceedings of 6th SITE research seminar 2001; 13-14.
2. Chakrapani GJ. Major and trace element geochemistry in upper Ganga River in the Himalayas, India. Environmental Geology 2005; *48*: 189-201.
3. Jameel AA and Hussain AZ. Assessment of ground water on banks of Uyyakondan channel of River Cauvery at Tiruchirappalli. Indian Journal of Environmental Protection 2007; 27(8): 713-716.
4. Rani SAF and Sherine HB. A study on measure of pollution load of well waters in Trichy area. Indian Journal of Environmental Protection 2007; *27*(8):721-723.
5. Kaushik A. et al. Heavy metal contamination of river Yamuna, Haryana, India: Assessment by metal enrichment factor of the sediments. Journal of Hazardous Material 2009; 164: 265-270.
6. Kannel PR, et al. Application of water quality indeces and dissolved oxygen as indicators for river classification and urban impact assessment. Environmental Monitoring and Assessment 2007; 132: 93-110.
7. Murugesan AG. Environmental status of the perennial river Tamirabarani with special reference to domestic and industrial pollution. In Proceedings of Workshop on enhancing the public awareness on the ecological and environmental status of the river basins 2000; 15-20.
8. Murugesan AG, et al. Water Quality Profile of the Perennial River Tamirabarani. Indian Journal of Environmental Protection 1994; 14(8): 567-572.
9. Murugesan AG and Mophin Kani K. Determination of water quality deterioration using coliforms as pollution indicators at river Tamirabarani, Tamil Nadu, India. Journal of Basic and Applied Biology 2010; 4(1and2): 209-215.
10. Murugesan AG and Mophin Kani K. Evaluation and classification of water quality of Perennial river Tamirabarani through aggregation of water quality index. International Journal of Environmental Protection 2011; 1(5); 24-33.
11. Murugesan AG, et al. Toxic impact of Environmental Pollutants on Freshwater Habitats - An overview. Ecology of polluted waters (Ed. Arvind Kumar) Ashish Publishing Corp, New Delhi, India 2002; 1207-1218.
12. Murugesan AG, et al. Pollution status of perennial river Tamirabarani with special reference to sewage mixing and coliform bacteria. Management of sustainable environment 2004; 187-195.
13. Murugesan AG, et al. Conservation of the Perennial river Tamirabarani with special reference to restoration of catchment area and aquatic habitat. *Ecology and Ethology of aquatic biota* (Ed. Arvind Kumar), Daya publishing house, New Delhi, India, 2002a; 258-273.
14. Hema S, and Muthalagi S. Mass balance approach for assessment of pollution load in the Tamiraparani river. Int. J. Chem. Tech. Res*,* 2009; *1*(2), 385-389.
15. Umamaheswari S. Water quality assessment of River Thamirabarani at Ambasamudram. Journal of Ecotoxicology and Environmental Monitoring 2004; *14*(4):273-276.
16. CPCB (2009). Water quality criteria. http://cpcbenvis.nic.in/waterpollution/criteria.htm. Accessed on 4 November.

17. WHO (2004). *Guidelines for drinking water quality*, 3rd ed. Geneva: WHO.

18. Mishra VK. Water pollution management in an open cast coalmine area. Ph.D. Thesis, Department of Botany, Banaras Hindu University. In Environ. Monit. Assess 2010; 165:407-433.

19. Rai PK and Tripathi BD. Impact of thermal power effluent on aquatic environment. National Journal of Radiation Research 2006; 3(4), 190-192.

20. Dugan R. *Biochemical ecology of water pollution*. New York: Plenum. 1972.

21. Hutchinson GE. *A* treatise on limnology. Limnological botany, Hoboken: Wiley 1975; 3: 660.

22. Elmanama AA et al. Seasonal and spatial variation in the monitoring parameters of Gaza Beach during 2002-2003. Environmental Research, 2006; 101(1):25-33.

23. De AK. Environmental chemistry, New Delhi, India: New Age International. 2002; 4: 232.

24. Girija TR, etal. Water quality assessment of an untreated effluent impacted urban stream: the Bharalu Tributary of the Brahmaputra River, India. Environmental Monitoring and Assessment 2007; 130: 221-236.

25. Ravindra K, et al. Seasonal variations in physico-chemical characteristics of River Yamuna in Haryana and its ecological best-designated use. Journal of Environmental Monitoring 2003; 5: 419-426.

26. Schulze DL, et al. Water quality studies red rock and Saylorville Reservoirs Des Moines River, Lowa. Annual Report. Department of the Army, Rock Island District, Corps of Engineers, Rock Island, IL 2001.